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Conflict of Interest Disclosure

I have no conflict of interest to report in relation to this presentation.

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Physical Activity and Health: New Knowledge in Research and Technologies

Diet and Physical Activity: Using contextual data to improve assessment

Carol J Boushey

Epidemiology Program

University of Hawaii Cancer Center

Recognition to **Richard P Troiano** for providing physical activity content

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Outline

- Accelerometer benefits

- Temporal Dietary Patterns

- Contextual information to enhance dietary assessment

- Relevant methodological issues

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Outline: Accelerometer benefits

Stronger Associations with Biomarkers

Biomarker	Self-report		Accelerometer	
	Beta (SE)[1]	Adj. Wald F	Beta (SE)[1]	Adj. Wald F
SBP	0.01 (0.03)	0.23	-0.43 (0.14)	8.89**
BMI	-0.04 (0.01)	14.95***	-0.77 (0.08)	86.71****
HDL (mg/dL)	0.10 (0.03)	8.54**	1.41 (0.27)	27.77****
Glycohemoglobin	-0.004 (0.001)	7.91**	-0.05 (0.01)	47.11****
Glucose	0.01 (0.07)	0.06	-1.67 (0.30)	30.77****
Insulin (µU/mL)	-0.08 (0.03)	10.15**	-1.11 (0.12)	81.53****

** $p < 0.01$
*** $p < 0.001$
**** $p < 0.0001$

[1]Minutes in bouts, Beta per 10 min unit

Atienza AA, et al., Med Sci Sports Exerc 2011

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Outline: Accelerometer benefits

Take away…

Findings suggest:

- Self-reported and objectively measured PA may capture distinct aspects of PA associated with biomarkers of health

- Objectively measured PA demonstrates significantly stronger associations

- Both self-reported and objective PA measures are useful for examining the effects of PA behavior on health outcomes

Atienza AA, et al., Med Sci Sports Exerc 2011

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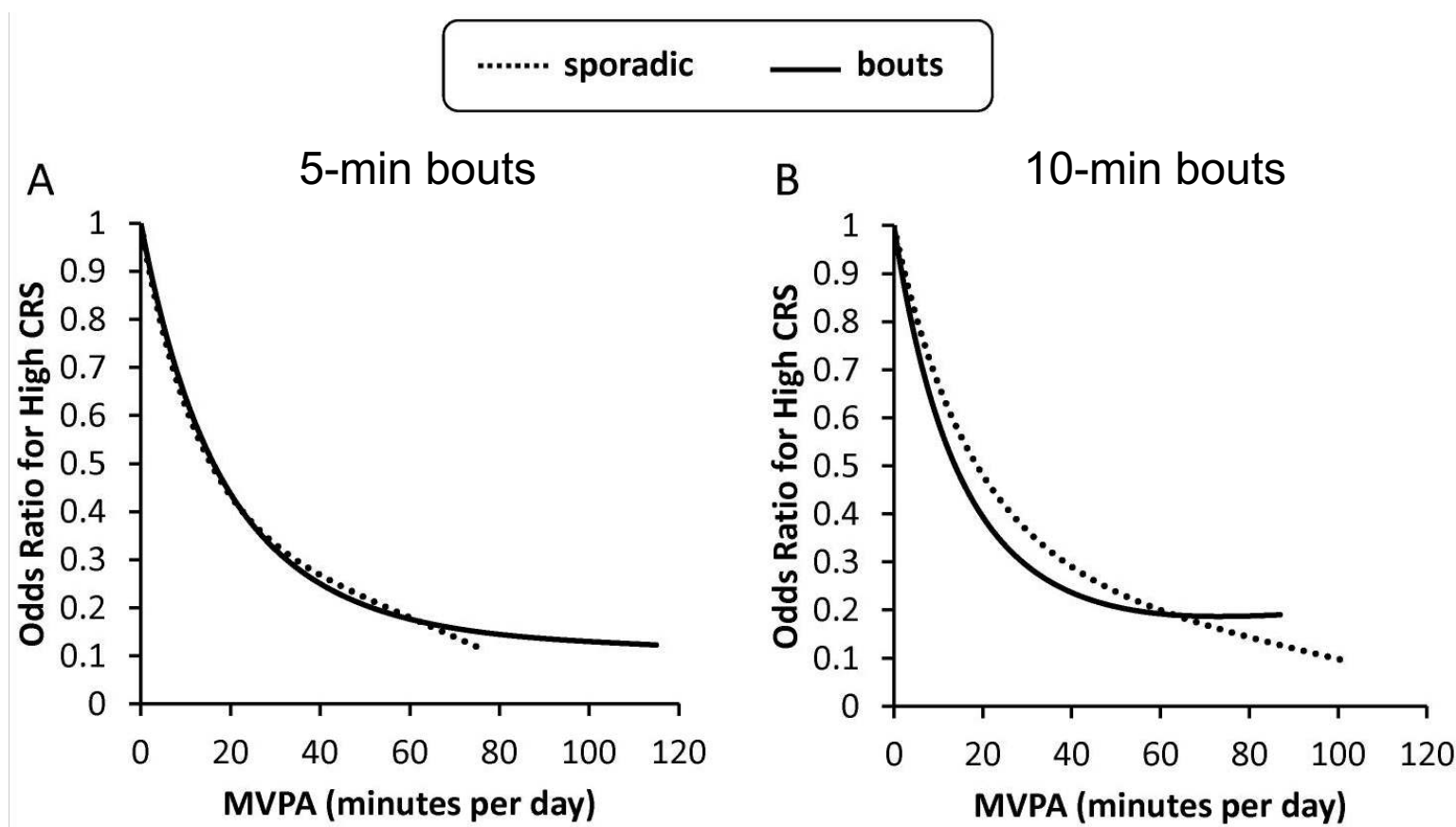info@iuns-icn2017.com

Outline: Accelerometer benefits

Do Activity Bouts Matter?

Does the fractionalization of daily physical activity (sporadic vs bouts) impact cardiometabolic risk factors in youth?

- NHANES 2003-2006
- Ages 6-19 y
- Cardiometabolic risk score (CRS):
  - Waist circumference
  - Non-HDL cholesterol
  - C-reactive protein
  - Systolic blood pressure

Holman RM, et al., Plos ONE 2011

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Outline: Accelerometer benefits

Sporadic vs. Bouts of moderate-to-vigorous physical activity (MVPA)

Holman RM, et al., Plos ONE 2011

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Outline: Accelerometer benefits

Take away…

Findings suggest:

- Moderate-to-vigorous physical activity (MVPA) is related to cardiometabolic risk factors within children and youth

- These relationships are comparable for equivalent doses of sporadic MVPA and bouts of MVPA

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Holman RM, et al., Plos ONE 2011

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Outline: Accelerometer benefits

Does benefit accrue if sedentary time is replaced with light activity?

- Accelerometer-measured dose-response for physical activity and sedentary time and mortality using NHANES and mortality follow-up data.

Matthews CE, et al., Am J Clin Nutr 2016

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Mortality associations for replacing 1 h of sedentary time with light- and moderate-to-vigorous–intensity activity in all participants and in the low-active group.
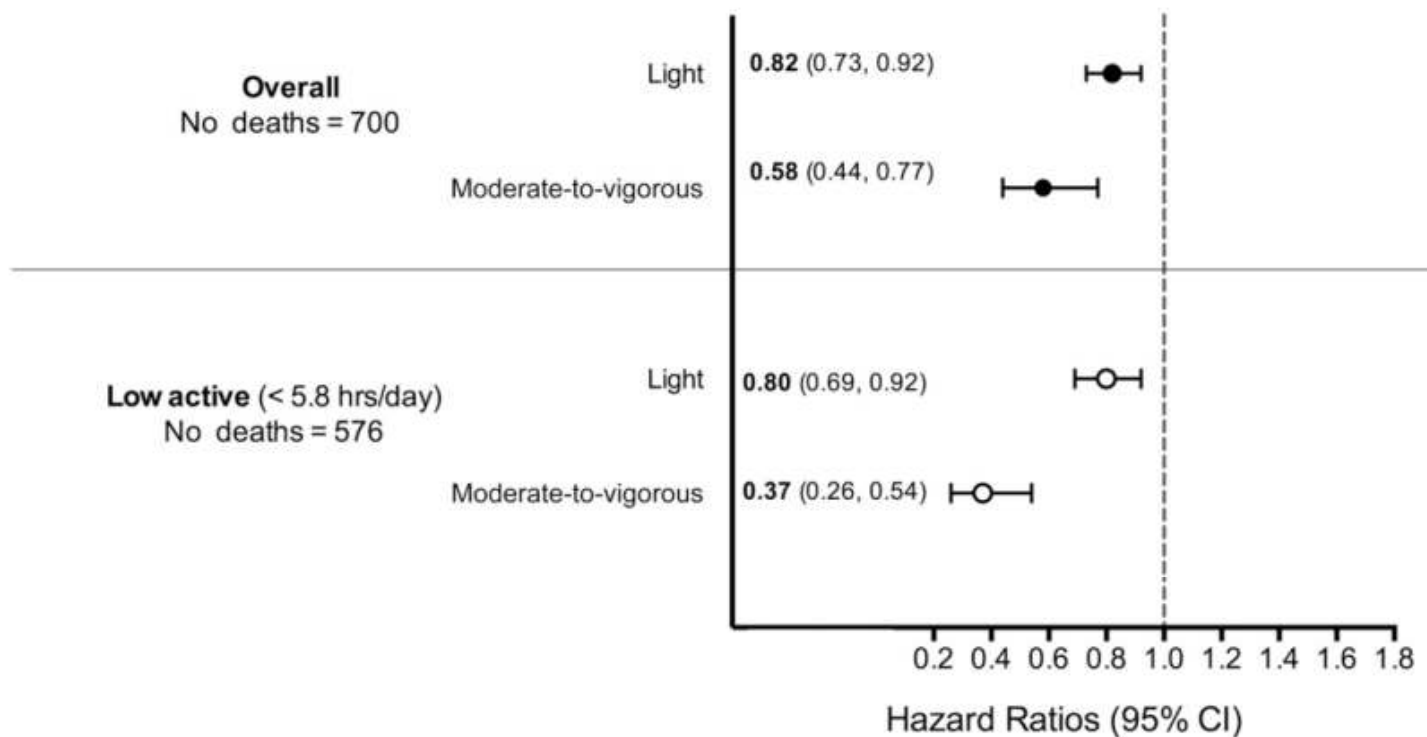
Adjusted for age, race, education, sex, smoking status, alcohol use, BMI, and a history of the following conditions: diabetes, coronary artery disease, stroke, mobility limitation, and cancer

Matthews CE, et al., Am J Clin Nutr 2016

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Outline: Accelerometer benefits

Take away…

Findings suggest:

- Whereas, health promotion efforts for physical activity have mostly focused on moderate-to-vigorous activity.

- Increasing light-intensity activity and reducing sedentary time are also important, especially for inactive adults.

Matthews CE, et al., Am J Clin Nutr 2016

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Outline: Temporal dietary patterns

Temporal Diet Patterns

– Goal: To determine relationship of energy consumption, time, and diet quality over one 24-hour day

1. Define feature vectors by quantizing time and determining proportion of energy consumed for each eating occasion

2. Find an appropriate distance metric for clustering feature vectors

3. Perform clustering procedure

4. Evaluate differences among temporal dietary patterns

Khanna N, et al., IEEE International Symposium on Multimedia, 2011; Eicher-Miller HA et al J Acad Nutr Diet 2016

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Outline: Temporal dietary patterns

Relationship of Time to Diet

- Times and proportional amounts consumed may be associated with health or diet quality

- NHANES 1999-2004

- 1-day 24-hour dietary recall

- Participants 20-65 y (n=9,326)

- Diet Quality indicated by 2005 Healthy Eating Index (HEI)

Khanna N, et al., IEEE International Symposium on Multimedia, 2011; Eicher-Miller HA et al J Acad Nutr Diet 2016

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Outline: Temporal dietary patterns

Distance Metric: Dynamic Time Warping

- Distance between two eating events m1 = (t1, v1) and m2 = (t2, v2), t=time, v=ratio of energy

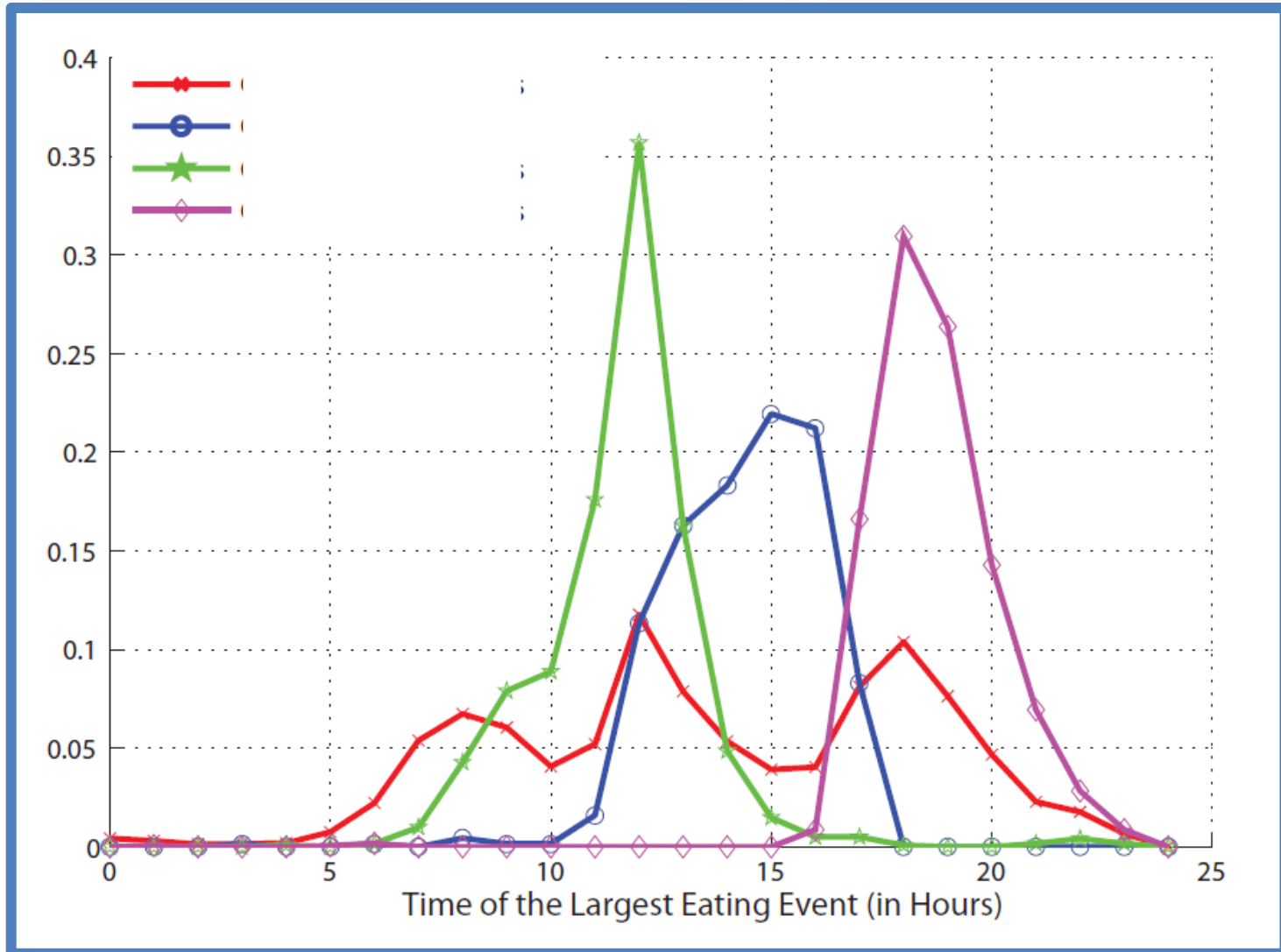$$d(m_1, m_2) = (v_1 - v_2)^2 + 2v_1v_2 \left(\frac{|t_1 - t_2|}{24} \right)^{\alpha}$$

- Distance between two "24-hour diets", D1 and D2,
  - *A "24-hour" diet consists of a collection of multiple eating events, the distance between them is estimated by appropriately "aligning" the two diets*

$$d(D_1, D_2) = minimize_j \sum_i d(m_i^1, m_{j(i)}^2)$$

$$\text{subject to } j(i) = 0 \text{ or } j(i) > j(i-1),$$

Khanna N, et al., IEEE International Symposium on Multimedia, 2011.

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Outline: Temporal dietary patterns

Kernal K=4 selected as the optimal number of cluster

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Outline: Temporal dietary patterns

Evaluate Differences in Diet Quality Among Temporal Dietary Patterns

Figure 2. Temporal dietary patterns of the second largest daily energy consumption event for clusters (C) of US adults aged 20 to 65 years from the National Health and Nutrition Examination Survey, 1999-2004 (N=9,326).

Eicher-Miller HA, et al., J Acad Nutr Diet 2016.

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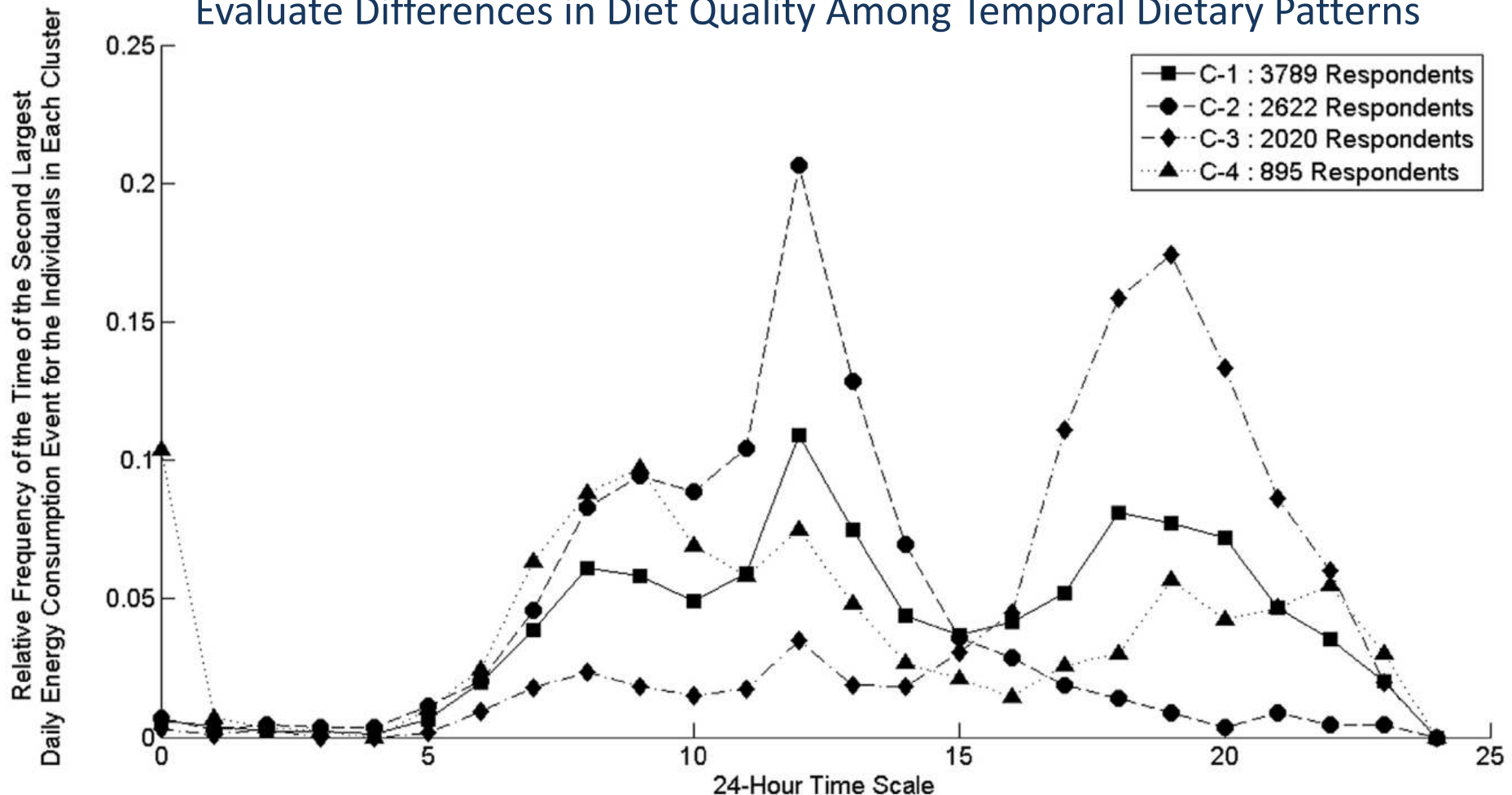
Outline: Temporal dietary patterns

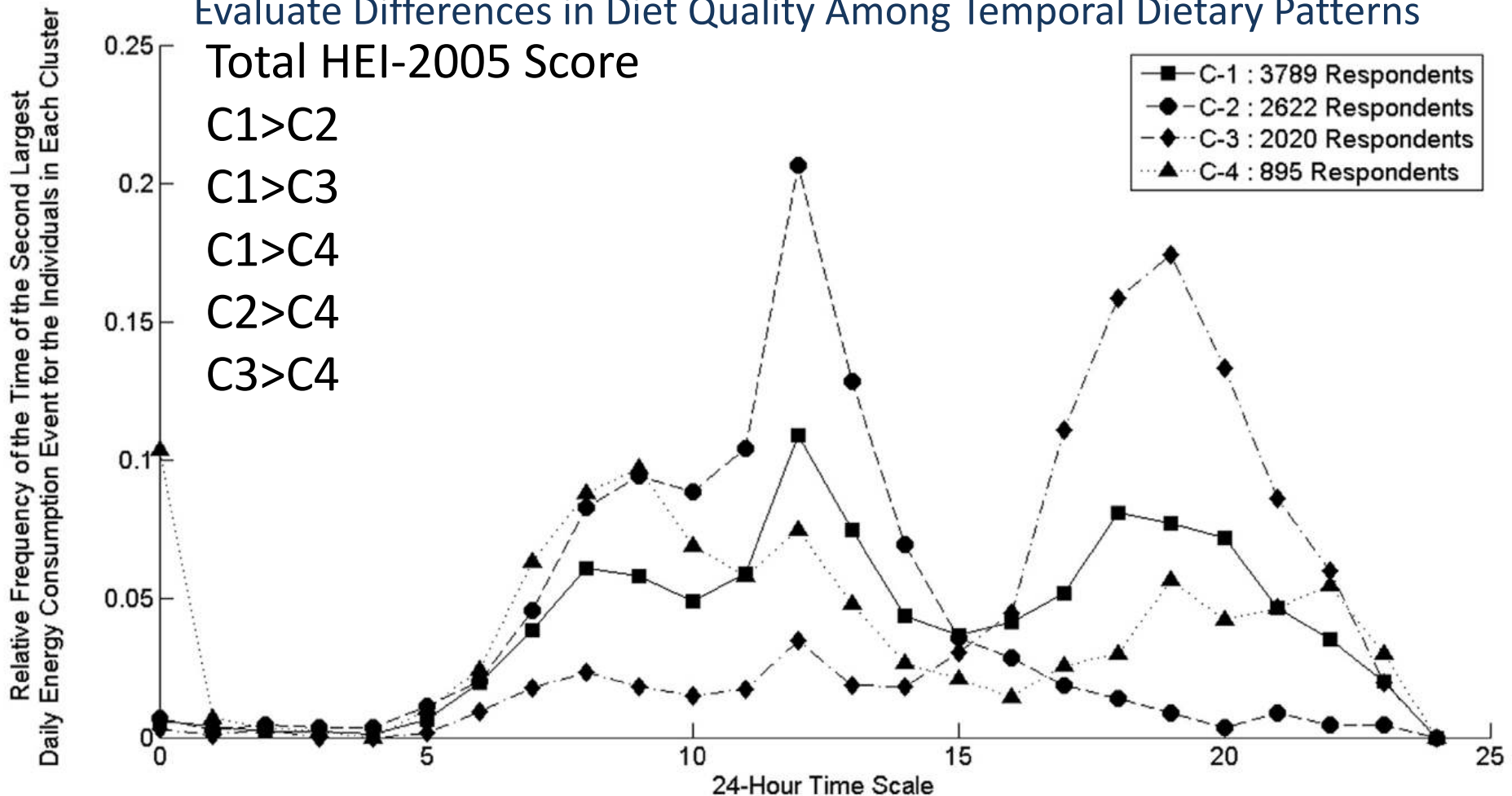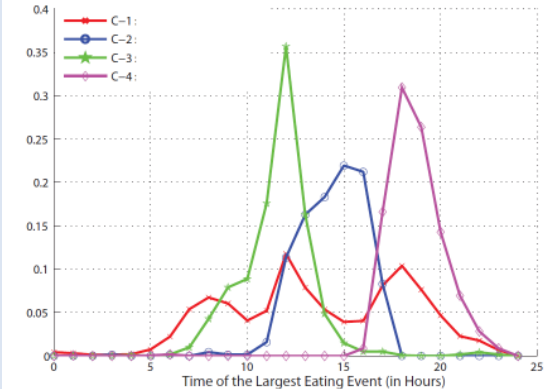Evaluate Differences in Diet Quality Among Temporal Dietary Patterns

Total HEI-2005 Score

C1>C2

C1>C3

C1>C4

C2>C4

C3>C4

Figure 2. Temporal dietary patterns of the second largest daily energy consumption event for clusters (C) of US adults aged 20 to 65 years from the National Health and Nutrition Examination Survey, 1999-2004 (N=9,326).

Eicher-Miller HA, et al., J Acad Nutr Diet 2016.

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Outline: Temporal dietary patterns

Take away…

- The temporal dietary pattern exhibiting proportionally similar energy consumption throughout a 24-hour day had significantly greater mean HEI 2005 compared with the other patterns.

- Temporal dietary patterns can be used to identify differences in diet quality and enhance understanding of the complicated interplay of time and dietary intake.

- Use of pattern recognition techniques, were found to be useful for identifying temporal dietary patterns.

Eicher-Miller HA, et al., J Acad Nutr Diet 2016.

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Capturing & using contextual information to improve dietary assessment

Contextual Information

- Definition: contextual dietary information refers to any information that is not directly produced by the visual appearance of an object in the scene

- Types of context
  - Food co-occurrence
  - Temporal information
  - Geo-location
  - Accelerometer
  - Outdoor or indoor
  - Temperature or weather conditions
  - User input

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Use of Contextual Information

3 → 4: From temporal information gathered with the original image, the classifier knows the person does not usually eat chicken in the morning. Thus, the food label is modified to "Fries"

4 → 5: From food co-occurrence patterns, instead of pepper sauce, people are more likely to consume ketchup with fries

5 → 6: The Personalized Learning Model informs us that the person only drinks diet coke

Wang Y, et al., IS&T/SPIE, 2015; He Y, et al., IEEE International Conference on Image Processing, 2013.

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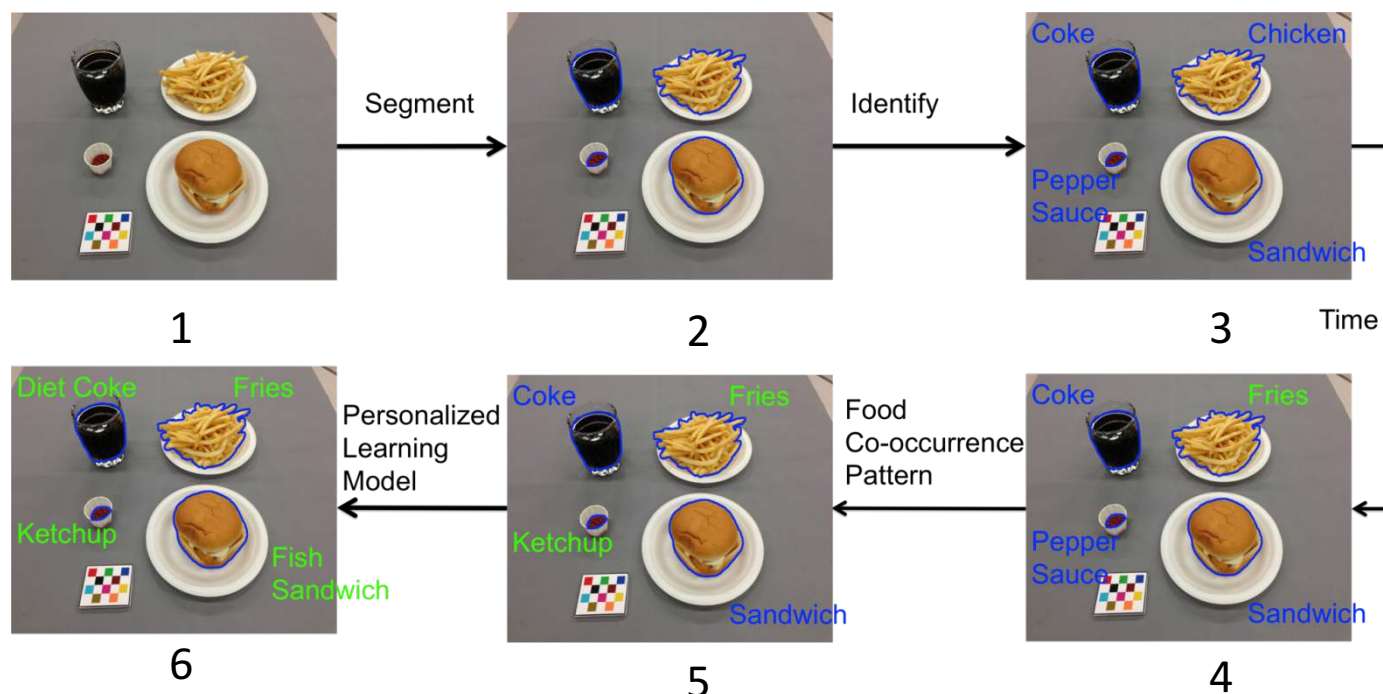
Outline: Contextual information

Food Co-occurrence Patterns

- Do you eat peanut butter with bagels?
- Or do you eat sausage with pancakes?

Wang Y, et al., IS&T/SPIE, 2015; He Y, et al., IEEE International Conference on Image Processing, 2013.

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Outline: Contextual information

Food Co-Occurrence Patterns

- The likelihood of food combinations --- their mutual probability of existing together in a single eating occasion

- A post-processing stage to promote agreement between the segment labels

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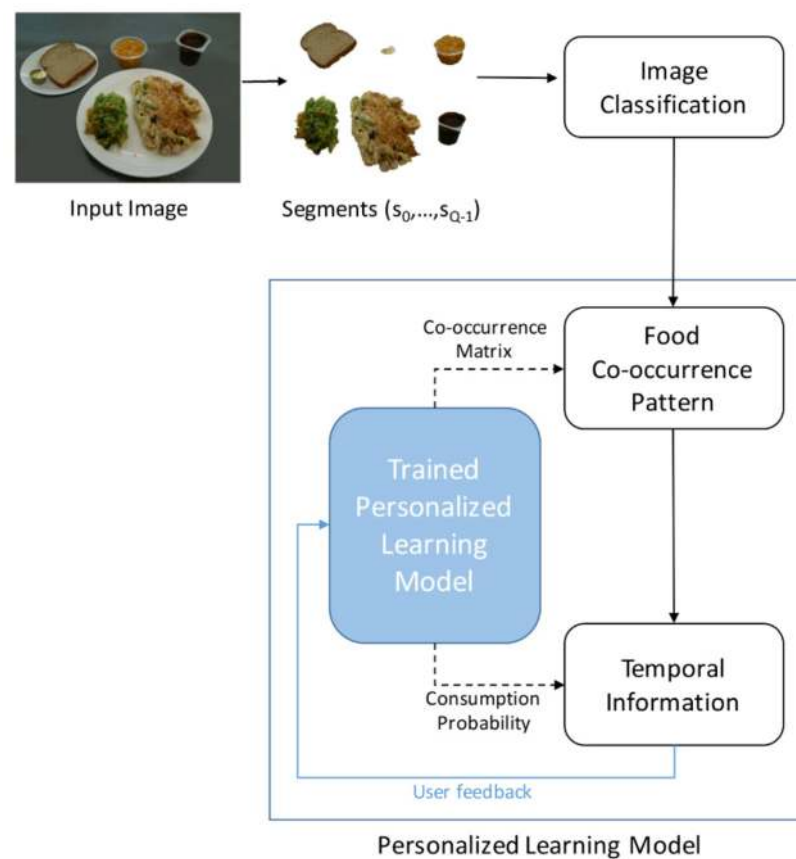www.iuns-icn2017.com
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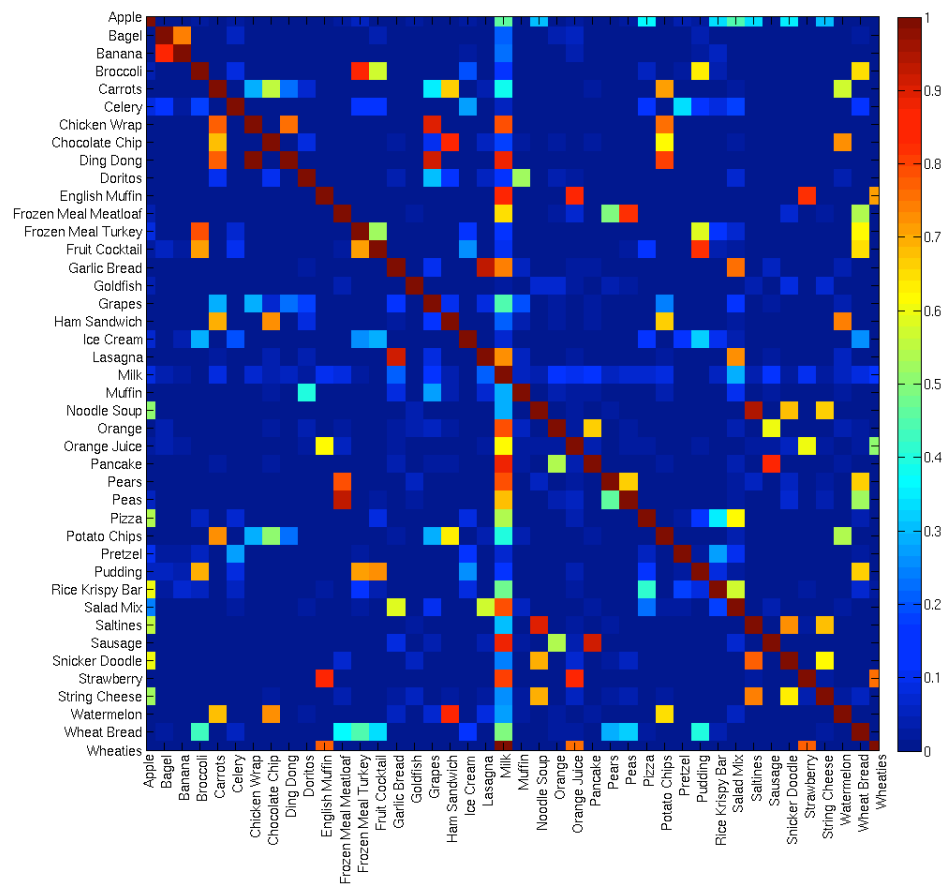
Outline: Contextual information

Personalized Learning Model

- The goal of a personalized learning model is to improve food classification by using dietary preferences

- The personalized learning model takes into account both temporal dietary information and food co-occurrence for an individual

Personalized Learning Model

Wang Y, et al., IS&T/SPIE, 2015; He Y, et al., IEEE International Conference on Image Processing, 2013.

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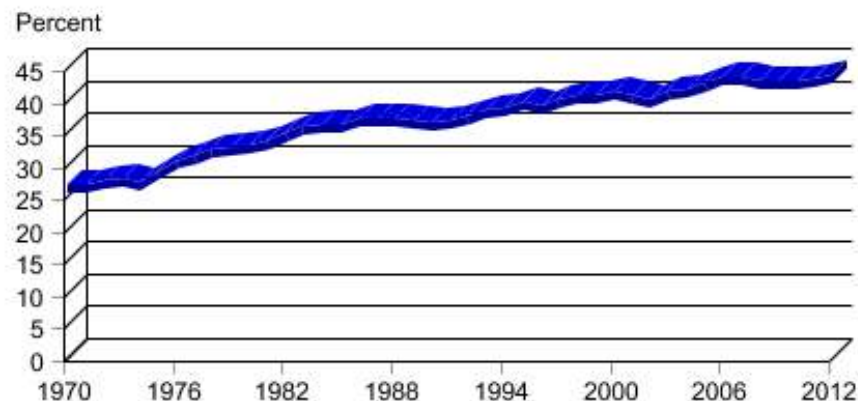
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Outline: Contextual information

Geolocation

- Dining at home or away from home?

- GPS data captured at the time meal images are taken can identify location.

Food away from home as a share of household food expenditures has risen steadily since 1970, reaching its highest level of 43.1 percent in 2012
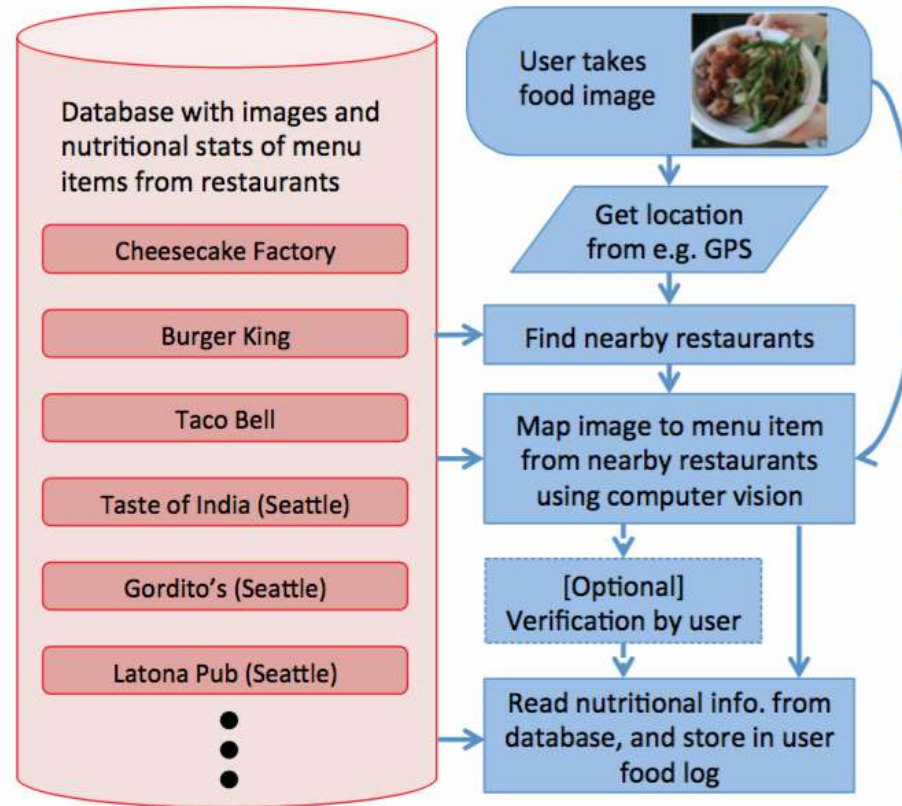

Food away-from-home expenditures divided by total food expenditures, for all families and individuals.

Total expenditures on food away from home include expense-account meals, food furnished to inmates and patients, and food and cash donated to schools and institutions. These items are not included in expenditures on food away from home for all families and individuals.

Source: Economic Research Service (ERS), U.S. Department of Agriculture (USDA), Food Expenditures
http://www.ers.usda.gov/data-products/food-expenditures.aspx

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Outline: Contextual information

Geolocation

O. Beijbom, et al. "Menu-match: restaurant-specific food logging from images." *Proceedings of IEEE Winter Conference on Applications of Computer Vision*, 2015.

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Outline: Contextual information

Take away...

Contextual information is important

- People often do not realize how surrounding factors influence food choices and the amount of food consumed. [1]

- Contextual information helps to infer an individual's activity level and an individual's well-being

- Contextual information can improve food recognition accuracy using computer vision techniques

[1] Cohen D and Babey S. "Contextual influences on eating behaviours: heuristic processing and dietary choices." *Obesity Reviews*, pp. 766-779, 2012

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# Different approaches to enhance dietary assessment with images

- **Passive**
  - Wearable camera/other devices
  - Lots of images/data collected
  - Users do not need to be "engaged"
  - Need to detect eating events
  - Images can be used for other things
  - Privacy issues

- **Active**
  - Use mobile telephone
  - Focused images
  - Users are "engaged"
  - Useful contextual information
  - Better quality images

Passive Approach

- Passive Approach

  ~ 1 image/5 sec ➜ 400,000 images/day – most not related to food

- Active approach

  ~ 6-12 images/day

Passive Approach
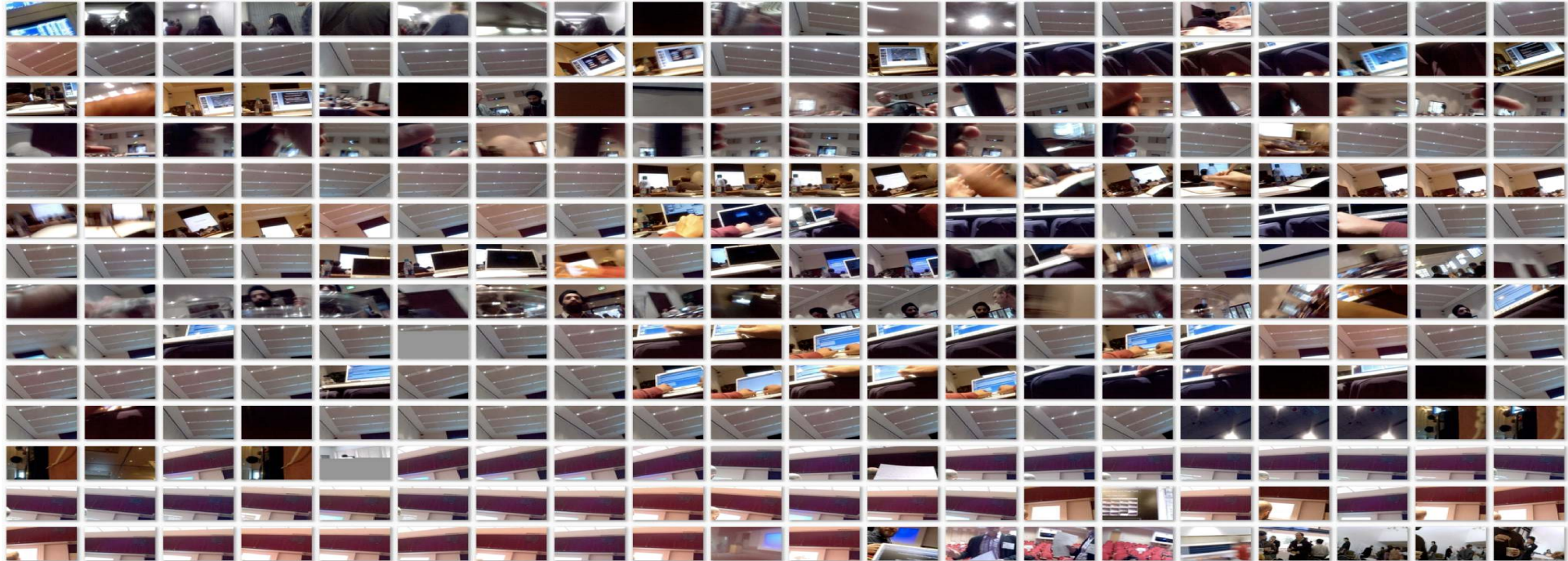
Time elapsed 24 minutes

Active Approach

Time elapsed 24 hours

Example of 1-day images captured with the mobile food record showing the eating occasions and time for a woman
BMI = 32.8

Eating Occasions = 8

One Eating Occasion

Passive
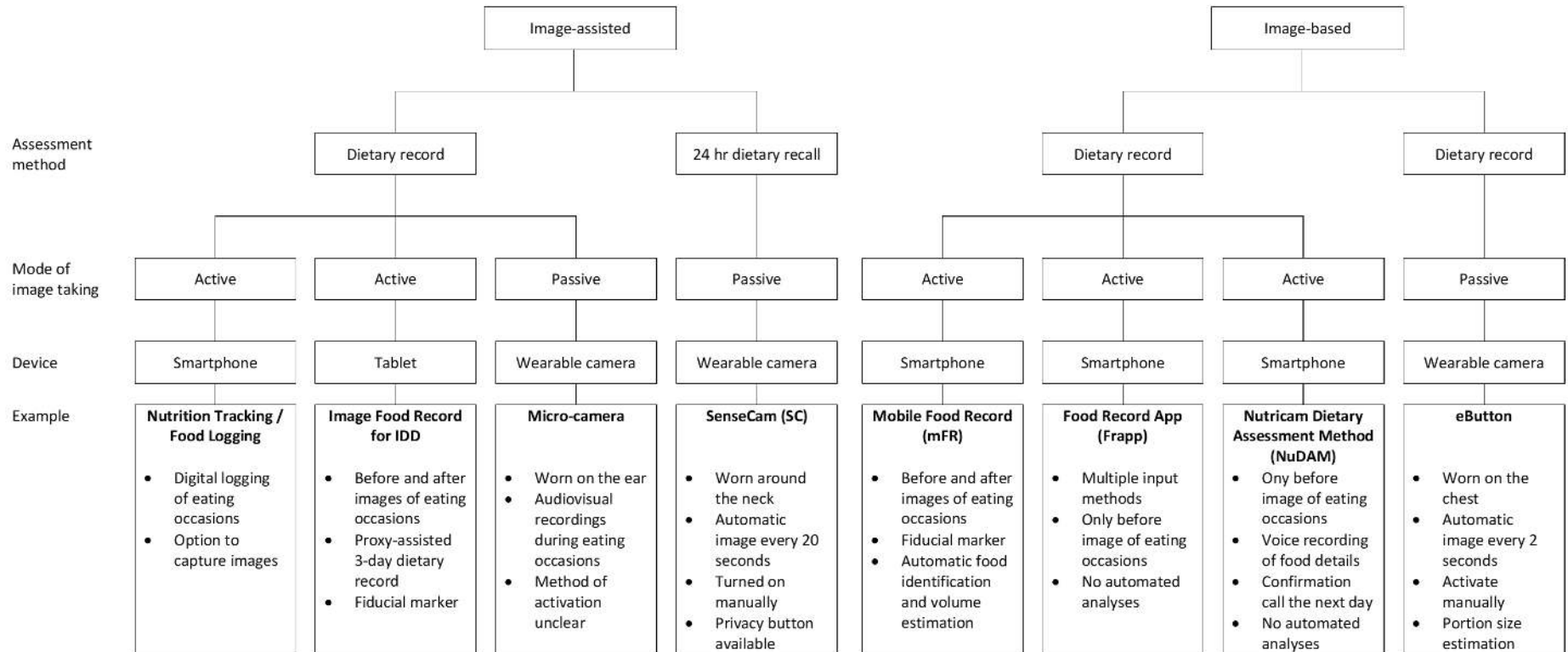

35 images from ~ 180 images over a 15 minute eating occasion

Active

Strategies using images for dietary assessment organized by terminology

Image-assisted | Image-based

	Image-assisted				Image-based			
Assessment method	Dietary record			24 hr dietary recall	Dietary record			Dietary record
Mode of image taking	Active	Active	Passive	Passive	Active	Active	Active	Passive
Device	Smartphone	Tablet	Wearable camera	Wearable camera	Smartphone	Smartphone	Smartphone	Wearable camera
Example	**Nutrition Tracking / Food Logging**	**Image Food Record for IDD**	**Micro-camera**	**SenseCam (SC)**	**Mobile Food Record (mFR)**	**Food Record App (Frapp)**	**Nutricam Dietary Assessment Method (NuDAM)**	**eButton**
	• Digital logging of eating occasions • Option to capture images	• Before and after images of eating occasions • Proxy-assisted 3-day dietary record • Fiducial marker	• Worn on the ear • Audiovisual recordings during eating occasions • Method of activation unclear	• Worn around the neck • Automatic image every 20 seconds • Turned on manually • Privacy button available	• Before and after images of eating occasions • Fiducial marker • Automatic food identification and volume estimation	• Multiple input methods • Only before image of eating occasions • No automated analyses	• Ony before image of eating occasions • Voice recording of food details • Confirmation call the next day • No automated analyses	• Worn on the chest • Automatic image every 2 seconds • Activate manually • Portion size estimation

Left to right: Image Assisted - Painter SL, et al. J Med Internet Res 2017; Ptomey LT, et al. Disabil Health J 2015; Pettitt C, et al. Br J Nutr 2016; Gemming L, et al. Br J Nutr 2014. Left to right: Image Based - Ahmad Z, et al. MADiMa Oct 2016, Casperson SL, et al. JMIR Mhealth Uhealth 2015; Rollo ME, et al. Nutrients 2015; Beltran A, et al. Proceedings of Measuring Behavior 2016 (www.measuringbehavior.org). Also see Boushey CJ, et al. Proc Nutr Soc 2016.

Acknowledgments

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