*uc\_Eating:*

*Ontology for unambiguous characterization of eating and food habits*

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*Abstract*— **The IC\_Foods repository consists of various ontologies (uc\_eating, uc\_sense, uc\_milk, uc\_FIDO, uc\_processing) working together to branch out existing ontologies. Each ontology seeking to create a standardized unambiguous characterization system for modeling various processes. The creation of a computational knowledge base allows for the assessment, identification and characterization of eating patterns. Simultaneously, providing an infrastructure for annotating the relationships between food consumption and eating behaviors while creating a foundation for the characterization of human eating processes. The uc\_eating ontology seeks to create a standardized unambiguous characterization system for modeling human food habits and eating occurences. Uc\_eating will transform the science of eating and the paralleled decision-making process around what, when, where, and why humans eat. Thus, enabling various disciplines to leverage and add data science to their tool box along with hypothesis driven science. Uc\_eating transfers from a primarily hypothesis driven model to a data driven science model where the hypothesis is supported by the decision support system.**

# Background

The study of food consumption persists vastly amongst anthropologists, biologists, nutritionists, and various allied scientists. Anthropologists continue to conduct ethnographic studies on why, how, where and what humans eat. However, empirical ethnographic data ceases to allow for a useful computable database by varying individuals. The existing semi-structured data from anthropological research provides the necessary basis for creating the uc\_eating ontology. The purpose of the uc\_eating ontology is to create a foundation for the characterization of human eating processes across multiple food and beverage consumption scenarios. The uc\_eating ontology allows for the integration of aggregated data classified into eating behavior pattern phenotypes. Using a data driven science model from various sources such as ethnographic data combined into a computable database permits for amassed food habits categorized across ethnic, age, socioeconomic and a variety of other groups/factors. The modeling of human eating practices stems from the very roots of history, critical in understanding intrinsic and extrinsic motivations behind food consumption. Such behaviors found in ethnographies such as the “Food Between the Country and the City” examines the relationship of food and the cities at which they belong to (Domingos et al.). Data collected from existing ethnographies allows for the integration and a basis for further understanding food choices and habits amongst populations. Utilizing sources such as sentiment analysis permits the examination of existing ethnographies providing useable data collected and exemplified in the uc\_eating ontology. More specifically, sentiment analyses usefully tags across food and how individuals feel surrounding their food. Relating to the definition of food experience, characterized as the combination of three main elements: food, human engagement, and a particular context.

Sentiment analysis most commonly utilized as a means for capturing attitudes towards a particular topic remain useful, however, do not contain quantifiable structured data. The absence of structured data makes it difficult to clearly and concisely extract data. Dissecting the ancestral behaviors of individuals is a key factor in further constructing an ontology that is accurate and qualitatively useful for various individuals. Natural language processing provides the necessary tools to conduct sentiment analysis on existing ontologies. The volume of food related websites and applications are rapidly increasing. Data across different platforms such as Yelp, Facebook, Twitter and other technological websites and applications make it challenging to extract relevant information. Existing ontology-based systems use keyword-based search engines make it difficult for concise extraction of words and data. Ontologies reformulate full-text query present in many search engines extracting only the relevant data available. Thus, the creation of ontologies requires a combination of informatic experts as well as subject matter experts to build abridged foundation of knowledge. Subject matter experts such as nutritional anthropologists provide information unobtainable through the basic internet search. The use of existing material such as Health and Taste Attitudes Questionnaire, Motivations to Eat Scale, Dutch Eating Behavior Questionnaire and the Food Choice Questionnaire can subsequently be consolidated with the abilities of informaticians in building the eating ontology. It is vital in building the uc\_eating ontology to obtain a plethora of data to ensure the diverse variability of eating habits and consumption behaviors that exist amongst the human population. Ontologies such as the Hontology characterizing hotel attitudes towards experience hotel outline the analogous data mining practices at which the uc\_eating ontology builds around food (Chaves, Freitas, & Vieira). The Hontolgy acts as one of many existing database structures containing web data in the Semantic Web. Analogous to the Hontology,  uc\_eating is dependent on a taxonomy based characterization process. The taxonomy includes root classes determining the basis for the occurrent eating processes. We propose to model the framework of eating behaviors and food experiences as an ontology in order to have a shared and commonly understood basis for computerizing this domain while linking it with causes and consequences, enabling technology to drive a personalized well being.

# 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 largest global public health challenge [1]. Diabetes and obesity result from misguided behavior over many years of ongoing ill informed behaviors. The plaguing of the United States health system is not going to be repaired using medically prescribed drugs or surgery restoring thirty years of damage. The leading causes of death in the Untied States persist to be due to chronic disease attributed to a multitude of factors including nutrition; thus, highlighting the need for a homogenized vocabulary base to use as a common language throughout the population. The human diet is critical in solving the chronic disease epidemic in the United States, inappropriate food guidance and food availability mainly to blame. Often, we are seeing obesity coupled with malnutrition and vitamin deficiencies from the consumption of empty calories. Educating the population on correct eating behaviors whilst using a common language allows for a more effective communication and implementation of behaviors. Dietary recommendations do exist such as the government run system “My plate” although attempting to be personalized in the realm of health and nutrition such systems continue to fall short providing any type of relevant advice. In our effort to provide information that is the greatest good for the greatest number we end up misinforming people about appropriate foods for them based on their genes, life style, cultural appropriateness, and geographical location. The reality is “one size fits all” does not exist however technology provides the opportunity to enable personalization on a larger scale. Companies such as Netflix, Amazon, and Facebook use similar personalized recommendation systems however, these systems have not occurred in the eating or dietary realm. Currently, our modes of inquiry are fragmented missing the opportunity for personalization due to the lack of vocabulary, taxonomy, or ontology that unites the knowledge sources.

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, many socioeconomic and sociocultural factors may be related to choice architecture surrounding foods consumed. Food is often consumed as part of sociocultural rituals. Similarly, food habits can be aggregated and categorized across ethnic, age, socioeconomic and a variety of other groups/factors. Various 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. According to the obesity-related eating pattern ontology developed by Sojic et al. “an eating pattern ontology can create 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]. Sojic’s model of obesity-related ontology supports the classification of domain-specific patterns utilized by the uc\_Eating ontology. Features such as eating habits, social and psychological influences as well as nutritional condition all played a role when building our model of eating behaviors. The uc\_Eating ontology seeks to create a standardized unambiguous characterization system for modeling human food habits and eating processes. 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 conceptual model. The uc\_Eating ontology is located in a Web-based graphical interface Github, located in a repository titled ic-Foods/uc\_eating. Within the National Center for Biomedical Ontology, classifications of eating behaviors exist within a very 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 coincides [10]. Our goal is to create a further detailed characterization of those eating behaviors. Uc\_eating expands on existing ontologies such as the Uber anatomy ontology (Uberon), Chemical Entities of Biological Interest (CHEBI), and the Neuro Behavior Ontology providing a more specified characterization of eating. The eating ontology is part of building informatics platforms to enable ecosystems of open and proprietary technologies. IC-FOODS is capable of supporting decision support, and automation as well as appropriate levels of traceability and transparency. Together, ontologies work together to provide the personalized health system for individuals.

# 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 algorithm 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 being another ontology with the class “feeding behavior” contains the subclass “pharyngeal pumping”[14]. The uc\_Eating ontology seeks to characterize actual processes and create a broader range of specifications 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 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 details of the physiological consumption process itself inhere in eating behavior characteristics.

Breastfeeding provides a base model for several biological eating processes. The pattern begins with the age of the baby and how often milk is consumed or pumped. Subsequently, FIL (feedback inhibition of lactation) decreases milk production therefore ceasing breastfeeding. 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. 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.

# 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. Unambiguous characterizations of occurent processes create a useful tool that can be applied across multiple scenario.

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