Sensory Descriptive Ontology Design and Analysis

Abstract

In the field of biological ontology there have been many recent innovations in how to categorize entities in the natural world. This paper illustrates the importance of analyzing how the entities are perceived and the various ways in which they can be perceived. By creating an ontology of perceived sensory stimuli and the ways it can be interpreted, it is possible to connect the different ways to perceive these sensations and stimuli. Analyzing this aspect of biology in the form of an ontology will help us to better understand the way we perceive sensations. In designing this ontology we have been able to better understand the way perception affects behavior and mannerisms. This ontology also opens the door to studying what causes organisms to experience similar stimuli but react, or interpret, that stimuli differently by categorizing the perception events with sensory descriptive terms that fit into this ontological hierarchy.

Introduction

The field of biological ontology has been rapidly expanding as researchers have worked to develop many different ontologies. By using OWL: Web Ontology Language (6) researchers have been able to interconnect ontologies and expand our understanding of the natural world. This paper seeks to continue on this path by creating an ontology of perceived sensory stimuli and their interconnections with one another. We have defined sensory qualities in much the same way as Austin Clark: "A whiff of lilacs presents a particular sweet odour. The warmth of the rising sun yields certain tactile sensations. Bees’ honey has a specific taste. The qualities that characterize the smell of the lilacs, sensation of the sun, or taste of the honey are all what I will call sensory qualities" (2). Proceeding from this point, the next stage was to construct an ontology which contained as many different sensory qualia as possible in order to achieve a detailed ontology. In doing this, we looked at published food and beverage flavor wheels in order to establish a baseline for the variety of forms a sensory stimuli could be interpreted. Another important part of developing this ontology was to mark all stimuli as 'perceived' to denote that, while individuals can interpret stimuli differently there is a degree of consistency between perceptions. We looked at previously published ontologies to improve the structure of our own (which was produced using the program protege) by making the ontology as reusable while still maintaining specificity (4,7). We also incorporated the ideas presented by Simons, treating each subclass and superclass as part and whole in order to ensure our sensory ontology was consistent with previously produced ontologies(3). The importance of ontologies in the development of database management and even artificial intelligence has already been detailed by Varzi et al (9) and other researchers, therefore it is just as essential that we create an ontology for perceived sensory stimuli.

Design and Methods

First we began by gathering various food and beverage flavor wheels that accounted for more than just taste (ie aroma, mouthfeel, etc), we then used these wheels to design classes of perceived stimuli that an individual experiences. The classes needed to interconnect but also remain distinct in the event that a stimulus could be perceived with or without any number of other stimuli. These classes were not just limited to the standard human senses because there are some sensations that do not fall into a single sense as it may be a product of multiple types of sensation simultaneously. We found it difficult to categorize some sensations as a subclass of another which required a good deal of ontological remodeling to remedy the clutter. Ultimately, the subclasses for perceived flavors and aromas became so similar that in the end we decided to categorize the ultimate perception of a stimuli in similar terms between the two categories to avoid confusion. The ontology covers perceived aroma, flavor, mouthfeel, tactile stimulus, audio stimulus, visual stimulus, elasticity, viscosity, and spiciness, and breaks them down to the component parts that are interconnected. We felt it was important to distinguish between mouthfeel and texture, since texture can be any tactile stimuli on an individual's body, while mouthfeel is generally relating to consumption. The ontology is logically organized, going from general to complex in classifications of stimuli in order to remain consistent with ontological design, 'is a' and 'is a part of' format (1). This format is perfect for describing sensory stimuli since the perceived stimuli can be described with general terms or identified specifically as a subset of other perceived stimuli, similar to how a gene product can be a part of a process (1). The format of the ontology also connects the subclasses to other senses to represent how multiple senses can be involved in the interpretation of a stimulus. Austin Clark's research on sensory qualities was also helpful in clarifying how some sensory stimuli can be linked with reactions that may indicate other senses that interpret the stimuli (2). The final step was to clean up the ontology and link perceived stimuli between subclasses and to review the final structure of the ontology. This required careful examination of each category and the entities contained inside, as well as removal of unnecessary entities and subclasses.

Results

The ontology revealed several unexpected connections, for example, we were able to connect perceived mouthfeel with auditory stimuli and texture as well as sensory descriptive terms that are commonly used to explain mouthfeel (warming, parching, drying, etc). The sensory descriptive ontology also shows a great number of connections between aroma and taste that are consistent with other representations of sensory qualia (2). Additionally, the ontology revealed that some terms have very similar names but apply to very different perceptions of a stimuli, flat (in the sense of tactile stimuli) and flatness (in the sense of carbonation) for example, these terms relate to different perceptions even though they are similar terms. The ontology also connected perception of pain and heat to the perception of spiciness, which has previously been measured using only scoville heat units. In general, the ontology reveals many connections between perceived stimuli and how one sense can be linked to another, leading to a complex sensory web represented by the ontology. The ontology also reveals the overall complexity of sensory perception by classifying stimuli into interconnected pathways. Unfortunately, there is no way to know if the ontology contains all possible perceived stimuli and connections since it is the first sensory descriptive ontology, however that does not diminish the importance of the connections revealed by the stimuli that have been categorized in the ontology.

Analysis

The connections drawn from the creation and analysis of the ontology reveal that it is possible to classify sensory stimuli into classes and relate them to each other. The ontology also helps to underline the importance of further research in the field of sensory perception in order to better understand how these pathways are related, which will improve the accuracy of the ontology. While the ontology does not account for quantitative measurement of sensory stimuli, it does succeed in revealing how one sense can be related to another and what kinds of perceived stimuli these multi-sense pathways relate to. The ontology is helpful in visualizing pathways of sensory perception and in characterizing the way stimuli are perceived. Another important aspect of this ontology is that it can continue to expand and be made more complex as more about sensory perception is learned, the ontology acts as a dynamic database and be altered as our knowledge of sensory perception increases. The ontology can also be corrected in the event that there is evidence contradicting a sensory pathway.

Conclusions and Further Research

Bibliography

1. **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 Nat Genet,* *25*(1), 25-29. doi:10.1038/75556**

**2. Clark, A. (1996). Sensory Qualities. doi:10.1093/acprof:oso/9780198236801.001.0001**

**3. Doepke, F., & Simons, P. (1991). Parts, A Study in Ontology. *Noûs,* *25*(3), 393. doi:10.2307/2215517**

**4. Gangemi, A., & Presutti, V. (2009). Ontology Design Patterns. *Handbook on Ontologies,* 221-243. doi:10.1007/978-3-540-92673-3\_10**

**5. Khattak, A. (2011). Intelligent Healthcare Service Provisioning Using Ontology with Low-Level Sensory Data. *KSII TIIS KSII Transactions on Internet and Information Systems,* *5*(11). doi:10.3837/tiis.2011.11.008**

**6. 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. doi:10.1007/11504894\_100**

**7. Presutti, V., & Gangemi, A. (n.d.). Content Ontology Design Patterns as Practical Building Blocks for Web Ontologies. *Lecture Notes in Computer Science Conceptual Modeling - ER 2008,* 128-141. doi:10.1007/978-3-540-87877-3\_11**

**8. Scharffe, F., Zamazal, O., & Fensel, D. (2013). Ontology alignment design patterns. *Knowledge and Information Systems Knowl Inf Syst,* *40*(1), 1-28. doi:10.1007/s10115-013-0633-y**

**9.** Varzi, A. C., & Vieu, L. (2004). *Formal ontology in information systems: Proceedings of the Third International Conference (FOIS-2004)*. Amsterdam: IOS Press.