Sensory Schema: From Sensory Contrasts to Antonyms

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Abstract

The article explores sensations’ role in cognition through analyzing expressions in natural language in search of a sensory schema. I argue that if it exists, the schema originates from the universal need to differentiate between patterns by increasing contrasts, which is linguistically manifested in the practice of grading adjectives and adverbs in the context of antonyms.

Keywords

intensity – extent – contrasts – sensory schema – image schema – graded antonyms – binary opposition

1 Introduction

“Everything we know about the world comes to us through our senses. We experience the world as we do because our organs of sight, hearing, and smell are constructed in a certain way.”

(Fain, 2003:1)

1 The article is one of three papers (see Raykowski, 2018, 2019) about the sensory schema. The primary purpose of the article is to introduce the reader to the inner workings of the proposed theory. To avoid distraction and prevent obfuscation, an overview of linguistic literature in the article has been kept to a minimum.
Much has been said about the body: its role in cognition and the ways in which it shapes human thinking and reality perception. One detail has been omitted from these discussions. This detail concerns not the senses but the sensations without which no organism can be consciously aware of its environment, its own body and its movements.\(^2\) The quotation at the beginning of this section reminds us of the sensory basis of all aspects of human cognition, including natural language.

The role of the senses at the physiological level is relatively straightforward—a sensory receptor detects a stimulus, the signal from which is then transferred along the neuron to various parts of the nervous system. At the individual scale—the level at which senses turn into sensations—the situation is more complex. Sensations are private—they can be experienced only by their owner. To communicate them, sensations must be expressed publicly, and their expressions must include both the intensity and extent of sensations, the communication of which is not always consistent (Raykowski, 2019). For example, in the case of a painting, the paint’s intensity always comes with its extent, whereas in natural language, one or both are frequently omitted, as demonstrated in the sentence “Those red apples are tasty”. Furthermore, sensations of some intensity can always be described as including a lower level of intensity, which in turn includes another level, and so on. Because of their nested structure, which is indivisible, intensity levels are perceived as essential constituents of discrete units. Sensation of an extent, on the other hand, can be characterized as a succession of discrete units, the collection of which can be divided, concatenated and scanned sequentially. The striking difference between intensity and extent can be fully appreciated if they are visualized with brackets arranged in a nested pattern (((()))) for intensity and a concatenated pattern ()()()()() for extent. The brackets demonstrate that sensations have quite sophisticated structure. Furthermore, the use of the notions of intensity and extent is widespread, as they can be found in areas of expression as different as engineering, sciences, arts and music and in practically all forms of expression, including natural language (Raykowski, 2018, 2019).

These and other observations have led to the development of a sensory schema hypothesis presented in this article. The hypothesis interprets sensations as an intricately structured and meaningful phenomenon attributed

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\(^2\) Simple organisms, such as worms and mollusks, move as a result of often very complex reflex responses. They do not have a means to monitor and represent deformations of their own bodies during movement. For an example of a discussion on this topic, refer to Robert W. Elwood’s paper (Elwood, 2011) regarding the sensation of pain in invertebrates.
to sensory organization, in which cortical maps in the brain play a key role. On this basis, I argue that sensations are not only inherently meaningful (Raykowski, 2019) but also give rise to a single sensory schema that precedes, as indicated below, the emergence of image schemas:

\[
\text{sensory schema} \rightarrow \text{Gestalts}^5 \rightarrow \ldots \rightarrow \text{image schemas} \rightarrow \text{cognitive metaphors} \rightarrow \text{expressions}: \text{analogies, linguistic metaphors, arguments or narratives, etc.}
\]

The boundary between these two schema types is not well defined, mainly because the concept of image schemas is a subject of debate (Hampe and Grady, 2005). There is a general consensus, however, that image schemas are dynamic multimodal patterns of embodied experiences liable to grouping and transformations. As a result, a wide range of image schemas exist, and their number seems to be growing.

In contrast, only one sensory schema exists. I argue that because all cortical maps share, in general, very similar organization (Kaas, 1997), their properties can be described using a single schema. The sensory schema is, therefore, a generalization of all sensory modalities organized into maps. Such generalization is possible only before sensory patterns are identified as specific “objects”. In the case of the sensory schema, patterns are intuited only in terms of their intensity and extent. However, if they are processed further, these intuitions could become available to the individual as fully fledged image schemas used in reasoning and communication.

Several advantages lie in separating sensory from image schemas: the sensory schema provides an alternative explanation for transduction-based views without contradicting them; it argues on behalf of the biological (cell-based) origins of cognition; it clarifies sensory maps’ role; and it points to the key

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3 “In all mammals, much of the neocortex consists of orderly representations or maps of receptor surfaces that are typically topographic at a global level, while being modular at the local level. (...) Topographic maps provide an especially suitable substrate for the common spatiotemporal computations for neural circuits. Finally, aspects of perception suggest the functional importance of topographic maps” (Kaas, 1997: 107).

4 “An image schema is a recurring dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience. ... ‘Experience’ ... is to be understood in a very rich, broad sense as including basic perceptual, motor-program, emotional, historical, social and linguistic dimensions” (Johnson, 1987: 16).

5 Gestalt theory’s main area of study is the visual perception of patterns. It describes various ways in which smaller patterns can be grouped by proximity, similarity, figure-ground, etc., into larger patterns. Note that in the context of the article, these processes take place before the patterns are recognized as specific “objects".
roles of intensity, extent and contrasts in human reasoning and expressions. Although its presence could be found in many if not all forms of expressions, I will limit my discussion of the schema to its application in analyzing gradable, binary and complementary antonyms, as well as in grading adjectives and adverbs with a few examples of nonlinguistic entities. Before the sensory schema is defined and discussed in detail, the issue of representation is revisited in the next section.

2 The Issue of Representation

The essence of life is movement. To move consciously, most multicellular organisms must be aware of spatial relations both in and outside their own bodies. This information can only be provided by the sensory organs. Unlike physical “objects”, none of which can be represented in the brain in their entirety (e.g., as a solid model), spatial relations among and within those objects (including the body) are easy to duplicate with collections of identical elements capable of adopting at least two contrasting states. Such collections include assemblies of pixels on television or phone screens, particles of paint or ink on surfaces, or even Lego blocks – practically anything capable of creating various forms of contrasts.\(^6\) One such example is a geographical map of the world, as shown in Figure 1, and another is the visual cortex in multicellular beings’ brains. Both arrangements can convey spatial relations between contrasting elements, constituting their surfaces. The sense of space in such maps is derived from the fact that their elements occupy physical space (Raykowski, 2019).

Cortical maps in the brain\(^7\) are large sensory neuron collections, the arrangement of which duplicates the distribution of their receptors in the body (Kaas, 1997) just as the arrangement of hexagons in Figure 1’s map duplicates their distribution on the Earth’s surface. Perceiving continents in the geographical map results from the contrast between the light elements, which represent land masses and dark elements, which represent oceans. In the case of cortical maps, contrasts are created by different levels of electrochemical activation of sensory cells (and their proxies) constituting the cortices. Sensations’ character and their intensity are defined at the receptor end of sensory cells.

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\(^6\) For examples of contrasts in art, see Danny Rozin (2019). YouTube video by Wired. How This Guy Makes Amazing Mechanical Mirrors (https://www.youtube.com/watch?v=kV8v2GKC8WA).

\(^7\) The fact that the maps are often fractured and overlapping does not affect the argument.
The plurality of adjacent elements activated at the same or similar levels contributes to the sense of extent (e.g., area or duration of sensation). Because sensory cell activation can vary continuously, cortical maps can convey many intricate contrasts simultaneously. As a result, cortical maps can represent an immense range of spatial patterns that can be activated internally (simulated offline) or created directly by “objects” interacting with the body. Contrasts are experienced as differences between levels of some activation of contiguous cells against the background of lower or zero activation. The experience of sensory intensities is truly universal, as no sensation (whether simulated or occurring in real-life interaction) can be experienced without it. Furthermore, no sense of intensity can be experienced without sensory cells. As a result, intensity is always experienced with extent. Because the cellular elements of cortices represent a network, the boundaries between adjacent cells (where one cell ends and another starts) can be defined only in terms of their receptive fields, which are the areas of the body whose stimulation causes the greatest activation of sensory cells (Purves et al., 2004).

An example of a specific pattern, such as that of a container, demonstrates the sophistication of representations. The characteristic pattern associated with a container is defined against a contrasting background. More often than not, representations of the container in visual maps are fragmented due to occlusions, illumination, and other viewing conditions. Such fragments must be pieced together by extracting various aspects, including edges, orientation and a variety of other features. The process of merging the fragments is likely
to include such Gestalt-like operations as grouping by proximity, by similarity, by closure, by continuation, and by common movement (Behrmann and Kimchi, 2003: 19). Regardless, the ultimate goal of such processes is to interpret two-dimensional contrasts as objects in three-dimensional space.

The experience of containers is not restricted to a single sensory modality (e.g., visual maps). This means that there are as many notions of containers (and space in general) as there are sensory modalities taking part in interactions with physical “objects”. These experiences differ dramatically from one another. For example, the visual experience of a specific container (e.g., walls of a room) bears no resemblance to the proprioceptive experience, which defines containers by the ways they limit body movements. The senses of intensity and extent also differ in character between sensory modalities. When associated, such dissimilar sensations from the same container contribute to the full sensory experience of this “object”. In conclusion, for sensory patterns to be more than a plethora of contrasts of some intensity and extent, they require further processing to turn collections of activated cells into a meaningful pattern.

3 Sensory Schema

“There is a curious pattern involving sensations – they are experienced only when their magnitude is sufficiently high, and their extent is sufficiently large. If one of those factors is missing, there can be no sensation.”

(Raykowski, 2019: 202)

It is often assumed that complex concepts emerge late in cognitive processes or that they are socially created. One reason why this might not always be the case is that human intuition of intensity and extent already exists at the level of sensations. I argue that, if considered in the context of sensory maps, many more notions, such as sense of space/time, addition/subtraction, differentiation/integration, sum/product, part/whole, opposite/inverse, idempotence, and other ideas (Raykowski, 2014, 2015, 2018, 2019), known for their sophisticated nature, are already accessible as intuitions at the level of sensations that, when processed further, are transformed into image schemas and their expressions.

People commonly discuss the intensity of their sensations without mentioning extent or discuss extent without mentioning intensity, which can lead to the impression that the intensity of sensations can be somehow separated from their extent. The quote starting this section reminds us that, at least in the
case of sensations, intensity and extent are inextricably bound together due to their origins in cortical maps.

I use these and other observations to argue for cognitively separating sensations from perceptions and other higher-order processes, especially image schemas, on the basis that cognition’s structural foundation must already be present in sensations in order this foundation’s elements to apply to image schemas. I claim that this foundation emerges from the interaction between the intensity of activation and its extent in the context of sensory maps in an individual’s brain. The interaction’s structure, which I refer to as a sensory schema, comes to us not as a specific concept but as intuitions of concepts.

Note that the notion of intensity is included in the image schema list assembled by Johnson, who designated intensity initially as Scale (Johnson, 1987: 126) and later as Scalar Intensity (Johnson, 2017: 152–4). Curiously, Johnson does not specify any schema of extent, at least not directly. Likely candidates for extent include Iteration and Path, both of which involve repetition. Unlike sensations, image schemas are multimodal and structurally complex: Path, for example, has been described by Johnson as the experience of a landmark (often static) and a trajector (an object or person) moving in space. Such movement’s salient aspects include a source, path, and goal (Johnson, 2017). This complexity comes with the fact that image schemas were introduced as an integral part of conceptual metaphor theory (Lakoff and Johnson, 1980), which describes relatively advanced processes of pattern recognition and movement as they are reflected in natural language. The multimodal character of image schemas is one reason for postulating the sensory schema.

To introduce the sensory schema, I refer to the diagram in Figure 2, which shows a generalized notion of a container filled with a substance, the accumulation of which results in a rise in levels.8 The use of containers has many advantages, as they reflect the experience of sensations fairly well. Note that neurons can be thought of as containers, different molecules as substances of accumulation, the intensity of neuron activation as levels, the number of cells as extent, sensory modalities as properties, and so on. Another advantage is that containers are more familiar to most readers than, for example, the concept of measure scales. It is important to keep in mind that the diagram in Figure 2a is not the sensory schema as such but its public expression.

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8 Accumulation is a special case of a general intuition called “cognitive/sensory product” which is understood as an association of containers or layers with levels. Because accumulation in Figure 2a involves single container, the extent of its product is one. A definition of sensory products and their application can be found in my earlier articles (Raykowski, 2014, 2015, 2018, 2019).
Additionally, note that for intuitions to be analyzed and reasoned about, they must be converted first into image schemas (e.g., MORE IS UP; LESS IS DOWN) and then expressed by means of a conceptual metaphor.9

The container diagram in Figure 2a can be applied to various sentences, including “Very sweet apple” displayed in Figure 2b. Because the diagram is a generalization, the apple can be thought of as a container, sweetness as a substance, and levels as the intensity of sweetness attributed to the apple. Note that the sense of sweetness in the figure is interpreted as a sensation without any reference to sugar. Nothing, however, prevents us from using the diagram to interpret the sentence in terms of sugar content. In this case, sugar is treated as a substance and its volumes as layers, the accumulation of which defines the ever-higher levels of sweetness. The apple’s total sweetness in this interpretation is a product of the apple’s sugar concentration and volume. This example shows that the same schema can be used in both “naïve” and scientific reasoning.10

In summary, the schema can be applied to a great variety of objects, containers, substances, properties and the ways they interact. Instead of defining it directly, I will describe the sensory schema’s accumulation aspect by using it to analyze adjective/adverb grading carried out in the context of antonyms.

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9 In cognitive linguistics, conceptual metaphor is defined as understanding one domain of experience (private or abstract) in terms of another (typically, public and concrete). Some examples motivated by the image schema MORE IS UP; LESS IS DOWN include: “The number of books printed each year keeps going up. His draft number is high. My income rose last year. The amount of artistic activity in this state has gone down in the past year. The number of errors he made is incredibly low. His income fell last year. He is underage. If you’re too hot, turn the heat down” (Lakoff and Johnson, 1980: 15–6).

10 The sensory schema provides the basis for conceptualizations of mixtures, blends and solutions, and for nonproportional reasoning (Raykowski, 2014, 2015, 2018).
However, before any specific examples are examined, the issue of contrast is revisited in the next section.

4 From Sensory Contrasts to Contrast in Language

The primary function of sensory maps in the brain is to duplicate spatial relations inside and outside the body to facilitate movement. A common challenge all organisms face in this situation is the problem of reliably distinguishing the sensation of “objects” from their background. Making this distinction requires the sensory systems to be more sensitive to contrasts rather than to the sensation's absolute value (Olsson et al., 2018).

Contrasts can be described in terms of the intensity of reflected light or, from the viewer’s perspective, as the intensity of visual sensations. Contrasts can be improved by widening their grading. For example, the contrast between the text and the background in this article is enhanced by making the letters darker (decreasing the intensity of sensations) and the background lighter (increasing the intensity of sensations). Intuitions of intensity and extent, as they are defined by the sensory schema, are also utilized in other forms of expression, including natural language. It can be argued that the experience of sensory contrasts provides an intuitive template for semantic contrasts at the language level.11 The grading of adjectives and adverbs is one example of creating contrast in language. Interpreting antonyms as an effect of maximizing contrasts and synonymy as a result of minimizing them is another example. As a way of creating contrasts, grading is therefore a universal characteristic of both sensory experience and language. If this is correct, then gradable antonyms are more fundamental than binary opposition (see Section 11). I argue that contrasts produced by varying intensity are used to create antonymy in its most basic form.

I refer to this as contrast-based antonymy to differentiate it from opposition-based antonymy constructed by juxtaposing two contrast-based antonyms.12

11 Ways of creating contrast depend on the scale at which they are considered. Compare visual contrast (achromatic and chromatic) with phonemic, lexical, syntactic or literary contrast.

12 Because contrasts are defined within the sensory schema framework, the intensity of which can only be positive (equal to or greater than zero), any opposition between two sensory schemas must, by definition, involve dissimilar properties. For example, cold and hot must be interpreted as two different properties and not as negatives of each other. To share a common property, both cold and hot should be defined within an absolute property such as that of hotness (Section 11).
To introduce these issues, I start the discussion of contrasts in linguistics with the concepts of *layers* and *levels* in the context of a water column (Section 5), a topic that provides a very good introduction to the antonyms *wet/dry*, followed by *full/empty, alive/dead, rich/poor, happy/unhappy, happy/sad, not happy and not unhappy*, and finally, *difficult and important*. Discussing these antonyms is intended to make the sensory schema more familiar to linguists and to demonstrate its utility. Before any examples are investigated, the notion of antonymy is reinterpreted in the context of the sensory schema in the next section.

5 Sensory Schema Interpretation of Antonymy

In the course of her PhD studies, Muehleisen compared the meanings of selected pairs of antonyms such as *wet/dry* “in order to see how similar or different they really are. Since all of the case studies focus on adjectives and since the function of adjectives is to modify nouns, a very good way to characterize adjectives’ meanings is by looking at the kinds of nouns they typically modify” (Muehleisen, 1997: 62).

The issue of wetness and dryness looks somewhat different when viewed from the experiential perspective. Muehleisen provides a list of nouns frequently associated with wet conditions: “bag, bar(s), boots, bottom, clay, climate, cloth, concrete, conditions, eyes, feet, field, finger, fly(-ies), footing, grass, ground, hair, handkerchief, harvesting, land, leaves, look, May, meadow, moss, nurse, paint, patterns, plaster, road, sand, season, snow, soil, sponge, spot(s), spring, suit(s), summer, Sunday, towel(s), track(s), weather” (Muehleisen, 1997: 124). Each noun in the list represents a different form of the object’s interaction with water. Water can be contained in a vessel (a cup full of water), be accumulated on a surface (morning dew on leaves), be absorbed (a wet towel), or be part of a mixture (wet concrete), and its vapor can be a component of the atmosphere (humid weather). Such relations are described in terms of extent (e.g., some/all/most of the towel) and levels (are slightly wet or dry, quite wet or dry, very wet or dry and extremely wet or dry).

All of these relations are conditional on water’s presence. Water is also a substance with certain properties. Unlike the notions of *wetness* and *dryness*, water is a material entity capable of physically interacting with the sensory system and other material entities. I argue that, at least at the level of sensations, the relationships between antonyms and related synonyms are defined not by the properties of *wetness* and *dryness* as such but by the experience of water interacting with objects. I also claim that this interaction is part of the sensory
schema emerging from the interplay of sensory receptors with both the water and objects. To appreciate the schema’s role, I analyze the process of handling water, which is the next section’s subject.

5.1 Thinking in Terms of Levels and Layers
Even though the handling of water may seem straightforward and hence inconsequential, the way we talk about it is quite revealing. Water is a physical substance, the density of which does not change with accumulation. Figure 3a illustrates the familiar situation of filling up a container with water. Stage “a” represents the empty container. Each time a full cup of water is added, the level rises until the container is full (stage “e”).

5.2 Layers
The example of water in a cup represents a discrete volume separated from its surroundings by space. When poured into a container, the water creates a “discrete” layer defined by the cup’s volume and the container’s shape. Simultaneously, the water level rises. The process of adding water is a repetitive act that is represented with brackets as a sequence, starting with one bracket (,), followed by a second bracket (()), a third bracket (())(), and then a final bracket pair (())(). This way of thinking is referred to as repetition and concatenation. Each pair of brackets represents a discrete layer in the sense that they can be separated from other layers by inserting a space between them.13

![Diagram](image)

**Figure 3** Applying the sensory schema to the antonyms full and empty. Figure 3a shows the stages of water accumulation, and Figure 3b depicts the stages of air being removed from the container as water levels rise.

13 In the schema’s context, space is expressed by way of large arrays of containers, some of which are empty (zero level = empty space between objects) while others are filled with a substance (the objects’ internal space).
Water is an example of a physical substance. Like water, other substances are additive in the context of one or more physical properties, such as length, area, volume, mass, amount, number or quantity. The notion of substances is significant for cognition because they can interact with sensory organs and define the intensity and extent of sensory experiences resulting from the interaction.

5.3 Levels
Each time the water is poured into a container, the water level rises. This phenomenon can be depicted with brackets as follows: \(\emptyset\) for an empty container, \((\emptyset_{O_A})\) for the level “\(O_A\)”, \((()_{O_A}O_B)\) for the level “\(O_B\)”, \(((()_{O_A}O_B)_{O_C})\) for the level “\(O_C\)”, and \((((()_{O_A}O_B)_{O_C})_{O_D})\) for the final level “\(O_D\)” (Figure 3a). Unlike layers, levels are organized such that each water level contains all of the lower levels. Thus, the level “\(O_D\)” includes the level “\(O_C\)”, which includes the level “\(O_B\)”, which includes the level “\(O_A\)”, which in turn includes level “\(O\)”, which is associated with the empty container. This way of thinking is referred to as nesting. To emphasize that all levels share the same container, the brackets \(((())\)) are modified to \((())\)). Next, they are organized vertically in accordance with their occurrence in nature as well as with the way levels are perceived, conceptualized, and subsequently expressed. Figure 3a illustrates this arrangement, which depicts five stages of water accumulation. The reverse bracket configuration representing a decrease in space above the rising water levels is pictured in Figure 3b.

The concept of nesting differs from the notion of inequality expressed with the “greater/lesser than” phrases or signs < and >. An inequality such as \(10 > 8 > \emptyset\) involves comparisons that draw attention to the difference between entities in the context of a property. In the example, the difference between the values 10 and 8 is two, and the difference between 8 and \(\emptyset\) is eight. Such comparisons are usually framed in the language of logic, with the focus on whether the entities in question have a specified property or relationship.

Nesting, by contrast, emphasizes inclusion in the sense Johnson described: “Scales have a cumulative character of a special sort. If you are collecting money and have accumulated $15, then you also have $10” (Johnson, 1987: 122). To appreciate the difference between nesting and repetition, one must consider the effects of removing layers and levels from the water column. As an example, consider removing the third layer from the following four-layer arrangement:

\[
O_{0A}O_{AB}O_{BC}O_{CD} - O_{BC} = O_{0A}O_{AB}O_{CD}.
\]

The opening brackets “((())) of the expression (((()))) refer to the bottom-level of a shared container and as such they can be replaced with the single bracket “(“.
Three layers remain. However, if the third of four levels is removed, as in

\[ (((0_A)_{0_B})_{0_C})_{0_D} - 0_{0_C} = 0_{0_D}, \]

only one level remains\(^{15}\) because the third level “\(0C\)” already contains level “\(0B\)”, which contains level “\(0A\)”. If all levels are removed [by removing \(((0_D)\)\)], then no water remains (level “zero”), which is interpreted as an empty container. Zero, therefore, has a specific meaning in the context of nested levels.\(^{16}\)

Nesting is the reason why levels cannot be added together the way layers can. In order for any two entities to be added together, they must contain identical levels of a common property.\(^{17}\) For example, adding red paint to red paint of identical value changes the extent (area or thickness) but not the paint’s color or intensity. Similarly, adding a car that travels at 100 km/hour to a group of cars traveling at a speed of 100 km/hour will change the number of cars but not their speed. What these and other examples represent is not the addition of levels but the addition of layers. The nonadditive property of levels (referred to as idempotence) is critical for perceiving contrasts, both sensory and semantic.

5.4 **Space above Water**

Pouring water into a container gradually displaces air from the vessel. The process is depicted in Figure 3b, which represents levels of depth. The act of displacing air from the container complements the liquid’s accumulation in the sense that the sum of the space occupied by the water and the space above it is constant and amounts to the container’s maximum capacity. This relationship is used in the current article to test for complementary antonyms. Note that, in Figure 3a, filling up a container (water accumulation) and emptying it (water draining) are not complementary but reverse processes. Notably, the adjectives *empty* and *full* are complementary only if they both refer to the same substance (e.g., water volume) for their relationship. This relationship is often interpreted in linguistics as the paradigm for “polar opposition”, depicted with arrows pointing in opposite directions (e.g., cold and hot). The use of arrows instead of nested brackets makes the expression vague, as it is not always clear

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\(^{15}\) Subscripts are used as placeholders for layer sequences and nesting for levels.

\(^{16}\) Systems that include empty “containers” for the zero level represent the absolute scale, which can always be “reduced” to interval, ordinal and nominal measurement types.

\(^{17}\) Combining entities of different intensity levels describes the process of mixing, not addition.
whether and exactly how those processes (and the antonyms they represent) are related. Section 11 discusses these issues.

5.5 Levels and Layers’ Role in Creating Contrasts

As Section 4 postulates, the intuition of sensory contrasts serves as a prototype for semantic contrasts, which in turn define the notions of opposition, antonymy and synonymy. Contrasts increase with the difference between levels; therefore, the greatest contrast exists between the maximum level and the minimum level. Maximum contrasts characterize antonyms. Adjacent levels, on the other hand, display minimal contrasts; hence, they represent synonymy.

The number of levels is not fixed. One way to add levels is to add more layers of a substance. For example, by adding two more layers, one can change the description of levels from \( \text{low} < \text{average} < \text{high} \) to \( \text{very low} < \text{low} < \text{average} < \text{high} < \text{very high} \). The resolution of levels can be changed by differentiating them (Section 10). Both strategies can be used to enhance the sense of difference or to bring levels of a property closer together. Most levels do not have distinct labels. Names are typically allocated to the most salient levels (e.g., minimum, maximum and average) as well as to significant levels in specific expressions, for example, \( \text{completely} > \text{nearly} > \text{half} > \text{somewhat} > \text{zero} \). Naming levels is nonessential for intuiting levels and the differences between them.

6 Full/Empty: Conceptualizing Abstract Properties as Substances

As an expression of the sensory schema intuition (Section 3), levels, layers and their interactions can aid our understanding of antonyms and synonyms in natural language and related concepts in other forms of expressions. To reveal the water column’s structure, I will now discuss a pair of antonyms: \text{full}/\text{empty}.

The concepts of ‘layer repetition’ and ‘nesting of levels’ discussed in the previous sections represent two tightly connected yet contrasting ways of thinking. All arrangements combining repetition and nesting exhibit conceptual duality – they can be conceived either in terms of layers or in terms of levels. This duality is reflected in the way we talk about many arrangements, including columns of liquid. For example, we can say that there are three cups of water in a container (layer-based intuition) or that the container is three-quarters full (level-based intuition). Levels can be expressed in several ways. To describe precisely which part of the container the water occupies, we can use ratios, fractions or percentages: \( 100\% \text{ full} > 75\% \text{ full} > 50\% \text{ full} > 25\% \text{ full} > 0\% \text{ full} \) (Figure 4a). If accuracy is nonessential, one could say that the container is
completely full > nearly full > half full > somewhat full > not at all full or simply empty (Figure 4b).

It is also possible to express levels in terms of water’s absence. In the water column context, water + air = total volume; therefore, air = total volume – water. The accumulation medium in this case is not “air” as such but water volume. Defined in this way, the scale has a top-down arrangement of levels, as in not at all empty < somewhat empty < half empty < nearly empty < completely empty (Figure 4c). Since Full$_2$ and Empty$_1$ both refer to the same container and to water as the accumulation medium, they complement one another (e.g., half full or half empty).

Accumulation is a schema that applies not only to material substances such as water but also to abstract entities. Consider the abstract property of emptiness in Figure 4d. Emptiness can be “accumulated” only if it is conceptualized as a kind of substance. The gradation can be expressed with such levels as (completely full > nearly full > half full > somewhat full > not at all full) of emptiness. Emptiness is interpreted as a “substance” that is unrelated to water, but like water, it can form distinct layers when added to the container. In addition, the accumulation of emptiness is represented as an absolute scale with the zero-value representing the “container” that is empty of emptiness. Thinking about emptiness as a substance is awkward, which is why most speakers prefer to talk about emptiness or fullness in terms of material content.

This section’s analysis suggests that the sensory schema can be used to change antonyms’ conceptualization through adopting different “substances”,

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18 In this context, a container is a vessel-like entity/system capable of accumulating layers and relating them to levels.
both physical and abstract, in the accumulation process. With these basic ideas in place, I will now explore applying the sensory schema to the antonyms alive/dead, which is the next section’s subject.

7 Alive/Dead: Binary, Graded or Both?

The antonyms alive/dead in Figure 5a are often described as representing a binary opposition with no middle values, which is characteristic of graded adjectives. Therefore, they are regarded as nongradable antonyms. Clearly, one can be dead or alive, but never both. Accidental death, if it occurs too quickly for any intermediate state to be observed, can serve as an example of this conceptualization.

However, in most people’s minds, dying is a slow process of physical degradation. It may involve clinical death if the vital organs stop working, brain death when some parts of the brain are no longer active, or biological death when the body’s cells begin dying on a massive scale due to a lack of oxygen. With the advent of life support, the boundaries between those states are no longer clear (Ettema, 2016). The matter is further complicated by the notion of extent. The phrase a half-dead tree could mean that half of the tree is dead (extent) or that the tree has a fifty percent chance of recovering (degree). From this view, it is possible to argue that alive and dead are not binary but fully gradable adjectives and that phrases such as “half dead” or “half alive” are not figurative uses of the adjectives but examples of a gradable schema in action. It is therefore conceivable to say that a person is 0% alive < 25% alive < 50% alive < 75% alive < 100% alive (Figure 5b).

![Figure 5](image-url) Some possible interpretations of the antonyms dead/alive in the context of the sensory schema
The above discussion suggests that the adjectives alive and dead can be conceptualized as an example of either binary antonyms or gradable antonyms. This duality in thinking is present in arguments not only about death but also about when human life begins. Some people strongly argue that life starts at the time of conception, while others assume that it begins at the time of birth. In the first case, life and death are defined as instantaneous changes in states. In the latter case, however, life is conceptualized as a slow accumulation of features that are critical for living, and death is conceptualized as a prolonged process of losing those features. According to the latter view, it is quite appropriate to say that a person is certainly not alive < barely alive < half alive < very much alive < certainly alive (Figure 5c). Therefore, the examples represent two ways of schematic thinking based on the same sensory schema.

Similar arguments can be made for pairs, such as true/false, clean/dirty or even male/female, which are typically regarded as nongradable binary opposites. Recent attempts to redefine the binary interpretation of male and female in terms of gender are one such example. In this approach, binary opposition is converted to a gradable relation known as gender variance. Nonbinary gender concepts can then be arranged from a nongendered version (androgy nous) to various combinations of both genders, which are each allocated a unique name.

Binary and graded conceptualizations are not the only possible construals based on the sensory schema. If life is conceptualized as the slow accumulation of features that are critical for living, then death could be thought of as the absence of life, containing the following levels: certainly dead > very much dead > half dead > somewhat dead > certainly not dead (Figure 5d). The graded adjectives Alive3 and Dead1 complement one another because they refer to the same body as the container and share aliveness as the accumulated substance. When added together (e.g., half alive + half dead), they produce a sense of completeness. However, if two adjectives do not refer to the same substance that accumulates, they no longer complement one another. Figure 5e shows the grading scale defined in terms of deadness as the accumulation medium with the levels certainly not dead < a little dead < half dead < quite dead < certainly dead. Such gradings represent an absolute scale indirectly related to other conceptualizations through the connection between aliveness and deadness.
Rich/Poor: Relative Antonyms

Poverty is a relative term. A poor person is not necessarily an individual without any assets but a person whose income is inadequate for meeting basic needs. The poverty line could be $100/week in one country and $1/week in another, and the poverty line can change with time. Poverty has meaning only if it is considered in the context of wealth. The level representing poverty can therefore vary in relation to the scale of wealth. For the relationship between antonyms rich/poor to be meaningful, the scale of wealth must be absolute.

Figure 6a depicts a nested scale with the following levels: not rich < hardly rich < moderately rich < very rich < extremely rich. The accumulation medium is wealth, which is typically defined in terms of money and other assets. Notably, the scale is not well defined because its lowest level is represented by the phrase not rich, which still suggests wealth, albeit not substantial. Tension lies between the phrase's meaning and its position at the bottom of the scale, which typically represents the zero level of the property. This feature disqualifies the arrangement from being an absolute scale.

Figure 6 Some possible ways of conceptualizing the antonyms rich/poor. Rich₁ is a scale that is not absolute (Figure 6a), Rich₂ is an absolute scale (Figure 6b), and Poor₁ is a relative scale (Figure 6c).

19 More generally, other properties, such as color saturation (“rich color”), fragrant scent (“rich aroma of coffee”), and unreasonableness (“that’s rich coming from you”), can be used in place of wealth.

20 The meaning of adjectives is defined by their position within the nested schema. If, in the mind of the speaker, poverty is permanently positioned at the schema's zero level, its concept will be associated with zero assets.
The diagram in Figure 6b, by contrast, represents an absolute scale with the zero level of wealth defined by the adjective destitute. Some possible levels of this scale may include destitute < hardly rich < moderately rich < very rich < extremely rich. This scale can be used to define the concept of poverty, as both Rich\textsubscript{2} and Poor\textsubscript{1} share the same interpretation of the zero level.

Figure 6c depicts the concept of poverty defined by the level hardly rich on the absolute scale of wealth. Poverty is defined by the nested structure of wealth. All levels of poverty are included in this notion. The nested arrangement of the absolute scale explains the peculiarities of the adjective poor and other similar gradings. The wealth scale starts with the zero level of wealth, which can be increased infinitely, at least in theory. Poverty, however, is limited by the zero level of the absolute scale. It starts at some level of wealth that decreases towards the zero level but never falls below it. This characteristic makes it impossible to create scales of poverty and other similar concepts, such as shortness, thinness, shallowness, easiness, slowness, and badness. For the same reason, it is abnormal to say that “something is twice as short.”

Figure 6c shows only one level nested under poverty, i.e., destitute. Additional levels can be easily differentiated, as in poor > quite poor > very poor > extremely poor > destitute, which involves restructuring the entire scale. The level of poverty cannot be less than destitute, which is the level at which wealth is zero. The adjective destitute is therefore nongradable. Even though it is easy to imagine a situation involving debt as being worse than destitution (especially if the debt cannot be forgiven or discharged), such a condition represents a different nested scale, the medium of which is debt and not wealth.

In summary, the rich/poor antonym pair represents a relative relationship governed by nested levels’ inherent structure. Many antonyms can be conceptualized in this way, including good/bad, large/small, long/short, old/young, dirty/clean, wet/dry and hot/cold.

9 Happy/Unhappy, Happy/Sad, Not Happy and Not Unhappy

The previous sections’ examples indicate that the sensory schema can be applied to the same concept in contradictory ways. For example, dead and alive

\[21 \text{“X is twice as short/cheap/slow as Y” is possible but awkward. It seems to imply that X is shorter/cheaper/slower than Y, which means that its length/price/speed is a fraction of Y, which, in this case, can be expressed as } X = \frac{1}{2} Y \text{ or “X is a half of Y.” Note that the last two expressions do not refer to scales of short-ness, cheap-ness, or slow-ness but to the absolute scales of length/price/speed.} \]
could be interpreted either as graded or nongradable antonyms (Section 7). If
graded, the concepts can be construed as complementary, relative or absolute
antonyms. This is possible because the sensory schema relates concatenated
patterns (()) to nested patterns (((()))), i.e., layers to levels. I will further
explore the issue by analyzing the antonyms happy/unhappy and happy/sad,
which are depicted in Figure 7.

The word happy is commonly regarded as an example of a graded adjective.
Some of its levels may include indifferent < somewhat happy < fairly happy <
quite happy < happy, as shown in Figure 7a. The accumulated ‘substance’ in
this case is happiness. The word indifferent, which represents the zero level,
suggests that happy is an absolute scale. The adjective unhappy can also be
conceptualized based on an absolute scale, which consists of levels, such as
indifferent < slightly unhappy < fairly unhappy < quite unhappy < unhappy,
as depicted in Figure 7b. The accumulated substance in this example is unhap-
piness. The adjective sad represents yet another application of the sensory
schema. The medium of accumulation is sadness. Some possible levels of grad-
ing of sad can include indifferent < somewhat sad < fairly sad < quite sad < sad,
as presented in Figure 7c.

In line with the discussion thus far, the antonyms happy (Figure 7a) and
unhappy (Figure 7b) as well as happy (Figure 7a) and sad (Figure 7c), are not
directly related because they do not have the same accumulation medium. The
indirect relation between these absolute scales can be clarified by considering
smiling and frowning, the experience of which includes the state of indifference
when all the muscles of the face are relaxed. Similarly, happy and unhappy or
happy and sad are related indirectly through the sense of “indifference”. Such

![Figure 7](https://example.com/figure7.png)

**Figure 7** Conceptualization of the antonyms related to happiness and sadness: happy versus not happy (Figure 7a), unhappy versus not unhappy (Figure 7b), and sad versus not sad (Figure 7c).
a relationship is usually represented with two opposing arrows separated by zero interpreted as *neither happy nor sad* in the relationship referred to as binary opposition.

Note that the sensory schema always applies to one property at a time. Therefore, if the schema is used to grade a property A (e.g., *happy*), it cannot refer in any way to the property B (*sad*). Consequently, *sad* cannot stand for the zero level of *happy* and *happy* cannot be the zero level of *sad*. These points are defined by *not happy* and *not sad*, respectively. When combined, the negations “not happy” and “not sad” are transformed into “neither happy nor sad” which represents a state of indifference relating *happy* to *sad*. Note though that above relationships are possible only in relation to binary scales, which suggests that negation may play a significant role in construing binary opposition.

If the binary opposition is a result of negation, then two possible interpretations of negation exist: the binary and graded versions. In the binary interpretation, negating the adjective *happy* implies *unhappy* or *sad*, and negating *unhappy* or *sad* implies *happy*. By contrast, due to the nested arrangement, the graded interpretation of negation incorporates all levels below *happy*, which include *quite happy > fairly happy > somewhat happy > indifferent* depicted in Figure 7a with a curly bracket. As a result, not just one, but a range of opposite meanings are associated with negating happy, including such levels as *unhappy > quite unhappy > fairly unhappy > somewhat unhappy > indifferent*. Similarly, negating *unhappy* (referred to as double negation) does not imply *happy* but the range of levels including the nested states of *quite happy > fairly happy > somewhat happy > indifferent*. A similar argument can be made for the adjective *sad*.22

The nested arrangement of adjective levels explains the mitigation hypothesis“(…) according to which a negated adjective conveys an intermediate meaning between the adjective and its antonym (e.g., not large ≈ medium-sized)” (Aina et al., 2018: 58). For example, the phrase *not unhappy* does not imply *happy* but the middle level of the negated range. The ambiguity created by double negation fulfills several functions: it weakens expressions so that they can then be used to make more polite statements; it provides flexibility regarding context; and it makes banal statements profound (Krifka, 2007: 1). Verhagen (2005) refers to such construals as *morphological negation*, which he then contrasts with *sentential negation* at the level of intersubjective discourse understood as a way of creating relations between conceptualizers. Verhagen interprets construals of sentential negation mainly in terms of mental spaces.

22 This analysis suggests that binary opposition is a special case of graded scale reduced to one active level.
This topic is not discussed in the current article the focus of which is the sensory schema and its role in language. Consider two sentences adapted from Verhagen’s article:

[1a] He almost passed the exam. 
[1b] He barely passed the exam.

The relationship between almost and barely could be represented as a nesting the lowest level of which stands for zero value:

\[
\left( \left( \left( \left( \text{Did not} \right) \text{almost} \right) \text{barely} \right) \text{easily} \right)_{\text{pass(ed) exam}} \right)_{\text{he}}
\]

If considered as grades/scores, the sense of “He did not pass the exam” is intuitively contained in “He almost passed the exam”, which is included in “He barely passed the exam”, which in turn is included in “He easily passed the exam”. Note that the sensory schema organizes the relationship between all relevant levels irrespective whether they are mentioned in the sentence. Furthermore, the levels almost and barely are located very close to the level of minimum grades (not shown) and away from both the bottom and top levels of the nesting. I claim that the nested relationship between almost and barely must be established well before any mental spaces of sentential negation are invoked. The example above suggests that the sensory schema can play a significant role not only in the case of negation, but also in other construals including negative polarity, superlative and comparative clauses and sentences (Section 10).

In summary, whether an adjective can be graded is not inherent in the word itself but depends on applying the sensory schema’s grading aspect. The meaning and properties of graded antonyms and their negations depend on their status within that schema. Thus, quite sad means what it means because it is one level above fairly sad and so on. Some levels, such as the zero and average levels, are more salient, and as a result, their positions are explicit and more permanent, which the distinct names allocated to them signal.

10 Difficult and Important: Levels without Names

All of the examples depicted thus far show antonym modifiers, such as somewhat, fairly or quite, occupying the “adjacent” levels of scales. The analysis carried out by Paradis (2008: 321–2) seems to suggest that modifiers are not
always evenly spaced along a scale. For example, boosters (e.g., extremely, highly, terribly, very) tend to be located at the top, moderators (e.g., fairly, pretty, quite, rather) tend to be located in the middle, and diminishers (e.g., a bit, a little, slightly, somewhat) tend to be located at the bottom of the scale.

The irregular organization of modifiers can be achieved by adding levels within the sensory schema as depicted in Figure 8a, where the scale not difficult < somewhat difficult < — — — difficult < — — — really difficult < extremely difficult includes additional levels to create a sense that, for example, somewhat difficult is closer to not difficult than to difficult. Notably, such levels do not need to be defined (e.g., named) to exhibit this property because, as noted in previous sections, the meaning is derived from the position of the words within the nested schema. The phrase not difficult in Figure 8a can serve as another example. In the context of schema’s zero level, not difficult does not function as a typical negation outlined in Section 9. Instead, it is interpreted as another grading level.

Figure 8b depicts an example related to comparative and superlative expressions of the adjective important. The comparison levels include not important < important < — — — more important < — — — — most important. These forms can be conceptualized as having additional levels, as Figure 8b depicts, or no gaps between the named levels (not shown). Interpreting the adjective in each case is slightly different. Grading with gaps appears more pronounced than grading without gaps. The antonyms can, therefore, be conceptualized as

![Diagram](image_url)

**Figure 8** Using additional levels to create uneven distributions of word meaning in relation to the antonym easy/difficult (Figure 8a) and important/unimportant (Figure 8b).
complements, binary opposites, absolute, or relative through rearranging the nested schema.

Sensory schema use is not limited to adjectives and adverbs but also includes other parts of a sentence and speech. These issues cannot be discussed comprehensively in the current article; therefore, only a few nested examples are mentioned:

– Embodiment: none, knuckle, finger, hand, arm, body (Langacker, 2008: 64)
– Movement: standing, walking, jogging, running, sprinting
– Comparative and superlative grades: many, more, most; much, more, most; few, fewer, fewest; little, less, least, etc.
– Natural order: species, genus, family, order, class, division, kingdom, domain
– Units of volume: 0, a drop, a smidgeon, a pinch, a dash, a tad, half a spoon, a spoon, four spoons, etc.
– Magnitude: none, some, half, most, all
– Numerical systems: 0, 1, 2, 3, 4, 5, 6, 7, ...
– Exponential scale: 1/64, 1/32, 1/16, 1/8, 1/4, 1/2, 1, 2, ... with the unit \( \log_2(1/32)/(1/64) = 1 \)

The examples in the current and previous sections demonstrate that the sensory schema, with its levels, layers and accumulated substances, is a general cognitive tool that applies not only to natural language but also to concepts in science and other forms of human expression. The argument aligns with Paradis’ observation that “DEGREE is pervasive in language and may be associated with most meanings” (Paradis, 2008: 317). In addition, the examples show that the sense of contrast lays a foundation for antonymy’s most basic form from which other notions can be constructed. For example, opposition-based antonymy (e.g., positive/negative) can be understood as two contrast-based antonyms (positive antonym and negative antonym), which share the zero level and zero extent.

11 Croft and Cruse (2004)’s Survey of Antonym Types

In this section, I argue that the proposed sensory schema and its application are substantially compatible with the interpretation of antonym types that Croft and Cruse (2004) developed. One advantage of the sensory schema is its compactness; the single diagram at the schema’s core can replace the four diagrams that Croft and Cruse (2004: 169–73) created, which Figures 9b, c, d and e depict in a slightly modified form. The diagram in Figure 9a represents the sensory schema’s nested levels.
According to Croft and Cruse (2004: 169), the single arrow in Figure 9b represents a “monoscalar system” of length. However, from the sensory schema perspective, the scale portrays a biscalar arrangement in which the scale of shortness is not expressed with an arrow. The following figure depicts the scale of merit (Figure 9c), which Croft and Cruse (2004: 171) describe as an “overlapping system”. The sensory schema suggests that bad is already included in the nested levels of good. In the example, the average level of good is adopted as the minimum level of bad.

Because bad is defined as having merit below a certain level, the zero level of goodness becomes its maximum. A similar argument can be made for the monoscalar system in Figure 9b by interpreting short as an antonym relative to length’s absolute scale. Croft and Cruse ultimately redefined the monoscalar system as a relative concept in the following statement: “Even in the case of a single gradable adjective we need to postulate an absolute and a relative scale, since gradable adjectives are prototypically relative in their basic use” (2004: 173).

Figure 9d shows a diagram that Croft and Cruse describe as a “disjunct equipollent system” (2004: 170) interpreted as two independent scales (hot and cold) extending in opposite directions from the common zero point. In the sensory schema context, the arrangement is a variation of relative antonymy from Figure 9c. Both the notions of cold and hot are defined by the absolute scale of hotness. The average level of hotness is adopted in the example as the zero level of hot and cold, with their properties defined by the nested levels.
One example of this relationship comes from physics, where the zero degree of the Celsius scale is defined as approximately 273 degrees on the Kelvin absolute temperature scale.

Figure 9e shows yet another version of relative antonyms, which Croft and Cruse call a “parallel equipollent system” (2004: 170–1). The diagram depicts the relationship between the antonyms hard and soft such that the maximum of hard stands for the minimum of soft and vice versa. The interesting aspect of such conceptualizations is that they are complementary in the sense that, when considered together, the level of hardness and the equivalent level of softness produce a sense of the conceptual whole.

12 Conclusion and Suggestions for Future Research

Making a comparison with the Croft and Cruse’s antonym types above demonstrates the sensory schema’s parsimonious characteristics. A single diagram of nested levels can replace four arrow-based diagrams used to explain diverse gradation types. This simplicity is not the only benefit. The same schema can conceptualize the gradation not only of antonyms but also of other parts of speech and a sentence (Section 10). The schema can be applied equally to both material and abstract entities (Section 6), and their conceptualizations can be manipulated simply through adopting a different “medium” for the accumulation process (Sections 3, 6 and 9). Moreover, the schema combines two distinct ways of schematic thinking into a single thought system (Section 3). It merges disparate concepts such as states and processes, private and public, or mental space and public space (Raykowski, 2019) and clarifies the differences between complementary, reverse and inverse relations; adding and mixing (Section 5.3); and various comparison types (Sections 5.3, 8 and 10). Applying the sensory schema to concepts such as alive/dead (Section 7) suggests that schematic conceptualizations are not “fixed” at the level of sensations. This characteristic shows that no preconceived experience of the physical world exists at that level. “Wrong” interpretations are simply eliminated by recurring interactions with the world.

The sensory schema’s utility has been demonstrated thus far by analyzing mainly adjective antonyms. The narrow scope of the analysis could leave the reader with the impression that the schema is limited to the processes of accumulation in a single ‘container’. However, to experience changes in space and over time (e.g., movements, actions and states) or to simulate them, huge arrays
of sensory cells\textsuperscript{23} capable of changing their own internal activation are needed (Raykowski, 2014, 2018, 2019). Such changes are expressed in natural language with verbs typically modified by adverbs or adverbial clauses/phrases.

The sensory schema hypothesis defines verbs as the totality of unique associations between the repetition of a unit and the gradable content of the repeated units. The case for the sensory schema utility would be substantially strengthened if it could be demonstrated that various types of antonymy (e.g., absolute and relative scales, various contrasts, inversions and reversives, negation and opposition) and such notions as \textit{ratio} and \textit{rate} (often involving more than one property) – can all be derived directly from the schema. Due to its range and complexity, the matter will be discussed in a separate publication.

In closing, I would like to stress that the proposed sensory schema does not challenge the status of image schemas as the lowest level of thinking. Rather, it adds another explanatory layer to the theories of image schemas, embodiment and cognition in general. This layer involves sensory maps in the brain from which human intuitions emerge. My own understanding of the importance of the sensory schema came with realization that no thought or reasoning, no idea or explanation, no belief or theory, no knowledge or philosophical doctrine, and their expressions, can exist without sensations, simply because “Everything we know about the world comes to us through our senses” (Fain, 2003: 1).

References

Aina, Laura, Raffaella Bernardi and Raquel Fernández. 2018. A distributional study of negated adjectives and antonyms. In E. Cabrio, A. Mazzei and F. Tamburini (eds.), \textit{Proceedings of the Fifth Italian Conference on Computational Linguistics CLiC-it 2018}, 10-12. Torino: Accademia University Press.

Behrmann, Marlene and Ruth Kimchi. 2003. What does visual agnosia tell us about perceptual organization and its relationship to object perception? \textit{Journal of Experimental Psychology}, 29(1): 19–42.

Croft, William and D. Alan Cruse. 2004. \textit{Cognitive Linguistics}. Cambridge: Cambridge University Press.

\textsuperscript{23} At the level of natural language, the arrays of sensory cells (somatosensory maps) can be conceptualized as large collections of container-like cells (refer to Section 2 and 3). The sense of movement across such static arrays is achieved by coordinating the change of levels in adjacent cells.
Elwood, Robert W. 2011. Pain and suffering in invertebrates? *Institute of Laboratory Animal Resources Journal*, 52(2): 175–184.

Ettema, Eric. 2016. Brain death. In H. ten Have (ed), *Encyclopedia of Global Bioethics*. Heilderberg and Berlin: Springer.

Fain, Gordon. 2003. *Sensory Transduction*. Sunderland: Sinauer Associates, Inc.

Hampe, Beate and Joseph E. Grady. 2005. *From Perception to Meaning: Image Schemas in Cognitive Linguistics*. Berlin: Mouton de Gruyter.

Johnson, Mark. 1987. *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason*. Chicago and London: The University of Chicago Press.

Johnson, Mark. 2017. *Embodied Mind, Meaning, and Reason: How Our Bodies Give Rise to Understanding*. Chicago and London: The University of Chicago Press.

Kaas, Jon H. 1997. Topographic maps are fundamental to sensory processing. *Brain Research Bulletin*, 44(2): 107–112.

Krifka, Manfred. 2007. Negated antonyms: Creating and filling the gap. In U. Sauerland and P. Stateva (eds.), *Presupposition and Implicature in Compositional Semantics*, 163–177. Houndmills: Palgrave Macmillan.

Lakoff, George and Mark Johnson. 1980. *Metaphors We Live By*. Chicago and London: The University of Chicago Press.

Langacker, Ronald, W. 2008. *Cognitive Grammar: A Basic Introduction*. Oxford: Oxford University Press.

Muehleisen, Victoria L. 1997. *Antonymy and Semantic Range in English*. Ph.D. dissertation. Northwestern University. Accessed December 7, 2019 http://www.f.waseda.jp/vicky/dissertation/.

Olsson, Peter, Olle Lind and Almut Kelbera. 2018. Chromatic and achromatic vision: Parameter choice and limitations for reliable model predictions. *Behavioral Ecology*, 29(2): 273–282.

Paradis, Carita. 2008. Configurations, construals and change: Expressions of DEGREE. *English Language and Linguistics*, 12(2): 317–343.

Purves, Dale, George J. Augustine, David Fitzpatrick, William C. Hall, Anthony-Samuel Lamantia, James O. McNamara and S. Mark Williams. 2004. *Neuroscience* (3rd edition). New York: Sinauer Associates.

Raykowski, Wes. 2014. *Conceptual Understructure of Human Experience: Volume 1-Thesis*. North Charleston: CreateSpace.

Raykowski, Wes. 2015. Conceptual duality of mathematical expressions. Manuscript.

Raykowski, Wes. 2018. Layers and levels: What a column of water tells us about human cognition. *Cognitive Semantics*, 4(1): 104–134.

Raykowski, Wes. 2019. Is there such a thing as orthogonyms? *Cognitive Semantics*, 5(2): 201–223.
Rozin, Danny. 2019. YouTube video by Wired. How This Guy Makes Amazing Mechanical Mirrors (https://www.youtube.com/watch?v=kV8v2GKC8WA). Accessed December 7, 2019.

Verhagen, Arie. 2005. Constructions of Intersubjectivity: Discourse, Syntax, and Cognition. Oxford and New York: Oxford University Press.