The Ontological Treatment of Sight and Blindness

Patrick L. Ray*, Alexander P. Cox, Mark Jensen, Travis Allen, and Alexander D. Diehl
The State University of New York at Buffalo
Buffalo, NY, USA
*plray@buffalo.edu

***Abstract*—There have been relatively few attempts to represent sight or blindness ontologically. This is unsurprising as the related phenomena of sight and blindness are surprisingly difficult to represent ontologically for a variety of reasons. This paper discusses those reasons, explores the current attempts to represent sight or blindness, and how these attempts fail at representing certain types of blindness, viz., color blindness and flash blindness. We then explore a possible solution to representing sight and blindness ontologically. The solution capitalizes on the resources afforded to one who adopts the upper-level Basic Formal Ontology. Roughly, we characterize sight as a function and blindness as a reduction in the conditions under which the sight function is realized.**

Keywords—ontology; sight; blindness; function; disposition; color blindness; flash blindness; Basic Formal Ontology.

I. Introduction

In its most basic form, blindness is the impairment of visual function below a certain threshold. Where this threshold lies varies depending on context. The World Health Organization characterizes blindness as visual acuity of less than 20/500 or a visual field of less than 10 degrees [1]. In the United Kingdom, the Certificate of Visual Impairment characterizes blindness as visual acuity of less than 20/400 [1]. In the United States, the American Medical Association characterizes blindness as visual acuity of less than 20/200 or a visual field of less than 20 degrees [1]. This indicates that the standards of blindness vary across international borders. Furthermore, there are the recent calls by the International Council of Ophthalmology to define blindness and visual impairment according to their own standards, at least part of which involve visual substitution skills employed by persons [1]. Moreover, visual acuity only represents one dimension of blindness. There are other types of visual impairments that fall beyond the scope of visual acuity – such as the ability or inability to differentiate color. Blindness then has many types and presents in degrees.

There are two obvious problems with representing and defining blindness and visual loss. First, different groups use different standards of measurement. Second, different standards of classification can be used while adopting a single standard of measurement. The primary difficulty arising from these problems is that it is exceedingly difficult to gather and compare data on blindness and vision related disorders. In addition, there are more complex problems that arise in representing blindness in formal ontology. This paper explores the difficulties that arise in representing blindness ontologically and proposes a novel solution to these problems.

II. Representing Blindness Ontologically

A. Seeing and Sight

Seeing is a relational process in Basic Formal Ontology (BFO). The process is a relation between an agent who detects and processes stimuli from the environment (external to the agent herself) and the stimulus itself. The process of seeing is representational insofar as the agent represents the stimulus in some manner (we will leave the nature of this representation to further examination). The diminishment or cessation of this relational process is often characterized as loss of vision or blindness. The main subject of this paper will be an examination of the loss of vision (seeing) in formal ontology.

Currently there are very few ontologies that seek to represent blindness. The reasons for this are as follows: first, it is rather difficult to characterize an entity via a lack or absence, which seems to be the case with blindness (the lack of sight) [2]. Metaphysically speaking, it is unclear whether a lack is ontologically significant. Taking the paradigm case of ontological absence involving material entities, a hole, there does not even seem to be anything to which one can attribute characteristics at all. This seems to indicate at least a *prima facie* problem with characterizing entities via lacks; if one is defined by a lack, then there are all sorts of things that seem to count at least when it is both a necessary and sufficient condition. Although a strategy for representing a lack of a part in the context of anatomy has emerged, it is contentious whether such a strategy will translate well for functions (dispositions) as the latter are not material entities [3].

Second, blindness does not seem to yield a precise definition or even clearly differentiated conditions under which it is present or absent. Many cases of blindness are progressive and it will be exceedingly difficult to determine at which point blindness has come into existence. Many cases present in degrees, which is common with the degeneration of the eye or apparatuses associated with vision. In addition to these complications, there is controversy over the threshold for blindness. It is common for publications regarding blindness to specify which definition of 'blindness' they employ [1].

Even with these complications regarding blindness, we feel it is useful to give a univocal account of the phenomenon for purposes of ontological development. Such an account should capture all or a vast majority of the cases of blindness and the various classifications of blindness found in the literature. Thus, it should remain general and flexible enough to capture a wide range of characterizations yet it should also be rigid enough as to remain informative and insightful.

There are many types of blindness. It is also the case that blindness can be defined relative to a context. For example, there is color blindness and change blindness, which both seem to be types of blindness themselves. An individual might be legally blind but still be able to detect some light stimulus – or one might be blind enough to be prohibited from flying a jet aircraft but not blind enough to be prohibited from driving. In this way, we might say that someone is 'blind according to [x]' where [x] is some standard of evaluation for sightedness. In this sense it can be said that blindness comes in degrees. The extent to which someone has a lack of sight or cannot see will be graded. If we think of seeing or sight as a relational process between an agent who is representing and the thing represented and the accuracy of such representations ranging from 1 (complete representational veracity) and 0 (no representational veracity), blindness will be somewhere on the continuum from 0 to 1 – the closer to 0 one's representation of stimulus, the more blind that individual is. Given the above considerations, one might draw the conclusion that there does not seem to be an ontological category that corresponds to what blindness is as an entity – blindness could be an amalgam of loosely related entities or something that is not itself ontologically well formed. While this conclusion is tempting, we do not find it to be satisfactory.

Lending to the confusion surrounding the status of blindness (and sight) is the method used for assessing visual acuity. Typically, visual acuity is expressed as a relationship between two values – the distance a subject stands from an optical chart, and distance at which a normal subject would stand from the chart to discern the same visual detail. Putting aside the problems associated with this particular type of visual acuity assessment, we have discussed above how this can lead to confusion regarding what conditions are indicative of blindness [4].

It is useful for clinicians and researchers to have a coherent theory of blindness that encompasses the range of conditions commonly understood to be forms of blindness. We simultaneously realize that blindness seems to be characterized as relative or context-sensitive (the term itself might be context-sensitive or the phenomenon might be context-sensitive or both). We favor the view that the term 'blindness' denotes a single phenomenon reflecting severe visual impairment relative to a particular context of evaluation. Thus, 'blindness' denotes an ontologically well-formed category.

Attempts to characterize blindness using current ontologies yields the results listed in table 1.

B. *Some Preliminary Distinctions*

According to the framework we have adopted, functions are a type of disposition. Functions are realizable entities that are realized in processes (what are sometimes called 'functionings'). Because functions are non-accidental, all of the functions a given entity possesses are intimately tied to the type of entity under examination, whether the entity is biological or artifactual. Functions are internally-grounded realizable entities so changing the physical structure of its bearer may alter the realization of the function in question; and if the function ceases to exist, the bearer must be changed physically [5].

We think that sight is a BFO function of visual systems (or at least visual systems of creatures with higher-order cognitive functions). One of the reasons we have for maintaining this proposition is that sight appears to be a result of an evolutionary process and the various mechanisms of sight for biological organisms straightforwardly seem the product of evolution. For non-biological entities possessing sight, if any, the sight that they possess is not accidental, but rather a product of design or intention on the part of the creator. This is consistent with with the non-accidental nature of functions.

Another reason to think that sight is a function is that it is realized by processes grounded in a material entity. This is a hallmark of a function as described above. Furthermore, another reason that sight is a function lies in the fact that if sight ceases to exist, then the bearer is physically changed. Although the entities still have the sight function, it is that they cannot realize that function due to some change in their physical constitution. Thus, there are many good reasons to support the assertion that sight is a function.

TABLE I. CURRENT ATTEMPTS TO CHARACTERIZE BLINDNESS

Ontology	***Term***	***Definition***	***Parent Class***
Gene Ontology (GO)	Visual perception	The series of events required for an organism to receive a visual stimulus, convert it to a molecular signal, and recognize and characterize the signal. Visual stimuli are detected in the form of photons and are processed to form an image.	Sensory perception of light stimulus
GO	Detection of visible light	The series of events in which a visible light stimulus is received by a cell and converted into a molecular signal. A visible light stimulus is electromagnetic radiation that can be perceived visually by an organism; for organisms lacking a visual system, this can be defined as light with a wavelength within the range 380 to 780 nm.	Detection of light stimulus
GO	Detection of light stimulus involved in visual perception	The series of events involved in visual perception in which a light stimulus is received and converted into a molecular signal.	Visual perception
GO	Determination of sensory modality	The determination of the type or quality of a sensation. Sensory modalities include touch, thermal sensation, visual sensation, auditory sensation and pain.	Sensory processing
Mammalian Phenotype (MP)	Blindness	Loss of the sense of sight.	Abnormal vision
MP	Abnormal vision	Inability or decreased ability to see.	Abnormal eye physiology
MP	Decreased visual acuity	Loss of visual acuity or ability to distinguish small details	Abnormal visual acuity
Human Disease Ontology (DO)	Blindness	N/A	Retinal disease
DO	Color blindness	A blindness that is characterized by the inability or decreased ability to see color, or perceive color differences, under normal lighting conditions.	Blindness
Human Phenotype (HP)	Blindness	Blindness is the condition of lacking visual perception due to physiological or neurological factors.	Visual Impairment

Proceeding with the proposition that sight is a function, we can characterize the specific type of function it is by identifying its defining features. Employing such a strategy, we characterize sight as the function to receive photons and interpret them as visual information. Relatedly, we can characterize seeing as the process by which photons are interpreted as visual information. Having given an account of sight as the realization of a function, it is then natural to identify the process by which the sight function is realized as vision.

An additional feature of functions (dispositions) and their functionings (realization processes) is that they are associated with certain triggering processes under which they are realized. The nature of this association is currently the subject of discussion in BFO but this much is clear: the relationship between the realization of a disposition and the disposition itself is mediated by the trigger, and the triggering process is connected to the realization process (perhaps causally) such that the presence of the trigger and the disposition lead to the realization of the disposition. For example, a sample of salt has a disposition to dissolve when placed in water. The realization process would be the physical mechanism of the dissolving process while the triggering process (or trigger) is the salt and water being together such that the process can manifest the disposition to dissolve. Although there are few attempts to formalize such entities as triggers, they are a commitment of BFO [6].

III. Two Interesting Cases

The reasons for thinking that sight is a function realized by a vision process in higher-order animals detailed in the last section provide our initial motivation. This section details two cases of blindness or types of blindness according to this account of sight.

A. Color Blindness

Color blindness is a condition wherein an individual has an inability to distinguish between two or more colors. In some cases the two wavelengths of light are represented or interpreted as the same when they are distinct. In other cases, an individual cannot report a difference between two or more wavelengths of photons [7]. The inability to distinguish between two or more types of light is not limited to just one cone type [8]. Complicating this picture somewhat is that there are many mechanisms identified as causes of color blindness and that these mechanisms are not localized to one anatomical region. Some color blindness is due to an individual lacking cone cells or a certain type of cone cell. Other times the cause is cortical [9]. Thus, color blindness is similar to other types of blindness in that the causes and mechanisms associated with it are diverse and complex.

B. Flash Blindness

Flash blindness is a type of blindness that results from exposure to sudden-onset bright light. The sudden light will oversaturate the photopigments of the retina and the individual will be unable to convert photons to a neural signal due to this oversaturation [10]. Flash blindness is commonly temporary blindness, where the subject regains their full ability to see within a few minutes. There are some extreme cases, however, where flash blindness will result in permanent vision loss [11].

C. Current Solutions

Given the above discussion, it seems that there should exist the resources to represent blindness. One of the most likely candidate solutions involves using the Human Disease Ontology (DO). DO currently does not provide a definition of blindness but one plausible candidate posited on their behalf would follow their characterization of color blindness as an inability or decreased ability to detect light stimulus. Color blindness in DO is defined as: "a blindness that is characterized by the inability or decreased ability to see color, or perceive color differences, under normal lighting conditions." [12] Moving from this definition of a specific type of blindness to blindness generally should produce the result that blindness is "the inability or decreased ability to see or perceive, under normal lighting conditions."

While an attractive view in general and one to which we are mostly sympathetic, such a definition of blindness will not stand up to careful examination. In the first place, DO categorizes blindness as a disease. Blindness is not a disease. Moreover, it is not a type of retinal disease as DO currently characterizes it. Blindness may result from many diseases and many diseases will complicate blindness and the sightedness of individuals, but is not itself a disease. But it may also be the case that blindness does not result from a disease but rather a single event, as is the case with flash blindness. It is also not the case that blindness is limited to problems in the retina. Cortical blindness is a type of blindness that does not involve any malfunction with the retina. Even some specific types of blindness are not limited to just one mechanism of realization in one location, as detailed in the last section.

These rather easily remedied problems notwithstanding, the more pressing concern is that there does not seem to be any indication of what an inability or decreased ability would be. The concern is plain – abilities cannot lack according to BFO. If abilities are dispositions or functions, then they are realizable entities. Realizable entities cannot present in degrees, as their existence is an all-or-nothing affair. If blindness is an inability to detect light, then all cases of blindness will be a complete inability to detect light stimulus, which fails to capture the cases of blindness that are not the complete inability to detect light stimulus. If blindness is a decreased ability to detect light, then it cannot be represented as a decreased function or disposition in BFO. But, since sight is a function, and blindness is the lack of sight, we are left to wonder whether an account of blindness can be given as an inability. We believe that this type of account is confused.

Another route for capturing blindness is to maintain that blindness is a disorder, where a disorder is "[a] material entity that is clinically abnormal and part of an extended organism." [13] The problem with this approach is that it is unclear that blindness, as a phenomenon, is a material entity. If one thinks that blindness is the absence of the sight function, then it does not seem that blindness is a material entity (material entities are not absences of functions). Further, one cannot point to a material entity and identify it as blindness as blindness is not spatially extended; but spatial extension is a hallmark of

material entities. For these reasons, blindness cannot be a disorder.

D. Proposed Solution

Drawing on the lessons from the previous sections we propose a solution to the problem that blindness poses for ontology development. Because sight is a function and blindness is seemingly the non-realization of the function that is sight, we set forth an account of blindness where blindness is a reduction of the conditions under which the disposition that is the sight function is realized. To put it another way, the range of the triggering processes is narrowed such that the sight function is realized under a narrower range of conditions.

This solution is able to deal with the cases outlined above. For color blindness, we would say that color blindness is a reduction in the (color) conditions under which a vision function is realized. Although different types of color blindness will involve different types of reduction of conditions, they will be unified into a single phenomenon by the fact that they all involve the reduction of the light wavelengths that result in differentiated visual representation. For flash blindness, we say that there is a temporary (or possibly permanent) reduction on the conditions under which the vision function is realized – whatever the mechanism realizing the function of sightedness may be. Because the function is realized by a rather complicated functioning in both cases, the type of blindness can range over different types of failure in functioning so long as the reduction of conditions is similar. One could also classify types of blindness by the types of failure in sight functionings, if one so chose.

IV. Discussion

With the problems associated given the above classifications of blindness we propose a new definition of blindness that acknowledges the problems encountered with previous definitions and seeks to capture the nature of the phenomenon of blindness identified earlier. If blindness admits of degrees, then it seems that blindness cannot be a function or disposition. It also seems that blindness cannot be a lack of a disposition or function because many things lack the function yet should not be classified as blind. One of the options available for defining blindness is to say that sight is the function to receive photons and interpret them as visual information and then proceed to define blindness as a reduction of the conditions under which the disposition is realized (trigger conditions).

This view has certain advantages. First, it accounts for the graded nature of blindness. The slow and sometimes gradual onset of blindness raises special problems for ontology construction as it admits of degrees and seemingly vague boundaries. Second, it classifies sight as an internally-grounded realizable entity, which makes use of the framework provided by an upper-level ontology such as BFO. Third, it is ontologically innocent in that there are no new entities to countenance in any upper-level ontology. The entities that are referenced in the theory we advocate are already present in BFO and so there is no need to introduce new entities. Fourth, such a treatment of blindness lends credence to discussions of triggers and dispositions in formal ontology. This discussion is a step toward providing an account of causality in BFO.

The motivation of this project is to provide a simple yet flexible ontological account of blindness. Since blindness is the result of many ocular diseases, the construction of ontologies that incorporate both blindness and the diseases that result in blindness, either directly or indirectly, is of importance to the biomedical community. But this is not a purely classificatory exercise – the employment of the conditions under which a disposition is realized (in this case a function) is a novel application of a tool that has been available for ontological developers for some time. It is the opinion of these authors that this type of usage could yield further fruitful results.

Acknowledgments

The authors would like to thank William Duncan and Isaac Berger for their insights in commenting on this manuscript. We would also like to thank three anonymous reviewers for helpful comments.

References

[1] August Colenbrander, “Visual Standards, Aspects and Ranges of Vision Loss with Emphasis on Population Surveys.” Report prepared for the International Council of Ophthalmology at the 29th International Congress of Ophthalmology, Sydney, Australia, April 2002.

[2] David Lewis & Stephanie Lewis, “Holes,” *Australasian Journal of Philosophy*, 1970, 48:2, 206-212.

[3] Robert Hoehndorf, Anika Oellrich, Michel Dumontier, Janet Kelso, Dietrich Rebholz-Schuhmann, Heinrich Herre, “Relations as Patterns: Bridging the gap between OBO and OWL.” *BMC Bioinformatics* 2010, 11:441

[4] Hans Strasburger, Ingo Rentschler, Martin Juttner, “Peripheral Vision and Pattern Recognition: A Review.” *Journal of Vision*. December 28, 2011. 11(5):13, 1-82.

[5] Robert Arp, Barry Smith, “Function, Role, and Disposition in Basic Formal Ontology,” *Nature Precedings* : 2 Jun 2008.

[6] Johannes Rohl and Ludger Jansen “Representing Dispositions.” *Journal of Biomedical Semantics*. 2011, 2(Suppl 4):S4.

[7] Bevil R. Conway, Soumya Chatterjee, Greg D. Field, Gregory D. Horwitz, Elizabeth N. Johnson, Kowa Koida, Katherine Mancuso, “Advances in Color Science: From Retina to Behavior.” *The Journal of Neuroscience*. November 10, 2010 • 30(45):14955–14963.

[8] George Wald, “The Receptors of Human Color Vision,” *Science*, New Series, Vol. 145, No. 3636 (Sep. 4, 1964), pp. 1007-1016.

[9] S. Kohl, T. Marx, I. Giddings, et al. (1998). "Total Colourblindness is Caused by Mutations in the Gene Encoding the Alpha-Subunit of the Cone Photoreceptor cGMP-gated Cation Channel." *Nature Genetics* 19 (3): 257–9.

[10] John Lott Brown, “Experimental Invesigations of Flash Blindness.” Human Factors: *The Journal of the Human Factors and Ergonomics Society*. 1964 6: 503.

[11] Ruth W. Shnider, “Compilation of Nuclear Test Flash Blindness & Retinal Burn Data and Analytic Expressions for Calculating Safe Separation Distances,” Defense Atomic Support Agency Document, April 1971.

[12] Lynn Marie Schriml, Cesar Arze, Suvarna Nadendla, Yu-Wei Wayne Chang, Mark Mazaitis, Victor Felix, Gang Feng, Warren Alden Kibbe, “Disease Ontology: a backbone for disease semantic integration.” *Nucleic Acids Research*. 2012, Vol. 40. D940-D946.

[13] Richard Scheuermann, Werner Ceusters, Barry Smith, “Toward an Ontological Treatment of Disease and Diagnosis.” In AMIA Summit on Translational Bioinformatics, 2009, 116-120.