uc_Eating:

Ontology for unambiguous characterization of eating and food habits

Kimiya Taji
Department of Food Science and Technology
University of California Davis
Davis, CA
khtaji@ucdavis.edu

Matthew Lange, PhD
Department of Food Science and Technology
University of California Davis
Davis, CA
mclange@ucdavis.edu

Abstract— **The uc_Eating ontology is a standardized unambiguous characterization system for modeling human food habits and eating processes. The uc_Eating ontology along with the physiological, environmental, behavioral, and food ontologies it maps to, provide an infrastructure for annotating the relationships between food, food consumption, eating behaviors, and environments creating a foundation for computable knowledge bases around food and beverage consumption scenarios, their observation, interrogation, and manipulation at biological, behavioral, and environmental levels.**

I. INTRODUCTION

1.1 billion adults worldwide are considered overweight and 312 million are medically diagnosed as obese. Obesity is a growing epidemic, and rapidly becoming the single largest global public health challenge [1]. Food, often consumed primarily for nutrifying and energetic purposes, is also consumed for purposes of improved performance of an array of human activities. As an example, individuals consuming multiple small meals per day compared to infrequent large meals, generally have an increased energy intake concomitant with increased energy expenditure in sports or other physical activities [2].

Aside from the frequency and timing of food consumption, food is often consumed as part of sociocultural rituals. In fact, many socioeconomic and sociocultural factors relate to choice architecture and behavioral responses surrounding foods consumption. Similarly, food habits can be aggregated and categorized across ethnic, age, socioeconomic and a variety of other groups/factors. Influences throughout life affect individual food choices, with downstream consequences for health phenotypes [3]. Food consumption practices often facilitate sharing of culture and bringing together of people in a social setting. In the last decade, American adult participation in social media climbed from seven to sixty-five percent of the population [4]. Exposure to social and mass media is altering food habits and consumption patterns of media consumers [5]. Modern science clearly demonstrates relationships between human eating behaviors and disease progression [6][7][8], to date they have received very limited attention in the world of ontological research. In their cogent assessment of obesity-related ontology patterns, Sojic and team highlight the need for "an eating pattern ontology of personalized profiles across several obesity-related knowledge-domains structured into dedicated modules in order to support inference about health condition, physical features, behavioral habits associated with a person, and relevant changes over time" [9]. The uc_Eating ontology has taken care to incorporate the most salient elements of Sojic's eating pattern model and supports classification of these domain-specific patterns. Features such as eating habits, social and psychological influences, as well as nutritional condition, were considered when building our model of eating behaviors. The identification of eating behaviors as well as temporal, geographic, and social contexts in which these behaviors occur, form the basis for the uc_Eating model. The uc_Eating ontology is located on Github as part of the IC-FOODS repository of ontologies dedicated to ontologies related to Food Systems, Food, Behavior, and Health. Within the National Center for Biomedical Ontology, classifications of eating behaviors exist within a limited range of specifications. For example, the Gene Ontology characterizes eating behavior as the "reduction of food intake in response to dietary excess" providing little regard to the actual processes that coincide with eating/drinking or otherwise consumption of foods [10]. Our goal is to create a further detailed, unambiguous characterization of those eating behaviors.

II. DESIGN AND METHODS

Open world assumptions of semantic web ontology languages (OWL) provide a means for capturing the diverse array of human food consumption behaviors [11]. As a basis for our knowledge model, the construction of the food habit knowledge model enables the quantification and characterization of individual eating patterns [12]. Ontologies provide infrastructure for annotating relationships between food consumption and eating behaviors, providing the encoding of the unambiguous uc_Eating knowledge model into tractable and computable vocabularies. Existing ontologies such as the Neurobehavioral Ontology provide classes such as food consumption however, characterizations are not relevant to the uc_Eating ontology. For example, the Neurobehavioral Ontology contains the base class "feeding behavior" with the subclass "food consumption" characterized by "saccharin consumption" [13]. The Emotion ontology also contains the class "feeding behavior" with the subclass "pharyngeal pumping" [14]. The uc_Eating ontology

seeks to characterize actual processes and create a broader range of specifications. We were therefore unable to completely utilize existing classes. Within The uc_Eating ontology, classes such as acquisition processes, production processes, and consumption processes can be utilized in other ontologies such as the Gene ontology and the Neurobehavioral Ontology. We used Protégé a ontology design software to create the uc_Eating ontology [15]. Types, costs, frequencies of foods consumed, times, locations and settings of food consumption, internal/external influences on consumption, and physiological consumption process itself inhere in eating behaviors, essential characteristics.

Breastfeeding, most of Mammalia's initial mode of food consumption, provides an interesting model for several biological and behavioral eating, as well as food production processes. The pattern begins with the frequency of milk consumption (or production i.e. "pumping"). This changes as the baby ages. Immediately after birth, infants are able to suckle their mother's breast to receive nutrients that are necessary for life. FIL (feedback inhibition of lactation), a substance in breast milk responsible for controlling milk production remains vital. As a baby suckles milk, FIL allows for the appropriate amount of milk to be produced based on the babies intake. Thus, being crucial for determining the needs of a baby. FIL is also capable of completely ceasing lactation within the mother's breast modeled in the uc_Milk ontology. Attachment to the breast is key for the baby to successfully receive milk. Effective suckling results from adequate attachment to the breast. Together, the various processes work in collaboration as a cyclical pattern within the mother's body. Weaning, and the gradual termination of breastfeeding leads to consumption of various non-milk foods consumed throughout life, giving rise to various food habits and patterns adapted from internal and external stimuli experienced during breastfeeding. Additionally, an overlap between breastfeeding and milk production exists within the uc_Milk ontology and the uc_Eating ontology. Captured in the uc_Eating ontology, breastfeeding enables the characterization of other eating patterns such as, regulated eating behavior, snacking behavior, eating influenced by the environment etc.

Differentiation of behaviors and processes allow individual comparisons amongst various scenarios. The base class "meal eating behavior" characterizes numerous types of meals consumed by individuals including, celebratory meal, post-workout meal, feasting meal, religious meal, and holiday meal behaviors. Part of human nature involves the ability to make decisions on what to eat based on the environmental and social influences. Compensatory meal behaviors involve food consumed to compensate for sleep, stress, physical activity and for other foods consumed. Characterizing environmental influences as entities help create a full understanding of one's eating patterns. Other subclasses include "snacking behavior", "regulated eating behavior", "eating behavior concomitant with other behaviors" and "eating influenced by external and internal stimuli". The entity "eating concomitant with other behavior" enables classification of eating while engaging in other activities. For example, if eating is occurring whilst laughing, exercising, reading, crying, talking and etc. An intersection of behaviors from the "Physical Activity Health and Fitness Ontology" occurs with behaviors sourced from "Compendium of Human Physical Activity" and "American Time Use Survey"[12][16][17]. Various behaviors implement a multitude of activities with concomitant behaviors. The base class "Food Consumption Measurement Methods" allows for the detailed characterization of various food measurement methods including, real-time monitoring, real-time logging and distinctive measurement data types. Measurement methods enable food patterns and habits amongst individuals to be assessed, quantified and categorized.

The base class "snacking behavior" consists of distinctive types of snacking behavior delineating when- snacking take place: after school, late-night, mid-day, etc. Characterizing various behaviors such as snacking enables determination and specific identification of eating patterns that occur.

Regulated eating behaviors classify the drivers behind why people consume various types of foods according to prescriptive diets. The base class of "regulated eating" comprises of subclasses identified as "ethically regulated" eating behavior, and "religiously regulated" eating behavior as well as "health" and "hunger"-oriented eating behaviors.

In uc_Eating, each eating behavior is classified as a either a single occurrent or regarded as co-occurrents. Moving forward, patterns of eating behaviors can be classified into eating behavior pattern phenotypes. Within multiple entities interact with each other such as micro-moments, concomitant eating behaviors and eating influenced by internal stimuli. Micro-moments remain characterized by specific in-the-moment occurrences that can elicit diverse responses. In relation to eating, people make decisions of what to eat, when to eat, and where to eat based on micro-moments. The class of "eating influenced by external stimuli" also connects to the micro-moments where all aspects of the environment, media and culture come into play. Although the recognition of individual occurrences occasionally transpires, the uc_Eating ontology provides clear and concise vocabularies and models for identification of behaviors amongst individuals. Deciding which foods to consume vary by individual contingent on countless attributes, recognized by the uc_Eating ontology.

III. CONCLUSION

The study of food consumption persists vastly amongst anthropologists, biologists, nutritionists, and various allied scientists. Eating patterns and the consumption of food help create a means for identifying disease progression. Future directions for the uc_Eating ontology include building multiple ontologies such as, the sense ontology and milk ontology to build an infrastructure with a wide variety of characterizations. Characterization of human eating patterns provides multiple current uses such as Google's micro-moments, which characterize specific in-the-moment occurrence eliciting different responses [18]. Through the uc_Eating ontology Google's micro-moments can be enhanced and more specified to a vast variety of individuals. Other uses include, creating inference patterns to personalize health condition assessments such as obesity [9]. Multiple processes affect unambiguous characterization of food consumption, and each containing an array of influences affecting which eating processes take place.

REFERENCES

[1] Hossain, P., Kawar, B., & Nahas, M. E. (2007). "Obesity and Diabetes in the Developing World — A Growing Challenge". *New England Journal of Medicine N Engl J Med, 356*(3), 213-215. doi:10.1056/nejmp068177.

[2] Hawley, J. A., & Burke, L. M. (1997). "Effect of meal frequency and timing on physical performance". *British Journal of Nutrition Br J Nutr, 77*(S1). doi:10.1079/bjn19970107I

[3] Nestle, M., Wing, R., Birch, L., DiSogra, L., Drewnowski, A., Middleton, S., Sigman-Grant, M., Sobal, J., Winston, M. and Economos, C. (1998), "Behavioral and Social Influences on Food Choice". Nutrition Reviews, 56: 50–64. doi: 10.1111/j.1753-4887.1998.tb01732.

[4] Perrin, A. (2015). "Social Media Usage: 2005-2015". Retrieved May 15, 2016, from http://www.pewinternet.org/2015/10/08/social-networking-usage-2005-2015/

[5] Coary, S., & Poor, M. (2016). "How consumer-generated images shape important consumption outcomes in the food domain". *Journal of Consumer Marketing, 33*(1), 1-8. doi:10.1108/jcm-02-2015-1337

[6] Gu, Y., & Scarmeas, N. (2011). "Dietary Patterns in Alzheimer's Disease and Cognitive Aging". *Current Alzheimer Research*, *8*(5), 510–519.

[7] Who, J., & Consultation, F. E. (2003). "Diet, nutrition and the prevention of chronic diseases". *World Health Organ Tech Rep Ser*, *916*(i-viii).

[8] McCullough, M. L., Feskanich, D., Stampfer, M. J., Giovannucci, E. L., Rimm, E. B., Hu, F. B., ... & Willett, W. C. (2002). "Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance". *The American journal of clinical nutrition*, *76*(6), 1261-1271.

[9] Sojic, A., Terkaj, W., Contini, G., & Sacco, M. (2016). "Modularising ontology and designing inference patterns to personalise health condition assessment: The case of obesity". *Journal of Biomedical Semantics J Biomed Semant, 7*(1). doi:10.1186/s13326-016-0049-1

[10] Ashburner, M., Ball, C. A., Blake, J. A., Botstein, D., Butler, H., Cherry, J. M., … Sherlock, G. (2000). "Gene Ontology: tool for the unification of biology". *Nature Genetics*, *25*(1), 25–29. http://doi.org/10.1038/75556

[11] Kim, J., Jang, M., Ha, Y., Sohn, J., & Lee, S. J. (2005). "MoA: OWL Ontology Merging and Alignment Tool for the Semantic Web". *Innovations in Applied Artificial Intelligence Lecture Notes in Computer Science,* 722-731. http://doi.org/10.1007/11504894_100

[12] "Physical Activity Health and Fitness (PAHF) Ontology," unpublished.

[13] Gkoutos, G. V., Schofield, P. N., and Hoehndorf, R. (2012). The neurobehavior ontology: an ontology for annotation and integration of behavior and behavioral phenotypes. *Int Rev Neurobiol*, 103, 69–87.

[14] Hastings J., Ceusters, W., Smith, B., Mulligan, K. (2011). Emotion Ontology: an ontology of affective phenomena such as emotions, moods, appraisals and subjective feelings.

[15] Hardi, J., Horridge, M., Musen, M., Tudorache, T., Tu, S., Nyulas, C., & Goncalves, R. (n.d.). "A free, open-source ontology editor and framework for building intelligent systems". Retrieved from http://protege.stanford.edu/

[16] Ainsworth, B. E., Haskell, W. L., Leon, A. S., Jacobs Jr, D. R., Montoye, H. J., Sallis, J. F., & Paffenbarger Jr, R. S. (1993). Compendium of physical activities: classification of energy costs of human physical activities. *Medicine and science in sports and exercise*, *25*(1), 71-80.

[17] Amerian Time Use Survey. News Releases. (n.d.). http://www.bls.gov/tus/

[18] Micro-Moments. (n.d.). Retrieved May 15, 2016, from https://www.thinkwithgoogle.com/micromoments/intro.html