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ARTICLE

From Sensations to Contrast, Opposition and Numbers

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ABSTRACT

Language can be deceptively simple in its use yet frustratingly complex in its analysis. Its apparent clarity often masks an inherent complexity, rendering the true meaning of words simultaneously obvious and elusive. This inquiry investigates the multifaceted nature of meaning, encompassing not only language but also forms of expression that do not rely on spoken or written words. Central to this exploration is uncovering the body's role in creating and shaping meaning. The article presents a summary of the sensory schema theory, introduced in the author's previous publications, and examines its application through selected examples. These examples include the notions of scales, opposition, integers, and the number line derived from the sensory schema.

Keywords: Natural language; Cognition; Sensory schema; Intensity; Extent; Contrasts; Opposition; Integers; Number line

1. Introduction

Language, despite its apparent clarity in use, presents a frustrating challenge for analysis. This inquiry explores the multifaceted nature of meaning, encompassing not only language but also non-linguistic communication. Central to this investigation is the role of the body in creating and shaping meaning.

Researchers have proposed a multitude of theories, each offering its own perspective on how language acquires significance. Structural linguists propose that meaning in

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language is derived from the systematic organization and interrelation of linguistic elements within a linguistic system (Holdcroft, 1998), while semanticists delve into the relationships between words, phrases, sentences, and discourse (Lyons, 1996). Contextualists, on the other hand, argue that meaning is contingent upon the context in which words are used, emphasizing the interplay between language and social interaction (Kompa, 2010). Meanwhile, cognitive linguists explore the role of cognition and embodiment in shaping our conceptual understanding of the world, positing that meaning emerges from the interaction of the human mind and body (Evans and Green, 2006).

The analysis of these theories reveals two distinct approaches to understanding meaning. On one hand, theories like contextualism prioritize communication between individuals and emphasize the role of context and social interaction in determining the meaning of words and sentences. On the other hand, cognitive linguistics demonstrates that, in addition to the external physical and social environment, the anatomy and physiology of the human body and brain play a crucial role in shaping the meaning of linguistic and non-linguistic expressions.

Further analysis reveals two distinct perspectives on context: the internal context of the body and the external context of the physical and social world. These two realms interact and mutually influence each other, representing distinct stages of the meaning-making process. In this framework, intrinsic meaning is characterized as stable but rudimentary, rooted in bodily experience and cognition. On the other hand, contextual meaning emerges as a dynamic process, modifying, clarifying, differentiating, expanding, and enriching intrinsic meaning, often beyond recognition. While intrinsic meaning is highly schematic and conceptual, contextual meaning is more specific and relative, closely tied to situational and social factors that can significantly influence how we interpret an experience or its expression. For example, when contextualized, physical pain (intrinsic experience) can represent emotional pain on the occasion of separation, uncertainty, or death (contextual reinterpretation). By recognizing the interplay between these two realms, we gain deeper insights into the complexities of linguistic comprehension and the multifaceted nature of meaning, which has its origins in the experience of sensations.

In this context, the current article traces intrinsic meaning to private experiences by examining their manifestations in natural language and other forms of expression. This exploration focuses on processes involving single sensory modalities within the framework of the sensory schema, proposed by Raykowski (2022). Building upon the foundation provided by the sensory schema, more complex cognitive constructs like multimodal image schemas and conceptual metaphors (Johnson, 1987) can be formed.

Among other things, the article serves as a summary of the theory, with foundational aspects introduced in previous articles by the author. Following the theoretical discussion, the article demonstrates some potential applications of the framework, including the concepts of cognitive division and concatenation, cognitive mixing, sensory products, the concept of scales and negation, and cognitive interpretation of contrasts, opposition, integer schema, and number line. Due to its foundation in sensory experiences, the meanings of these concepts are narrower and more specific, serving as fundamental building blocks for understanding. Consequently, while these concepts may appear at odds with more developed ideas, they actually represent the foundational elements upon which those advanced concepts are constructed.

A few housekeeping notes are in order. The reference to background literature in the article has been kept to a minimum to enhance clarity and prevent unnecessary complexity. One reason for this is that the article is intended to summarize and expand upon earlier articles by the author, which were published in the context of linguistics in the Cognitive Semantics journal. Another reason is that the article intends not only to present a specific hypothesis but also to outline a framework that is not easily introduced due to its multidisciplinary nature. In the authors' experience, the sheer richness of literature on related topics, ranging from philosophy and psychology to cognitive science and mathematics, tends to interfere with the proper understanding of the proposed framework. On some occasions, to signal that other perspectives were considered and provide context for the discussion, epigraphs are used at the beginning of sections.

1.1 Rethinking sensations: beyond raw data

Sensation refers to the registering of a physical stimulus on our sensory receptors.

(Schwartz and Krantz, 2017, p. 6)

In science, sensations are often described as raw data, stimuli, input, or information, implying a lack of inherent meaning and structure. In this article, an alternative interpretation of sensations is presented that possesses a simple yet powerful structure capable of defining experiences in terms of intensity and the extent of this intensity within sensory maps in the brain. In this view, sensations have a fundamental significance upon which more complex concepts are built. To access this perspective, readers are encouraged to shift away from reasoning solely in terms of "raw data" and instead embrace a framework that considers the intensity and extent of sensory experiences, as well as their simulated representations, within the context of sensory maps.

Consider **Figure 1**. It shows an image of still life constructed from approximately 1800 hexagonal units of gray varying in intensity from black (no intensity) to white (maximum intensity). Array elements of the same or similar intensity represent distinct patterns which, when combined, are perceived as an object such as a cup or a vase. To 'divide' the array-based representations, one needs to change the intensity of the relevant units of the array from their shared level to the contrasting intensity of the background. To see the procedure more clearly, refer to the simplified diagram below. It depicts an array of black rectangles, indicating high intensity, divided into two parts by inserting spaces represented by the underscores, which signify low or no intensity.

(_████████___) array A ↔ (_█████__███_) array A

Conversely, adding two parts back together involves the removal of space by adjusting the intensity of the relevant elements. If coordinated, the changes to intensity across the array can result in the representation of movement and/or alterations to spatial arrangement. Note that adding areas of any color to another area requires both areas not only to have the same color but also identical intensity. Only in this situation, inserting space (division) and removing space (addition) are 'inverse' operations (Raykowski, 2013).

Similarly, in music, compositions are created by, among other things, varying over time the pitch and volume of sound. The background for sound is provided by the sound of no pitch/volume (silence), the same way as the background for spatial patterns in vision is usually provided by units of no color intensity (black). In this context, the division of a sound could be understood as deliberately inserting periods of silence, which creates contrast and contributes to overall variety by capturing the listener's attention. Adding a sound with a specific duration to another sound can be thought of as removing the silence between them. However, this only works if the two sounds have the same pitch and volume.

In contrast, mathematical operations function differently: dividing a number (like 12) into smaller, equal parts (like 4 parts) results in a quotient (3). When we multiply this quotient by the number of parts (4), we should get back to the original number (12). This emphasis on creating equal parts is a key feature of mathematical division[1]. While sophisticated, this mental operation may not have a direct application in spatial and musical intelligence, which rely on a more general understanding of division and addition.

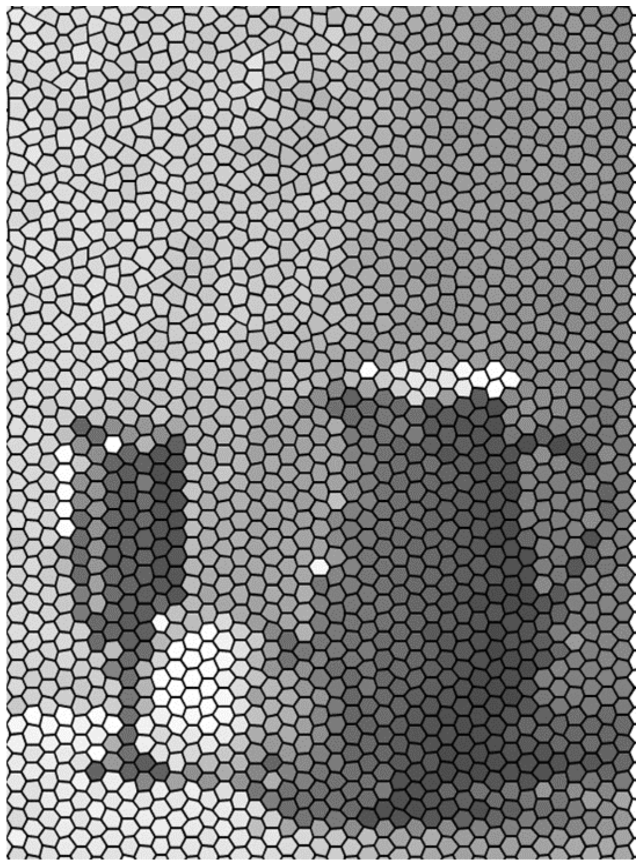

Figure 1. The figure, labeled 'Still life', provides a visual representation of sensory map experience discussed in Section 1 of the article (Based on "Red Blue Yellow and Earth", an acrylic painting by Goodnight-Melbourne (DeviantArt Order #10526884)).

[1]This process seems to be driven by the psychological need for social equality, which shapes how we divide food, objects, space, time, and other resources equitably.

The redefinition of addition as concatenation and division as the insertion of background space reflects a shift from abstract operations to concrete manipulations of sensory representations in the brain. In language, concepts such as division and concatenation are deeply ingrained in everyday expressions and actions. For instance, cutting bread involves the insertion of space between its parts (e.g., slices), facilitated by the shape of the knife (Raykowski, 2013, 2015). Similarly, when we talk about abstract concepts such as divorce, we invoke the notion of separation, akin to the operation of inserting space between two entities. Even in interpersonal relationships, such as marriage, there is an implicit understanding of concatenation, where two individuals are joined together in a cohesive unit.

Natural language intricately expresses a wide range of such operations, including division, concatenation, idempotence, and mixing. This reflects the inherent connection between the body, its sensory system, cognitive processes, and various forms of expressions. Emphasizing the embodied nature of thought underscores the fundamental idea that sensory experiences and their structures are the building blocks for human reasoning. While this reasoning may seem illogical at times, even contradicting well-established and sophisticated ideas in mathematics and science, tracing its origins back to the body and senses should help us understand and apply those complex concepts more effectively. In essence, this article explores how these foundational structures, along with human emotions, influence reasoning.

2. Overview of technical terminology

This section introduces the reader to four key concepts: embodied cognition (including sensory privacy), orthogonality, idempotence, and concatenation. Although not commonly used in cognitive linguistics and psychology, these terms are essential for understanding the proposed framework. To avoid confusion and ensure clarity, Sections 2, 3, and 4 will focus exclusively on these concepts. Exploration of other related topics will resume in Section 5 and beyond.

2.1 Embodied cognition

> *In order to begin this examination, then, I here say, in the first place, that there is a great difference between mind and body, inasmuch as body is by nature always divisible, and the mind is entirely indivisible.*
>
> (Descartes, 1641, pp. 1–31)

The private nature of mental processes is a topic often absent from discussions, not only in psychology but also in cognitive linguistics. For example, in a 2002 article, Margaret Wilson lists several claims about the role of embodiment in cognition[2], none of which addresses the privacy of thought processes. So far, this subject has garnered little interest from researchers, despite the likelihood that most would agree that no one can experience the sensations and thoughts of others directly[3]. How human individuals feel and what they think can only be inferred from their overt behavior, with natural language serving as one example. Therefore, addressing the privacy of thought processes is an important issue that has the potential to redefine natural language and other expressions as biological and physical phenomena[4].

The next section of the current article describes in some detail a simple cognitive strategy in which private sensations and feelings can be expressed by physically modifying the surrounding environment to create material objects with which the public can physically engage to experience the intended sensations. The diagram below depicts only a few main stages of such a process (Rajkowski, 2013; Raykowski, 2014):

(Private sensory simulation) $_{\text{individual 1}}$ → (physical modification to public space) $_{\text{individual 1}}$ →
→ (physical artefact) $_{\text{in public space}}$ →
(engagement with public expressions) $_{\text{individual 2}}$ → (private sensory impressions) $_{\text{individual 2}}$

Creating expressions by modifying the outside envi-

[2]Cognition is situated; cognition is time-pressured; we offload cognitive work onto the environment; the environment is part of the cognitive system; cognition is for action; offline cognition is bodily based.

[3]Most discussions about communication revolve around the conduit metaphor, wherein mental content is transferred between people through a conduit-like means. Unfortunately, this metaphor inadvertently reinforces the idea that thoughts and sensations can be accessed directly.

[4]The theory refers to the processes at lower level as 'private' in the sense that they cannot be accessed directly from higher levels/scales. For example, sensations experienced by the individual (lower level) cannot be experienced publicly (higher scale). To make them accessible at the higher level, they need to be expressed publicly.

ronment is possible only because the body, unlike the mind, is public – that is, an integral part of the physical surroundings. The body is actively involved in a two-way flow of impressions and expressions.

To conceptualize cognition fully, any prospective theory has to take into account the public and divisible nature of the physical body and the hidden and inaccessible nature of the mind, which presents itself as a single indivisible and private whole. The theory restated in this article does exactly that: It connects the nested and private activation levels confined to a sensory unit with a public collection of such units that are concatenated, hence divisible[5]. To convey this set of ideas, the theory uses a conceptual metaphor of a water column. This metaphor makes reasoning about abstract concepts possible in more concrete terms of layers, levels, and container(s).

As a synthetic construct, the theory can be reduced to its "components", which explains at least some of the claims made by Wilson (2002) and others. For example, by focusing on concatenation of units, one can interpret cognition as being situated and extended, and see the environment as a part of the cognitive system. Emphasizing the nested aspect of the theory, on the other hand, can explain the privacy of the mind and its offline simulations[6]. Only when both aspects are considered together does the theory have a chance to advance human understanding of natural language and cognition, and the psychology of intelligence in general, as biological phenomena.

In the following section, I discuss the use of a chair as just one example among many, illustrating how a public object expresses private sensations.

2.2 Materiality of communication

> *... language merely provides prompts for the construction of a conceptualisation which is far richer and more elaborate than the minimal meanings provided by language.*
>
> (Evans and Green, 2006, p. 8)

I hope the readers agree that it is practically impossible to directly experience the sensations and feelings of another being. In order for this to occur, both organisms would need to share the same body and sensory system, which is highly unlikely[7]. This raises a valid question:

> *How can one individual effectively communicate their thoughts, experiences, feelings, ideas,and intentions to another individual?*

To address this question, let us consider two individuals looking at the same chair in front of them. If they are standing close to each other, it is likely that they will have similar, if not identical, visual sensations associated with the chair. In a way, they "share" the sensory experience of that object[8].

Now, imagine that one of the individuals has created the chair as a means to publicly express his or her private experience of sitting in a chair. In order to do this, the individual must physically alter the shared space by constructing and displaying a chair. This process involves acquiring timber, fabricating the object, and painting it. Once the chair is ready, the viewer can be invited to engage with it by sitting in it. Due to its shape, the chair 'deforms' the body and, in turn, the molecular structure of specialized receptors, whose neurons are organized into sensory maps in the brain. When integrated, the sensations associated with the chair become multimodal percepts (sensations recognized as a chair), contributing to the object's meaning[9].

[5]It also connects the smaller scale of the mind with the larger scale of the body; the indivisible unit with a divisible collection of units; state with process; intensity with extent; content with container; internal with external; idempotent with additive; private with public, and so on.

[6]In cognitive linguistics, simulation has a specific meaning. It refers to the capacity of an individual's brain to recreate or evoke aspects of sensory and motor experiences to varying degrees of detail and fidelity in the absence of direct physical engagement. (Gallese & Lakoff, 2005)

[7]Conduit metaphor (Reddy, 1979) suggests a metaphorical hence non-physical answer to this issue.

[8]The common sensory experiences do not necessarily lead to identical perceptions.

[9]The argument shows how important the physical aspect of communication is. Limiting investigation to natural language and neglecting other forms of human expression is short sighted.

[10]The expressions may also include a person interacting with the object of expression.

[11]In the case of sound, the medium subjected to modification is the air. The human ear responds to temporal variations in pressure.

It is worth noting that there are alternative ways to express private sensations. One example is pointing at or reaching towards an existing chair or its photograph, which provide quicker but less precise alternatives to creating the actual object[10]. Similarly, writing the word "chair" or uttering the sound /tʃɛː/[11] can evoke associations with the sensory experience of a chair for some of us. However, these expressions differ significantly from the sensations of actually sitting in the chair. While photographs and drawings may capture certain aspects of the original object, such as its shape, sounds and words cannot. They can only serve as symbolic prompts to access meaning elsewhere.

The next section introduces the concepts of idempotence and concatenation.

2.3 Additive and idempotent interpretation of properties

> *If you are collecting money and have accumulated $15, then you also have $10.*
> (Johnson, 1987, p. 122)

In the subsequent sections, the terms "intensity of illumination/brightness" and "extent of intensity" are described as representing two distinct yet related modes of cognition. These aspects can be visualized using brackets as (((…))) for intensity and ( )( )( )( )... for extent. These two ways of thinking can be categorized as pairs of orthogonyms, and their relationship can be considered orthogonal (Raykowski, 2019). In the context of cognition, orthogonality implies more than just perpendicularity. To grasp this concept, let us consider the notion of value.

For something to possess *value*, there must be a human being capable of experiencing its significance and expressing it publicly, such as through coins in the case of money. Value can be seen as existing at a private level, which resides beneath the level of its public expression as coins[12]. As these levels exist in different 'spaces' (private vs. public), the concept of value and its extent are orthogonal to each other. This is distinct from concepts like *north* and *east*, which are perpendicular but not orthogonal since they pertain to the same space. Other examples of orthogonal pairs include the intensity of a hue and its area, the pitch of a sound and its duration, the intensity of pain and its extent, the sweetness of a food and its quantity, as well as the power of feeling and its breadth, the potency of a medication and its dosage, and so on (adapted from Raykowski, 2019, p. 203).

Idempotence is a concept related to orthogonality[13]. To understand it, let us consider a rectangular area Z in **Figure 2a**. If the nested rectangles a, b, and c are superimposed on Z (as shown in **Figure 2b**), there are two possible interpretations of this arrangement. The more familiar one, called an extensive/additive interpretation, is depicted in **Figure 2c1**, where the sum (concatenation) of the areas a + b + c equals Z. This sum represents an additive relationship, which can be expressed using brackets as ( )( )( ).

Visualizing the diagram (((...))) in **Figure 2c2** is more challenging as it involves the intricacies of nesting. For the areas to sum up to Z, rectangle 'a' must be interpreted as already encompassed by 'b' and 'c', and rectangle 'b' as already contained within 'c'. This implies that (a + a + a) + (b + b) + c equals (a + b + c), resulting in Z as shown in **Figure 2b**. Only then are the images in **Figure 2c2** and **Figure 2b** equivalent. This arrangement represents an intensive/idempotent interpretation, and the transition from the left to the right of the above equation is referred to as cognitive idempotence, signifying that the entities that are part of themselves are non-additive. However, if the rectangles in **Figure 2c2** are interpreted as three separate and unrelated areas of identical color intensity, their total would substantially exceed Z. In such a case, the areas a, b, and c behave as additive extents.

2.4 The role of sensory maps in construing 'reality'

The argument associated with **Figure 2** suggest that all properties are arbitrary as they can be seen as either additive or idempotent, depending on the schema applied. This perspective contrasts with the classification systems employed in physics, engineering, and related fields. Concepts like area, as well as analogous ones such as mass, weight, and volume, are consistently construed as extensive properties. They exhibit variations in size in direct proportion to the quantity of substance (being additive), in contrast to properties like color, temperature, and pressure, which remain

[12] See also the argument by Raykowski (2018, pp. 122–123)

[13] In this example, the area, typically interpreted as additive, is used to demonstrate the non-additive application of the sensory schema template. The gray color of the rectangles is solely employed to create visual contrast.

independent of the amount of substance (being idempotent).

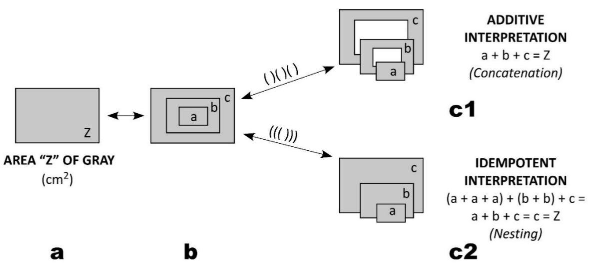

Figure 2. The figure shows two possible ways of interpreting 'area,' which is typically considered to be an extensive property.

This discrepancy does not appear accidental. In both this work and my earlier publications, I posit that the human interpretation of 'reality' is shaped by the anatomy and physiology of the body, with a particular emphasis on the embodiment of the sensory system and the role of sensory maps. My argument critically asserts that human individuals, as multicellular organisms, need sensory maps to monitor their bodies and, indirectly, the external world with which their bodies interact. These maps are constructed from specialized cells that replicate the spatial relationships between receptors embedded in various surfaces of the body. Consequently, the structure of these maps influences how individuals perceive external 'reality', including their own bodies.

Given that sensory maps are composed of discrete, concatenated cells, their collections have the capacity to define the notion of space, interpreted as continuous (with an absence of gaps), extensive, divisible, hence additive. Furthermore, because individual cells can be activated to various degrees and intensity of their activation is nested, their internal states are interpreted as private, internally coherent (continuous), indivisible and nonadditive. When these two aspects are combined, they give rise to the schema described in the subsequent sections.

The evidence for this interpretation could be found in human expressions. The interaction between additive and non-additive (idempotent) aspects of properties can be observed in both scientific and everyday situations. For example, adding one solution of a certain concentration to another solution of the same concentration increases the overall amount without changing the concentration. Similarly, adding 5 cars traveling at 100 km/hour to 5 cars already traveling at that speed is an idempotent action as it doesn't alter the overall speed but doubles the number of cars. This principle applies to various scenarios, such as when water of a certain temperature is added to water of the identical temperature, or when red paint of a particular intensity is mixed with red paint of the same intensity (Raykowski, 2014, 2018, 2019).

As demonstrated by the examples above, idempotence defines the concept of addition. To add two entities, they must possess not only identical properties but also the same intensity/value of those properties, though not necessarily the same extent. This distinction is crucial for a proper understanding of addition versus mixing, which will be discussed in Section 4.

However, before investigating this topic, it is necessary to elaborate on the theory describing the relationship between intensive and extensive aspects of human expressions referred to in this paper as the sensory schema.

3. Theory of sensory schema

The theory of Sensory Schema explores prelinguistic notions rather than traditional concepts, making them challenging to articulate solely through words. This necessitates the use of diagrams supplemented with carefully chosen words. These diagrams serve as schematic representations of sensory experiences and the ideas derived from them. It is crucial to note that the schema should not be misconstrued as a model of reality but rather as a complex arrangement of prompts for the brain to simulate intended experiences and, based on these simulations, generate ideas. To aid in conceptualization, I will begin with a brief history of the research.

3.1 Reality of sensory maps

> *One of the most profound findings in neuroscience is that nervous systems exploit topological and topographic organization.*
>
> (Johnson and Rohrer, 2007, p. 7)

The sensory schema originated from research conducted on contrast in fine art, where the notion of intensity plays a significant role. Creating contrast in painting often involves juxtaposing areas of the same color with different intensities (e.g., high intensity foreground against a low or no-intensity background). This observation led to the realization that nearly all color expressions in painting convey a sense of intensity combined with extent. In fact, it is impossible to express one without the other. Further investigations into expressions in music, technology, mathematics, and science have revealed that they all share this same design, in which intensity is associated with extent. Curiously, natural language appears to be the only exception to this pattern (Raykowski, 2019).

Subsequent studies highlighted the significance of sensory maps in defining the schema. Since the schema is rooted in studies of human expressions rather than biology, this article is based on a simplified, top-down view of sensory maps. Actual sensory maps exhibit complex characteristics—multilayered, highly interconnected, fractured, overlapping, and malleable—diverging from the regularity of artificial sensors like charge-coupled devices (CCDs). Unlike a conventional camera with a CCD sensor separate from a monitor, sensory maps in the brain function as both the 'sensor' and the 'display,' providing exclusive access to the patterns of sensations for the map's owner. To express private experiences publicly, sentient beings must physically modify the external environment using their own bodies, as detailed in Section 2.

While the reality of sensory maps is widely acknowledged, their role in cognition remains underappreciated. The significance of sensory maps arises from the necessity to coordinate voluntary movement. In this perspective, the brain can be interpreted as a large neural network that shares similarities with electrical circuits. For the information from such networks to be implemented in voluntary movement, stimuli from adjacent areas of the body must reach the brain nearly simultaneously. Achieving this is straightforward in electrical circuits but challenging in biological networks.

Compared to signal transmission in wires, the speed of signal propagation along neurons is extremely slow, potentially hindering the formation of representations. To ensure the simultaneous arrival of related action potentials, neurons from adjacent areas of the body must have similar lengths. All topographic/topological neuron arrangements exhibiting these properties can be referred to as sensory maps, and concurrent signal patterns can be regarded as sensory representations. From this perspective, sensory maps can be viewed as a type of network in slow transmission systems (Raykowski, 2014, 2019).

3.2 Sensory schema framework

> *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.*
>
> (Raykowski, 2022, p. 245)

As discussed in the previous section, the idea of the schema originated not from the field of biology but from linguistics. A perplexing discrepancy emerged when comparing expressions in science, visual arts, and technology with those in natural language. While non-linguistic expressions fully specify properties in terms of intensity and extent, natural language often falls short in this regard. This issue was carefully examined (Rajkowski, 2013; Raykowski, 2014, 2018, 2019, 2022), revealing that most, if not all, non-linguistic expressions are either directly derived from sensations or refer to sensory experiences. This observation emphasizes the biological interpretation of the sensory schema.

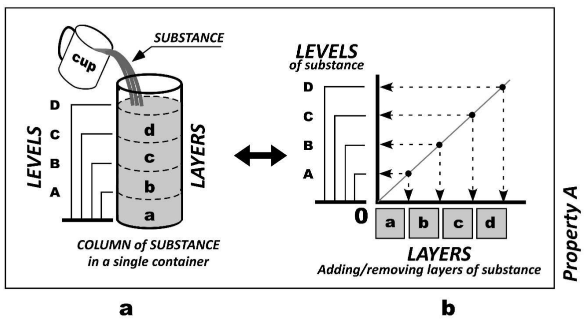

Figure 3. Sensory schema conceptual metaphor: (**a**) Column of a substance. (**b**) Unfolded representation of the column.

The issue with the biological perspective is that sensations are often regarded as raw data without inherent meaning (e.g., Skinner, 2014), and therefore, not possessing any internal structure that can be inherited. However, not everyone subscribes to this interpretation. I have been developing a theory that posits sensations as not only meaningful but also universally influential in cognition.

Beyond their widespread influence, the significance of intensity and extent lies in the fact that they represent two distinct yet closely related intuitions. Intensity captures the 'private' and nested aspect of properties, while extent exemplifies the 'public' repetition of units containing those properties. Several examples of such combinations include intensity combined with extent, nesting with concatenation, value with range, magnitude with multitude, quality with quantity, amplitude with period, rank with range, degree with scope/interval, pitch with duration, rise with run, velocity with time, density with volume, force with displacement, pressure with area, mass with velocity, cardinals with ordinals, and more broadly, *levels* with *layers* and *containers*. The sensory schema merges these different modes of thinking into a unified concept that cannot be split, as both aspects are necessary for viable expressions, which is the topic of the next section.

3.3 Substance: connecting sensations with the physical world

While the extent of an experience (such as touch) could be interpreted in many situations as public, the intensity is always private. As such, it can be expressed publicly only by referring to the physical world (see Section 2). One way to do that is by pointing to changing levels of a substance (or essence) in a container. The container can be anything from a cup with water to morning dew on leaves, a wet towel, or even a wet concrete surface (Raykowski, 2022, p. 249). In this context, a substance refers to any property, not necessarily material, that can be metaphorically accumulated. For example, Raykowski (2022) described the accumulation of emptiness conceptualized as a substance. All such expressions have a dual nature as they represent both the physical substance and its sensation:

The "substance" metaphor is a way of structuring and making sense of a wide range of sensory experiences, both concrete and abstract, which allows humans to reason about these concepts in an intuitive, accumulation-based framework. Consider a wet towel in the bathroom. When soaked with water, it feels wet; when allowed to air out, it feels dry. The words "wet" and "dry" express human sensations experienced when interacting with both the towel and moisture at the same time. These expressions represent two related perspectives, similar to the idiom about the glass being half full or half empty. Looking from below, the focus is on content (various degrees of wet), while looking from above, the focus shifts to the space above the content (various degrees of dry). The antonym "wet-dry" expresses the viewing perspective of the same situation and the same content. These experiences are intertwined: the increase of moisture content means the towel gets soggy, hence less dry. Thinking in terms of inverse relationships is cognitively difficult. Perhaps this is why humans prefer to think in terms of opposition which involves two containers with related but independent content (see Section 6). Such an arrangement bypasses complexity of inverse thought by reducing the relationship to comparison, addition and 'subtraction'.

What was described above concerns all properties listed in the table, and more, including the less obvious notions of good-bad, or fast-slow, all of which can be described in terms of layers and levels of a metaphorical material content. A more detailed account of this topic can be found in Raykowski (2022). That article, however, does not address the issue of opposition, where two viewing perspectives are presented as independent. This concept is discussed in Sections 5, 6, and 7 of the current article.

The next section will provide a more detailed examination of how various aspects of the sensory schema interact, using water as an example of a substance.

3.4 Layers, levels, water columns and containers

Whether derived from sensory-map studies or rooted in language, the sensory schema is an intuitive concept. In order to engage in reasoning about this intuition with others, it is necessary to express it publicly, and the most effective means of doing so is by invoking a routine experience of handling water (Raykowski, 2018). Water is an example of a material substance that can accumulate but it also can interact physically with human sensory systems and other substances and objects at the same time.

Figure 3a illustrates the accumulation of water in a container. The different stages of pouring water can be represented using brackets: ( ) for stage one, ( )( ) for stage two, ( )( )( ) for stage three, and ( )( )( )( ) for the final stage. Each pair of brackets represents a single layer. Thus, the process of pouring water and its accumulation in the container are inherently additive.

On the other hand, levels represent a nested arrangement, which can be visualized using brackets as follows: ( ) for the first stage, (( )) for the second stage, ((( ))) for the third stage, and (((( )))) for the final stage. Unlike layers, levels exhibit idempotence, making them nonadditive (re-

Table 1. Public expressions of private sensations.

Sensation:	wetness	sweetness	cleanness	good	hot	long	Fast
Physical substance:	water	sugar	dirt	merit	heat	length	space, time

fer to Section 2 for further details). Layers and levels are intricately linked: Every time a water layer is added, the water level in the container rises. It is important to note that the water must be added using the same cup. This aspect is critical for conceptualizing the schema, which is further elaborated in the subsequent sections.

3.5 Bracket notation used in the article

The sensory schema uses a container filled with a substance to represent levels of properties under consideration. Similar to mathematical notation, it is possible to depict aspects of the schema using brackets. However, interpreting this notation requires some effort because written text cannot represent vertical stacking. In the proposed notation, the underscore "_" represents an empty container. A single level in a container is denoted by ( ), two levels by (( )), and so on. For example, a container with four levels represented in **Figure 3a** can be expressed with four brackets: (((( )))). Here, the four consecutive opening brackets on the left represent a single empty container. To visualize it better, these four brackets could be replaced with a single opening bracket "(" or "[" – both symbolize the empty container. In other words, the four opening half-brackets ((((depict the bottom of the container (zero level), while the closing half-brackets)))) depict the four remaining levels of the property (see also Section 1.1).

With this in mind, it is now possible to express various combinations of levels, layers, and containers using brackets. Empty space, depicted as an array of underscores "_ _ _ _ _ _ " could be used to represent sensory-based division as inserting space between containers. For instance, a collection of concatenated containers, each with one level, can be divided into two parts as in ( )( )( )( )_ _( )( )( )( ), and two concatenated containers with four levels each could be separated with one or more spaces as depicted in (((( )))) _ _ _ (((( )))). This notation is used mainly in Section 4 to visualize addition as concatenation and division as inserting the background space.

3.6 Sensory schema expressions

The water column depicted in **Figure 3a** combines both levels and layers into a unified concept. Since levels and layers are orthogonal concepts, they can be represented using two perpendicular axes[14]. This visual representation, as shown in **Figure 3b**, helps to highlight the relationship between levels and layers. The 45-degree diagonal line, which represents the points where layers intersect with levels, aids in visualizing this relationship. The nested levels are depicted on the vertical axis, while the horizontal axis represents the repetition of discrete layers. Unlike layers, which contribute to a sense of space, levels represent a non-spatial relationship, such as hierarchies.

Due to their non-spatial nature, there can be infinitely-many nested diagrams of levels that illustrate identical relationships, potentially leading to ambiguity in expressions. To eliminate ambiguity, it is necessary for all layers to be identical. This is achieved by adding water to the container using the same cup, ensuring that the relationship remains independent of layer thickness (refer to Raykowski, 2018, pp. 112–118 for further details). The layers on the horizontal axis in **Figure 3b** are not only identical through unit repetition, but they are also concatenated, meaning that there are no spatial gaps between them. Examples of this repetitive nature of layers include steps in walking or running, centimeter units on a ruler, periods of sound, degree intervals on a thermometer, and so on — all of which have the potential for endless repetition.

3.7 Reciprocal relationship between levels and layers

Layers and levels are intricately connected through the sensory schema, influencing each other in significant ways. New levels are created by adding layers first. Layers impose their characteristics of regularity, discreteness, and a sense of progression (time), as well as their spatial and kinetic nature, onto static levels. By imposing repetition onto nested levels, an impression is created that the differences between

[14] To avoid any association with Cartesian coordinates, the axis lines are deliberately devoid of arrows.

subsequent levels are identical and equal to the thickness of the layers.

On the other hand, levels project their sense of nested order and confinement, along with their static and finite nature, onto the potentially infinite repetition of layers. For instance, when the containment associated with levels is applied to the repetition of layers, it generates a perception of the process being halted, terminated, and bounded.

Conceptual duality is another example of reciprocity observed in most properties. For instance, one can describe the container in **Figure 3** as having three cups of water, which is an interpretation based on layers, or as a four-level container that is three-quarters full, which is an interpretation based on levels. Continuity is another concept that demonstrates reciprocity. There are two interpretations of continuity: one related to layers, where continuity implies concatenation without spatial gaps between subsequent extents, and the other related to nesting, where continuity refers to indivisible units. Since nesting cannot be divided without losing its essence, such units are perceived as internally continuous and uniform.

Reciprocity can be observed in various domains, including temperature, time, distance, area, volume, mass, numerosity, as well as abstract concepts like monetary value, poverty, health, luck, importance, and even death. All of these concepts can be interpreted in terms of unit repetition or nested arrangements. For instance, we can say that half of a tree is dead, representing an extensive interpretation, or that the tree has a fifty percent chance of returning to full health, representing a nested interpretation. (Raykowski, 2022)

Due to limited space, a detailed analysis of the interactions between levels and layers will be presented through the examination of practical applications of the sensory schema. These applications include sensory products and the concept of contrast, which will be explored in relation to absolute, relative, binary, and oppositional contexts.

4. Applications of the sensory schema

Whenever addition and division are mentioned, most educated individuals think of mathematics with its well-defined concepts and rules. However, as introduced in Section 1.1, there is a more fundamental and intuitive way to understand these operations. This approach views division as inserting space between divided parts and addition as removing this space. Related to this interpretation is the concept of sensory products combining value of a unit with its repetition.

4.1 Cognitive sums and products

In this section, I shed light on the operations of sensory addition, multiplication, and mixing as they are understood within the context of the sensory schema. Money, given its widespread use and the clear differentiation between private values and their public and physical representations, serves as the ideal candidate for this investigation. **Figure 4** shows a small collection of monetary units depicted as containers positioned along the horizontal axis. The vertical axis represents values, a property humans attribute to money.

Like intensity, values exhibit a nested structure, as explained in Section 3. In the context of money, the individual perception of value is typically conveyed publicly through coins and paper bills, represented by the containers. To further illustrate the sensory schema's application, I will use a specific notation for sensory products in the next part of this section. In this notation, superscript refers to the unit value. Subscript, on the other hand, represent the extent (how many times the unit is repeated/multiplied). For example, ($\$2^{value} \cdot 6_{multiple}$) stands for a unit of \$2 repeated 6 times.

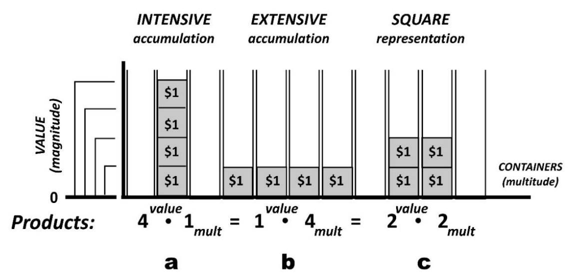

Figure 4. Concepts Based on the Sensory Schema. The content within these containers defines different sensory schema representations: (**a**) Intensive representation; (**b**) Extensive representation; (**c**) Square representation.

To demonstrate these concepts, let us consider the scenario of making a payment amounting to \$12. There are many ways to achieve this, limited only by the available denominations, which, in Australia, include coins such as ¢10, ¢20, ¢50, \$1, \$2, and bills of \$5 and \$10. Please refer to the example below:

[1] $12 = ($2 ^{value} · 6 $_{multiples}$)= ($1^{value} · 12 $_{multiples}$)
= (¢50 ^{value} · 24$_{multiples}$)=
= (¢20 ^{value} · 60$_{multiples}$)= (¢10^{value} · 120 $_{multiples}$) = PRODUCT

Each of the five forms of payment, which combine a private intuition of monetary value with officially recognized coins, can be described as sensory products that are equal and equivalent, though not identical. These sensory products offer a flexible way for humans to express value, allowing payments to be made using any agreed-upon denomination.

Among the various product configurations, three hold particular cognitive significance. The first configuration involves the accumulation of layers within a single container, as depicted in **Figure 4a**. This representation, known as the *intensive representation* of products, emphasizes the nested arrangement of levels in a single container. It functions as a coherent unit which cannot be 'multiplied' by a fraction like 0.5 or 1.5 (Raykowski, 2019)[15].

Figure 4b illustrates *extensive representation*, which involves a product with a value level of $1, the lowest denomination in **Figure 4**. Here, the accumulation of coins highlights the spatial aspect, reflecting the intuition of addition, sum, and the concept of space.

The *square representation* depicted in **Figure 4c** represents another important concept, where its value directly corresponds to multitude, hence the name. Raykowski (2018) discusses the significance of this representation in more detail.

Let us take a closer look at some examples to understand these concepts better. Consider the expression ($2 ^{value} · 5 $_{multiple}$) described in [2]. This represents a product with five groups of concatenated brackets, each with two levels. We can convert this to an extensive product with ten single-level concatenated brackets.

[2] $10 = $2 ^{value}· 5 $_{multiples}$ = (( ))(( ))(( ))(( ))(( ))=
( )( )( )( )( )( )( )( )( )( )$_{extensive\ product}$

[3] $10 = $10 ^{value}· 1 $_{multiple}$= (((((((((( ))))))))))$_{intensive\ product}$= { }$_{unit}$

Ten dollars can also be depicted using a single 'container' as shown in [3]. This flexibility in product representations allows switching between various forms of accumulation depending on the situation.

While addition can be used to express transactions involving bills and coins (as shown in example [4]), there is a crucial difference to consider. The '+' symbol might suggest a simple addition, but completing the transaction requires a cognitive step. The ten-dollar bill needs to be converted into units of the same denomination as the coins (e.g., two-dollar coins) before it can be truly added[16].

[4] $12 = ($10 ^{value} · 1 $_{multiple}$) + ($2^{value} · 1 $_{multiple}$)
= ($2 ^{value} · 6$_{multiple}$)

Example [5] demonstrates another application of product representations in repeated multiplication. Let us consider multiplying a one-dollar coin by four, and then multiplying the resulting product by three:

[5] $1 · 4 · 3 = ($1 · 4) $_{extensive}$ · 3 $_{multiples}$= ($4 · 1) ^{intensive} · 3 $_{multiples}$
= 12_{extensive}$

The task of multiplying becomes easier if the extensive representation is converted into intensive unit.

The sensory schema can also be used to understand exponents. Consider the example of 2^5 (two raised to the power of five). If 2 is represented extensively, it needs to be converted to the intensive representation before being multiplied twice: $2^{\text{intensive}} \cdot 2_{\text{extensive}} = 4_{\text{extensive}}$. The resulting product of 4 needs to be converted to the intensive representation and then multiplied again by two: $4^{\text{intensive}} \cdot 2_{\text{extensive}} = 8_{\text{extensive}}$. This process of converting to intensive representation and multiplying by two continues until we reach the final result, 32. Multiplication involving fractions is discussed in Raykowski (2018).

4.2 Cognitive division and concatenation

Cognitive addition differs from mathematical addition because it is defined in the context of sensory maps visualized as arrays of containers. Take the example in [6]:

[6] {( )( )( )( )( )( ) _ _ _ ( )( )( ) }$_{Array\ A}$
={( )( )( )( )( )( )( )( )( ) _ _ _ }$_{Array\ A}$

Adding, or more accurately, concatenating, involves removing three empty containers (marked with underscores)

[15] Sensory schema defines division as inserting space (e.g., cutting an apple into quarters) which creates new smaller units (apple quarters). This process precedes multiplication by fractions as practiced in mathematics. For example, $100 ▪ 0.5 = $10 ▪ 5. See Raykowski (2019) for elaboration.

[16] This is similar to adding decimal numbers. For example, 158 can be expressed as $100 \times 1 + 10 \times 5 + 1 \times 8$. However, in decimal representation, these numbers need to have the same unit, typically ones, for addition to be performed.

between the addends. It is important to note that the underscores are shifted to the right (or left) of the array, keeping the overall size of the array unchanged. Division, on the other hand, reverses the process by inserting empty containers between elements of the product. As depicted in [7], this process can be applied to the addition of multilevel products as long as their levels are identical. A similar approach is employed to represent movement across arrays.

To summarize, the cognitive interpretation of addition and division involves sensory arrays, the intensity or activation of which can be varied. This implies that not everything can be added together; only expressions with the same property and identical levels of that property can be concatenated. In cases where the property is the same, but the values are different, we are not dealing with addition but rather a process of mixing, which will be addressed in the next section.

4.3 Cognitive mixing

In this section, I argue that for addition (in the sense of concatenation) to take place, any two addends must not only belong to the same category (e.g., orange drinks) and share the same property (e.g., concentration) but also have the same level of concentration. When the levels of concentration differ, it is no longer a simple addition but rather a mixture. The example of orange juice demonstrates this concept. Here, the focus is on understanding why mixing concentrations can be non-additive, not on calculating the final concentration itself. Let us start with drinks of the same concentration, 20%, where concentration refers to the amount of dissolved substance (solute) present in a specific volume of the solution.

[7] $(400\ ml)_{20\%} + (1500\ ml)_{20\%} = (1900\ ml)_{20\%}$

Combining drinks with the same concentration simply increases the total volume without affecting the concentration itself. However, adding drinks with different concentrations results in a mixture [8] with a final concentration that depends on the initial volumes and concentrations of the drinks[17].

[8] $(400\ ml)_{20\%} + (1500\ ml)_{10\%} = (1900\ ml)_{12.1\ \%}$

Without the ability to create mixtures, achieving a variety of effects would be impossible. For instance, artists use this principle to create harmony or contrast by mixing paints of different tints and shades. Bakers adjust the sweetness or taste of their creations, and construction workers modify the strength of the concrete they use. Even seemingly simple tasks like adjusting the temperature of a bath involve combining water at different temperatures. The argument extends to other concepts beyond physical objects, such as the intensity of sensations (e.g., loudness of sound) or even abstract concepts like the intensity of love, importance, or educational levels.

In all these examples, cognitive products play a crucial role. Their widespread use suggests that they are fundamental to how we understand the world around us. Identifying, simulating, or manipulating these cognitive structures likely requires less cognitive load than processing highly variable spatial and temporal patterns or changes at the edges of sensory acuity. Some of these implications are explored further in the next section.

4.4 Sensory products overview

In the context of sensory schema theory, products are defined as unique associations of levels (a nested aspect of a property) with a multitude of units (a concatenated aspect of the property). While the product itself is extensive (directly proportional to size or quantity, e.g., distance), one of its factors must always be intensive (not dependent on size or quantity, e.g., average speed), while the other represents an extensive aspect of unit repetition (time, in the context of the example). It is important to note that the ratio of two extensive properties results in an intensive property interpreted as a unit. For instance, the ratio of distance over time, both extensive, produces an intensive unit of speed, indicating how much of one property (e.g., distance in kilometers) is 'contained' in a single unit of another property (time, e.g., one hour).

Humans often refer to larger entities as multiples of human-sized units (e.g., a twenty-five square-meter room) and smaller entities as fractions of those same units (e.g.,

[17]The concentration of the mixture in [8] can be calculated by finding the total amount of juice concentrate and dividing it by the total drink volume. Start by finding the amount of pure juice-concentrate in each solution. In the 400 ml of 20% solution, there are 80 ml of juice concentrate. Similarly, the 1500 ml of 10% solution contains 150 ml of juice concentrate. By adding these amounts, we get a total of 230 ml of juice concentrate in the final drink. To find the concentration of the resulting drink, we divide the total juice concentrate (230 ml) by the total drink volume (1900 ml) and get approximately 12.1%.

micrometers to express the diameter of a typical human cell). Measurement units are chosen to be relevant to human bodies and senses. All such multiples express easier-to-comprehend experiences. For instance, it is difficult to appreciate the impulse provided by the force when hitting a ball without converting this experience into a more stable and simplified representation. This reliance on human-scale units isn't just about convenience; it reflects how we understand the world. Complex and rapidly changing experiences, like the force of hitting a ball, are difficult to grasp directly. However, by representing them as products of an average force over time, we can make them easier to understand. This process of simplifying complexity is essential for making sense of the world around us (Rajkowski 2013, 2014).

Products also display high stability. In the example of currency in [1], whether one uses six coins of two dollars or twenty-four coins of fifty cents, the total value of such products remains the same. This demonstrates that products can be rearranged differently while still representing the same underlying value or effect. The ability of different structures to yield the same effect or outcome highlights the versatility and flexibility of products in various contexts. The concept extends beyond currency to many other areas of life and knowledge. For example, in mathematics, the commutative property of multiplication illustrates how changing the order of factors does not change the product. Similarly, in language, different word arrangements can convey the same meaning or message[18].

The utility of sensory products is tightly related to contrast. To create an equivalent product of a pattern, the area of identical or similar values must first be identified. Sufficient contrast is needed to distinguish such an area from its surroundings. To appreciate contrast as a sensory experience, the notion of scale must be introduced first, which is discussed in the next section.

5. Sensory scales and contrasts derived from the sensory schema

> *The principal image-schema in this account of antonymy is SCALE, which construes a property in terms of more and less.*
>
> (Croft and Cruse, 2004, p. 169)

This section introduces the concept of sensory scales, based on the sensory schema outlined in Section 3. **Figure 3a** depicts the sensory schema as a column of liquid, highlighting three key elements:

Stacked layers: These represent the accumulation of a property interpreted as a substance.
Nested levels: These signify the varying degrees of intensity/value of that property.
Imperceptible limit (absolute zero): Similar to an empty container, this represents the level where we can no longer detect the sensory property, not the complete absence of the property itself.

Scientific instruments like thermometers, rulers, and other scales define properties based on a theoretical zero point, which assumes the complete absence of relevant properties (e.g., absolute zero for temperature). Sensory scales, however, represent human subjective experience. They are based on human experience of intensity with an imperceptible zero level at the bottom of the sensation scale. For example, darkness in vision signifies an imperceptible level of light, not the absence of light altogether. Levels at which properties cannot be perceived by humans vary both with age and "viewing" conditions, unlike scientific scales which rely on stable and measurable phenomena for their definitions. To differentiate them from scientific instruments, such constructs are referred to as sensory scales. The next four sections introduce and discuss the concept of three sensory constructs: absolute scale, binary contrast, and relative scale, starting with the absolute scale.

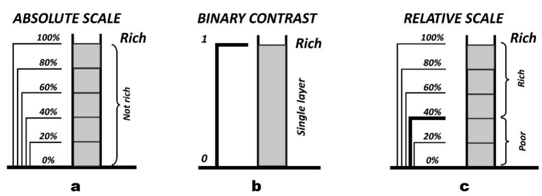

Figure 5. Types of scales based on the sensory schema — The diagram illustrates three distinct ways of conceptualizing scales: (**a**) absolute scale, (**b**) binary contrast. and (**c**) relative scale.

5.1 Absolute sensory scales and contrasts

This section introduces the concept of absolute (sensory) scale depicted in **Figure 5a**. The concept could represent not only sensory domains like vision and touch but also

[18]For more information regarding products in cognition, refer to Raykowski (2018) and (2019).

measurable properties (density, temperature) and abstract properties (like goodness or wetness). The analysis in the remainder of the section focuses on the abstract property of *wealth*. The graded levels of wealth can be expressed as percentages, fractions, or degrees, but also with dedicated names/phrases such as Destitute < Somewhat rich < Quite rich < Very rich. To simplify communication, percentages are used for levels in the next two sections.

Figure 5a depicts an absolute scale of wealth using nested levels. The 100% level of wealth comprises the 80% level, which contains the 60% level, and so on. At the bottom of each nest is a 0% level, referred here as an absolute zero, representing destitution. Absolute (sensory) scales capture the most basic experience and idea of absoluteness. There is no room for ambiguity with absolute scales; they involve only one property resulting in one zero which indicates no perceptible or measurable intensity of that property. Importantly, each layer is associated with only one level and there is only one direction of accumulation, and consequently, only one way in which accumulation can be undone. The scale is unbounded and context independent. Moreover, negating the property affects all levels below the negated level. For example, *not 90% rich* includes all levels below 90% including zero. This is unique to sensory scales because all levels within these scales are nested.

In the context of the absolute scale, contrast represents the difference in levels between a pattern and its background. The greater the difference between the levels, the higher the contrast. While sensory acuity varies with age and among individuals, there is always a threshold below which sensory detection becomes impossible. This threshold sets the zero point of the nested experience, defining the absolute scale. Considering all these characteristics, absolute scales could be regarded as the fundamental cognitive frame used to conceptualize all other scales and their associated contrasts, including the binary "scale" discussed in the next section.

5.2 Binary contrasts

In logic, certain systems treat properties as having only two states, resulting in binary relationships such as *rich* or *not rich*. This concept is illustrated in **Figure 5b**, which displays a scenario with only two distinct nested levels separated by a single layer. Contrasting this, **Figure 5a** shows a situation where an unlimited range of levels is allowed. **Figure 5b** represents the essence of classical logic's *principle of excluded middle*, as described by Łukasiewicz in 1951.

By restricting the property to two nested levels, the binary representation draws focus to the extremes, resulting in a stark contrast. It is important to note that, in the context of sensory scales, '1' represents the maximal level of a property, while '0' signifies the absence of content of that property, but not the absence of the property itself.

5.3 Relative sensory scales and contrasts

The concept of relative scales is as complex as it is ubiquitous. They are often discussed in terms of opposites like *hot-cold*, with reference to temperature scales like Fahrenheit or Celsius. However, these scales are relatively recent inventions, and the basic human experience of hot and cold predates them. Furthermore, focusing solely on instruments can overshadow the core concept of relative scales. In the context of human sensations, the zero-point on a relative scale is not experienced as an absence of a property or an imperceptible sensation. Consider the sense of temperature. For any individual, there is a range of temperatures considered "comfortable" (neither hot nor cold), with the sensation intensifying as one moves away from this "inflection point." This perceived neutral point acts as zero on a personal comfort scale.

The idea of inflection points is relevant for all sensory modalities. Concepts like "comfortable," "acceptable," or "neither/nor" can be found in numerous expressions: "neither loud nor quiet," "neither bland nor excessively sweet," and "neither pleasant nor unpleasant smell," or "just right sweetness," and "just perfect". This concept is not limited to sensory experiences either. Humans use phrases like "just the right size" or "perfect timing" to describe situations across various domains, including speed, distance, price, timing, and brightness or texture, for example. Other phrases like "optimal" or "a bit off" convey how close a situation is to ideal, often with a positive or negative connotation ("too little" or "too much"). Furthermore, this interplay of degree and valence extends across all aspects of life, from science ("accurate results") and engineering (± tolerances) to art ("pleasing composition") and cuisine ("sweet spot").

With these observations in mind, consider the relative scale of *rich - poor* in the context of the absolute scale of wealth depicted in **Figure 5c**. Unlike the absolute scale in

Figure 5a, where poverty is synonymous with zero wealth, **Figure 5c** presents poverty as wealth below a certain level, say, 40% on the wealth scale. This level could be described as an inflection point of "fair" redistribution of income. The same way as there is a personal range of "right" levels of sensation (e.g., perfect temperature, taste, loudness), there could be a range of socially "right" levels of income distribution that allows for an acceptable quality of life. Deviations from this inflection point, whether towards poverty or excessive affluence, are met with social disapproval.

The fairness of such a distribution can be assessed by contrasting the experiences of those at different levels of wealth. As in the case of absolute scale, contrast is a difference between two levels. Because relative scales involve two ranges of property, the contrast can be created between any two levels below or above as well as across the inflection point. For example, the contrast between −10 and +20 degree Celsius is 30 degrees.

Poverty and wealth, like other subjective experiences, vary between individuals. In the absence of objective scales like the Celsius scale for temperature, humans create ad hoc sensory-based scales to facilitate communication. These improvised scales often rely on adjectives and adverbs to define different levels or degrees of the subjective experience (Raykowski, 2022). The use of some words or phrases (such as "perfectly sweet lemonade") invoke a conceptual frame (Fillmore, 1982) in the listener's or reader's mind, with different levels or degrees of sweetness (not sweet at all, not sweet enough, perfectly sweet, too sweet). To bridge the gap between how we experience the world and how formal systems represent it, Section 5.4 examines the underlying assumptions of sensory schema and formal logic.

5.4 Bridging the gap between sensory experience and formal systems

Some aspects of the interpretation presented in Sections 5.1, 5.2, and 5.3 may seem to contradict logic. This apparent contradiction likely stems from the distinct contexts in which sensory schema and formal logic operate. Sensory schema theory seeks to understand how humans 'make sense' of their experiences by analyzing sensations, one modality at a time. Logic, in contrast, takes a broader approach, encompassing formal systems like axiomatic structures and reasoning (see Shapiro and Kouri Kissel, 2024). The problem arises when assumptions used in logic are extended to the investigation of sensory structures which results in negation in the sensory scales (e.g., not full, not on, not happy, not bright) being routinely described as the absence of the property.

Consider a simple property such as the color *red*. Its negation, *not red*, is interpreted differently in each framework. In logic, *red* is typically an attribute of an object, like an apple. In this context, *not red* refers to all apples that do not possess the property of being red. However, when the focus shifts to the property itself, like redness, the issue is no longer about the color of a specific object, but about the concept of redness. The sensory schema offers a way to understand this concept through scales. These scales are nested, with each higher level including the one directly below. Each level is separated by identical intervals, with zero representing the inability to detect the intensity of a property. This nested structure fundamentally alters reasoning about properties, especially regarding negation. When we negate a specific level on a sensory scale, all the nested levels below it are automatically included in the negation. Because they are nested, all levels are different. In contrast, in logic, all elements within the "not red" set are considered equally important (in terms of set membership). Sensory scales, therefore, offer a more nuanced perspective, as they can depict graded relationships and varying degrees of negation. For instance, in the case of shades, colors like crimson might be perceived as closer to the base color red than maroon or burgundy. These nested relationships convey, among other things, a sense of relative distance from the original property (red), which is important for many concepts. One such example is a notion of value.

The term *value* is very common not only in natural language but also in mathematics. When discussing numbers and mathematical concepts, humans commonly refer to value in phrases such as "function value", "the value is greater than/less than", "decimal value" or "absolute value of a number", "maximizing the value". The language of "value" is widely used in mathematics, even though the formal, axiomatic definitions of numbers, and mathematical structures in general, do not inherently rely on this notion. The recursive definitions of numbers, for example, provide a systematic way to construct and reason about numerical quantities without the concept of value. This suggests that humans have an intuitive understanding of "numerical value" that predates mathematical formalization. Since value is not inherent to numbers themselves, it must arise from human interpretation.

In the context of the sensory schema, value is described as a private and subjective experience, which cannot be easily and directly quantified or expressed objectively. Since the value we assign to money is subjective, expressing value of “$1” requires a physical and public representation like a $1 coin (see Section 2). Even then, there is no certainty that the coin will have the same value for all its users. This is one reason why mathematicians moved away from the private concept of value and used recursion instead in their definition of natural numbers. This shift reflects an attempt to ground mathematical reasoning on more objective and public foundations.

The next section looks into the issue of opposition and its relation to the sensory scales outlined so far.

6. Concept of sensory opposition

In cognition, opposition plays a role similar to contrast in scales, facilitating the process of comparison and differentiation, where stronger contrast helps distinguish potentially significant patterns. Unlike contrast in scales, which is defined in relation to one property, opposition concerns the relationship between two absolute properties in which contrast in one property adds to the contrast expressed in the other. This means that not all combinations of properties can improve contrast. For example, *watery*, *damp*, and *soggy* do not create strong contrast, if at all, when juxtaposed. These are classified as synonyms (Paradis et al., 2009). Only concepts that share a common property with varying degrees, such as moisture level in the case of wet and dry, and differ significantly in their degree of that property, can create an effective contrast. To experience an additive nature of contrasts, compare *very wet* with *somewhat dry* and then with *very dry*. The difference feels greater when contrasted with *very dry* than with *somewhat dry*.

Just like sensory scales, opposition is a mental framework: a template used to understand and categorize human experience. As a template, opposition can be applied to a variety of properties, including those that do not fit the framework perfectly. Consider antonyms like *short* and *long*. These are typically interpreted in the context of relative scales. It is easy to visualize *long* in terms of length. However, as a relative concept, *shortness* is difficult (but not impossible) to imagine in this role. Therefore, not all properties can be equally easily framed in terms of opposition. To arrive at defining features of opposition, the discussion in this article focuses on properties that can be readily analyzed within the opposition framework.

6.1 Gradable opposition

... the sum of debits equals the sum of credits
in a single monetary unit.
(Basu and Waymire, 2021, p. 2)

Having established the general concept of opposition in the previous section, this subsection explores ’gradable opposition,’ a specific type where the intensity of the opposing properties matters. Understanding opposition plays a crucial role in various domains. One such domain is personal finance, where managing assets and liabilities is essential. A prime example is the concept of *credit* and *debit*. Let us consider these concepts not from the perspective of the bank, but from the viewpoint of the bank’s customer. Most bank customers are likely to interpret credit as representing money coming into their account (a payment received or a deposit), resulting in an increase in their assets. Debit, on the other hand, represents money owed to the bank or another party (such as a bill that needs to be paid or a purchase made on credit), which decreases their assets.

The use of *credit* and *debit* concepts to discuss oppositions and related ideas is no accident. Human natural tendency to track what they possess and what they owe reflects a deep-seated understanding of credit and debit. These ideas likely originated with prehistoric trade and evolved progressively over an extended period of time[19]. As early as the sixth century AD, the Hindu mathematician Brahmagupta

[19]Traditional Single-Entry Bookkeeping (SEB) preceded Double-Entry Bookkeeping (DEB). The earliest forms of bookkeeping were simple positive-only records without the ability to represent negative balances algebraically. The key innovation of DEB involved adding another account/container and interpreting them in opposition to each other (credit vs. debit). (Basu and Waymire, 2021)

[20]Brahmagupta’s contribution to mathematics includes defining zero as the outcome of subtracting a number from itself and establishing rules for calculations involving both negative numbers, which he called “debts,” and positive numbers, sometimes called “fortunes” (Gokhale, 2023).

employed the notions of "property" and "debt,"[20] analogous to credit and debit (Mattessich, 1998), to define zero and negative numbers (Joseph, 2008).

Credit and *debit* demonstrate a key difference from sensory scales. Scales represent changes within one property, like adding or removing money in a container. In contrast, credit and debit embody opposition. Here, two separate properties are involved, each with its own container as defined by the sensory schema. Credit represents an increase in assets (adding to a dedicated container), while debit signifies an increase in what is owed (adding to a different container). This interplay between two independent containers, holding opposing properties, highlights the core distinction between scales and opposition.

To demonstrate the opposing nature of *debit* and *credit*, let us refer to them as "property X" and "property Y," as depicted in **Figure 6**. The two diagrams face away from each other, visually representing their opposing nature. For these properties to establish a quantifiable relationship, they must belong to the same category (e.g., money), share a common zero level (representing properties that act as containers for the same type of content), utilize an identical unit of accumulation (e.g., a dollar coin) and remain symmetrical (the sum of debits equals the sum of credits). Consequently, the values assigned to both properties align, allowing reconciliation of their respective balances using only addition and the operation of undoing those additions.

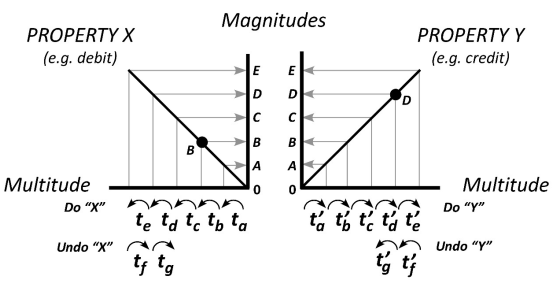

Figure 6. Gradable opposition of properties X and Y. The figure illustrates two containers positioned side-by-side in an unfolded configuration. Refer to **Figure 3** for a visualization of the unfolding process.

In the case of both *credit* and *debit*, the accumulation process typically begins with an empty container (at moment t_a). The content levels increase with each added layer at t_b, t_c, and so forth, up to t_e. Changes in value levels only occur through the addition or removal of layers. Since non-existent layers cannot be physically removed, the process of reversing accumulation can only be carried out from the last step (at moment t_f) until the container reaches an empty state (zero level)[21].

It is important to emphasize that both *credit* and *debit* accumulations are independent, potentially infinite, and symmetrical in this conceptualization. When considering opposition, such as credit versus debit, contrast refers to the difference between the levels of these two absolute properties. For example, the contrast between \$100 level of debt and \$160 level of credit is not simply a net balance of \$60, but rather the sum of their absolute values, \$100 and \$160. This is depicted in **Figure 6** as the 'distance' B-0-D.

As previously mentioned, the prospective properties need to belong to the same category and share a common unit. While finding a common unit for some properties like *good-bad*, *simple-complex*, or *tolerant-intolerant* can be challenging, the example of *polite-rude* opposition at the beginning of Section 6 shows that people can intuitively compare contrasts. This suggests a more abstract, underlying unit that might not be as readily apparent as meters for length. One way to describe this unit is as a sense of the common structure that both properties share.

Another requirement for properties to be in opposition is a common zero level. **Figure 6** shows the opposition of two absolute properties, *credit* and *debit*, depicted as two identical containers in an unfolded configuration. Because the containers are identical and the properties share a common unit, all levels (including zero levels) are aligned but separate. Therefore, there are two zero levels, one for each property, which can be interpreted as neither X nor Y. Building on the concept from Section 5.2 of simplifying absolute scales into binary contrasts, we can similarly transform absolute scales of *graded opposition*. The resulting *binary opposition* retains all key features: two properties related by a common category and unit, with a zero-point signifying *neither X nor Y*. By transforming graded opposition into

[21] In a double-entry system (DEB), every transaction is recorded as two separate entries, with one account being debited and another account being credited for the same amount. This means that all transactions can be recorded using only addition, without the need for more complex operations like multiplication or division. Note that the single-entry systems (SEB), that historically preceded DEB, were essentially just simple positive-only ledger records, without the ability to represent negative balances algebraically. (Basu and Waymire, 2021)

binary oppositions, we create an arrangement that mirrors how opposition functions in logic, which simplifies reasoning, allows for the application of logical operators, facilitates predictions, and enables comparisons across different senses.

In summary, absolute scales deal with variations of a single property (e.g., increasing/decreasing heat). Oppositions, in contrast, involve two distinct properties (e.g., hot and cold; credit and debit, etc.) represented with two independent yet related containers. These two-container oppositions are easier to manipulate because they rely on cognitively simpler addition, as discussed in the next section.

6.2 Concept of semi opposition

The previous section highlighted the importance of accumulation in establishing opposition. *Debt* and *credit*, for example, achieve their distinct and opposing nature through the independent accumulation within their own separate accounts or "containers". This concept is visually represented in **Figure 6**, where the properties of *debt* and *credit* are depicted as two opposing diagrams. This opposition creates an opportunity for unification into a single cohesive system by reversing the direction of accumulation for one of the properties.

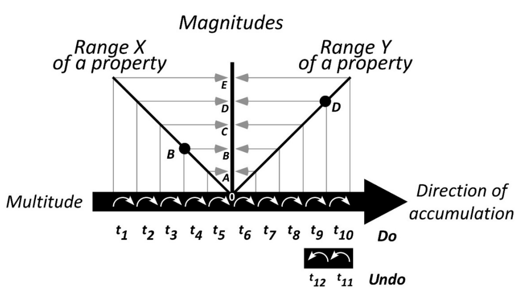

Figure 7. Semi Opposition. Take note of the reversal in the direction of debt accumulation.

Consider a scenario where fulfilling obligations, such as paying off a mortgage for a house or car, significantly improves a person's financial situation. From a credit perspective, the act of debt repayment can be viewed as accumulating credit[22]. This interpretation can be realized by flipping the direction of debt accumulation and aligning it with credit accumulation, as shown in **Figure 7**. The resulting construct represents a transformation of two opposing properties (represented by two containers) into one property (represented by the single container), with separate ranges for *debt* and *credit*. The unified accumulation is depicted in **Figure 7** with a sequence of white arrows on a black background.

Unifying accumulation positions layers for property X before those of property Y: $t_1 \rightarrow t_2 \rightarrow t_3 \rightarrow t_4 \rightarrow t_5 \rightarrow t_6$ and so on. It is important to note that this does not imply that the value of debt is less than zero; it simply indicates that any step to the left of a given point occurs earlier[23]. The arrangement resembles an absolute scale with the concept of absolute zero, which is not actually present.

Contrast in this scale is the distance B-0-D defined as the difference between levels of two ranges, X and Y, of the common property. As a half-step towards understanding integers and the number line, this concept is termed semi opposition.

6.3 Integer schema

The concept of semi opposition, as outlined in the previous section, may offer an answer to the difficulties in conceptualizing negative integers. By reinterpreting debt repayments as credit, the opposing properties can be unified through their common direction of accumulation. Instead of two containers representing levels of *debt* and *credit*, there is a single container representing the consolidated property. Such a property has only one direction of accumulation; hence, there is just one way to undo it. However, the process of consolidation also creates ambiguity, as all levels of the construct simultaneously refer to two different ranges of the consolidated property. For example, level B in **Figure 7** refers to step t_3 of the *debt* range and step t_7 of the *credit* range at the same time, creating uncertainty regarding their

[22] While a single account can be used for both adding and removing funds, managing opposing transactions often requires two separate accounts. One account is used for credit and the other for debit. To settle a debt in the debit account, an equal amount needs to be deposited in the credit account. (Basu and Waymire, 2021) This essentially reverses the direction of accumulation in the debit account to match the credit account, functionally creating a single unified account.

[23] Note that absolute values of credit and debit are identical for the same number of layers accumulated. The diagram in **Figure 7** resembles the basic absolute value function in mathematics.

interpretation.

To eliminate ambiguity without affecting accumulation, the rearrangement of magnitudes is the only schema aspect available for modification. Assigning negative magnitude below the zero line to *debt* and positive magnitude above the line to *credit* (as shown in **Figure 8**) avoids ambiguity while preserving a single direction of accumulation. The assignment of positive and negative magnitudes, positioning them above and below the line respectively, is not accidental or arbitrary. Rather, it reflects human sensory experiences of interacting with the physical world, embodied in the conceptual metaphor "more is up, less is down" (Lakoff and Johnson, 1980).

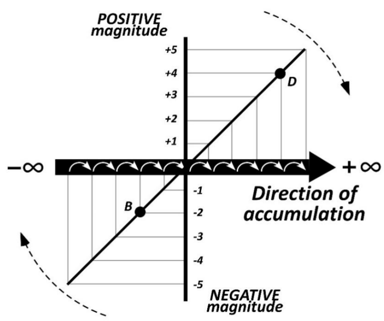

Figure 8. Integer schema. The diagonal line relates the layers of accumulation to levels of magnitude in the unfolded depiction of the sensory schema.

Symbolically, the diagram in **Figure 8** can be represented using inequalities as

$$... -5 < -4 < -3 < -2 < -1 < 0 < 1 < 2 < 3 < 4 < 5 ...$$

with numbers to the left of zero referred to as *negatives* and those to the right as *positives*. In the context of the diagram, the direction of the 'greater than' sign indicates an increase in magnitude from left to right.

Historically, the concept of negative numbers was a significant hurdle for mathematicians (Mattessich, 1998; Crabtree, 2024). Unlike positive numbers that represent quantities, negatives presented a challenge in visualization and application. To address this, mathematicians use minus signs to differentiate them from positive numbers and enable calculations involving both positive and negative values. The concepts presented in Section 6, from opposition to integer schema, suggests a potential link between natural language and mathematical reasoning. Investigating this connection in greater detail could lead to new insights into how humans develop and utilize numerical concepts.

6.4 Number line concept

A widely recognized version of the diagram from **Figure 8** is the 'number line' in **Figure 9**. This diagram is created by rotating the vertical magnitude line around the zero point towards the horizontal line (as illustrated by the broken-line arrows in **Figure 8**) until they converge into a single axis. **Figure 9** shows the number line as a wide black arrow with its conceptual structure in gray. It represents a single direction of increasing values, along with both negative and positive magnitudes. The line introduces key features like marked points for integers, a clear definition of order between numbers, and the concept of infinite extension in both directions. The number line also establishes a consistent unit length, emphasizes zero as the central reference point for positive and negative values, and defines contrast between two numbers as the sum of the absolute values of those numbers, where absolute value is the distance of a number from zero. The number line, with its applications in comparisons, measurements, and other spatial tasks, lays the foundation for multidimensional coordinate systems like vectors and two- and three-dimensional Cartesian coordinates.

The conceptualization of opposition in terms of the number line was an important step in mathematics. Humans understood the distinction between the concepts of *negative* and *positive* well before these ideas were formalized. The number line might have solidified and made more precise human understanding of those terms by organizing them visually on a line. However, the question remains as to why the relationship between these opposites had to be defined in this particular way, which still seems contradictory, so much so that it had to be defined entirely in terms of rules rather than intuitions.

The next section looks for answers to this question in human biology.

7. Closing remarks

> *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, 2020, p. 1)

In his book "Sensory Transduction", Gordon L Fain reminds us of the embodied nature of perception: how humans perceive "reality", including their own bodies, relies on the sensory organs, and the ways they are physically organized. However, the biological basis of cognition is often obscured by our everyday preoccupations and concerns. Humans tend to think of their daily activities through a social and cultural lens, focusing on fashion, trends, styles, and personal preferences. For example, they see clothing as a way to express themselves, houses as architectural statements, and food as a way of socializing. While these aspects certainly add richness to human lives, from a purely biological standpoint, there is another, more fundamental reason behind these activities: homeostasis, the process by which organisms maintain a stable internal environment, including body temperature, blood pH, and other critical factors required for proper metabolism. At the cellular level, metabolic processes can only function within a very narrow range of temperatures and other conditions (Rhoades and Pflanzer, 2003).

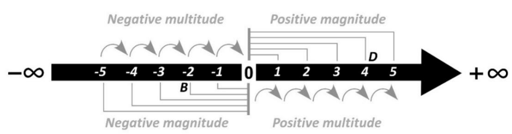

Figure 9. Number Line. This diagram depicts the number line, a more formal representation built upon the integer schema introduced in Section 6.3.

As multicellular organisms, humans must take action (clothing, shelter, food preparation) to protect their critical internal balance. Any deviation from this equilibrium, whether body temperature exceeding or falling below the optimal range, blood sugar levels becoming too high or too low, or hydration levels reaching extremes, triggers feelings of discomfort. The state of this dynamic equilibrium is directly reflected in their sensory experiences. All such experiences have an intrinsic structure which includes intensity, extent, valence, absolute and relative zero, inflection points, and other structures outlined in this article. I argue that the concepts of scales and opposition were developed to mirror these sensory structures, and the number line integrates all these pre-existing notions into a single construct. This synthesis allows for quantitative ideas across mathematics, science, and everyday experiences to be systematically explored, understood, and expressed. Without this synthesis, human understanding may have remained limited to qualitative descriptions and metaphors.

The foundation for this understanding lies in the theory of sensory schema. This theory is based on the theoretical frameworks of embodied cognition and the materiality of human communication. Building on this foundation, the article explored various applications of sensory schema in cognitive processes like addition, division, and mixing. Finally, an investigation into the development of sensory contrasts and scales led to the concepts of oppositions and the number line, and its potential influence on human understanding of "negative" and "positive" concepts. The core idea of this framework, based on shared human biology, suggests that people everywhere might experience the world in similar ways. Section 8 explores this issue in more detail.

8. Further research and some applications of the sensory schema

The proposed sensory schema framework, grounded in fundamental biological principles, is hypothesized to be universally valid. It posits that basic sensory experiences, such as hot/cold or loud/soft, are remarkably similar across cultures due to our shared biology. However, as we move to more complex structures built upon these experiences – such as image schemas, conceptual metaphors, and narratives – variations in interpretation emerge as context becomes increasingly influential. Narratives, for example, exhibit high variability across societies. Different cultures may have different experiences and values that shape the stories they tell. Conceptual metaphors, while less variable than narratives, can also be influenced by culture. For instance, the metaphor "time is money" might be more prevalent in cultures that emphasize efficiency and productivity. At the foundation of this hierarchy, common to all sensory modalities, is a single schema of sensations representing humans' most basic conceptual system. These shared sensory experiences are likely to be similar across cultures due to shared biology.

To strengthen the claim of universality, cross-cultural studies could analyze expressions across languages, art forms, and cultural practices. Psychophysical studies comparing responses to basic stimuli and developmental studies tracking schema formation in children from diverse backgrounds could offer valuable insights. Additionally, future research could investigate how sensory schemas interact with other cognitive and cultural processes. This might involve neuroscientific studies examining brain activity during language processing, anthropological studies exploring sensory experiences in cultural rituals, or mixed-method approaches combining surveys and interviews to understand how cultural biases and background knowledge influence perception. Longitudinal studies tracking individuals over time could provide further understanding of this interplay.

If confirmed, the universality of the proposed framework would represent a paradigm shift in our understanding of social relations. This shift would reorient our focus from what divides humans to what unites them, suggesting that our differences are primarily social constructs, while our core experiences and behaviors share a common, stable biological foundation. This stability makes communication between individuals possible.

Building on this foundation, the framework sheds new light on the philosophy of science, cognition, and learning. It posits a deep connection between the structure of sensory experiences and abstract concepts. This bridge can inform the development of teaching methods that leverage students' existing sensory understanding (intuition) to grasp complex ideas. Additionally, the framework sheds light on why formal systems like mathematics might not always align with our intuition – negative numbers being a prime example.

The framework's potential extends beyond education. In fields like artificial intelligence and robotics, it can help develop systems that understand and respond to user intent based on underlying sensory concepts. Unlike the prevalent "computer mind" metaphor, sensory schema theory emphasizes humans as complex multicellular organisms shaped by eons of evolution. Our intricate sensory processing, with countless cells working in concert, forms the foundation for how we understand the world.

Ultimately, this framework holds promise for enriching learning experiences, advancing knowledge in various fields, and fostering a more inclusive society by highlighting what humans have in common across cultures.

Author Contributions

This paper was conceptualized, researched, and written entirely by Wes Raykowski.

Conflict of Interest

The Author declares that there is no conflict of interest.

Data Availability Statement

Not applicable.

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References

Basu, S., Waymire, G.B., 2021. The Evolution of Double-Entry Bookkeeping. DOI: http://dx.doi.org/-10.2139/ssrn.3093303. Available online: https://ssrn.-com/abstract=3093303 (accessed on 2 June 2021).

Crabtree, J.J., 2024. Notes on the Origin of the First Definition of Zero Consistent with Basic Physical Laws. In: Gobets, P., Kuhn, R.L. (Eds.). The Origin and Significance of Zero: An Interdisciplinary Perspective. pp. 187–215. Leiden: Brill. Available online: https://brill.com/display/book/-9789004691568/BP000025.xml (accessed on 2 June 2024).

Descartes, R., 1641. Meditations on First Philosophy. In: Elizabeth, S. (trans.). Haldane. Internet Encyclopedia of Philosophy, 1996. This file is of the 1911 edition of The Philosophical Works of Descartes. Cambridge: Cambridge University Press.

Evans, V., Green, M., 2006. Cognitive Linguistics: An Introduction. London: Lawrence Erlbaum Associates, Publishers.

Fain, G.L., 2020. Sensory Transduction. New York: Oxford University Press.

Fillmore, C.J., Atkins, B.T., 1992. Towards a frame-based lexicon: the case of RISK. In: Lehrer, A., Kittay, E. (Eds.). Frames and Fields. Mahwah, NJ: Erlbaum Publishers. pp. 75–102.

Gallese, V., Lakoff, G., 2005. The brain's concepts: The role of the sensory-motor system in conceptual knowledge. Cognitive Neuropsychology. 22, 455–479.

Gokhale, P., 2023. Negative Numbers: Their History and Constructive Applications in Vedic Mathematics. Coppell, TX: IAVM.

Holdcroft, D., 1998. Structuralism in linguistics. In Routledge Encyclopedia of Philosophy. London: Taylor and Francis. Available online: https://www.-rep.routledge.com/articles/thematic/structuralism-in-linguistics/v-1 (accessed on 2 June 2024).

Johnson, M., Rohrer, T., 2007. We Are Live Creatures: Embodiment, American Pragmatism, and the Cognitive Organism. In: Zlatev, J., Ziemke, T., Frank, R., et al. (Eds.). Body, Language, and Mind. Berlin: Mouton de Gruyter. Vol. 1, pp. 17–54.

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

Joseph, G.G., 2008. A Brief History of Zero. Iranian Journal for the History of Science. 6(2008), 37–48.

Kompa, N., 2010. Contextualism in the Philosophy of Language. In: Petrus, K. (Ed.). Meaning and Analysis: New Essays on H. P. Grice. London: Palgrave Macmillan. pp. 288–309.

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

Lakoff, G., Johnson, M., 1980. Metaphors We Live By. Chicago and London: The University of Chicago Press.

Łukasiewicz, J., 1951. Aristotle's Syllogistic from the Standpoint of Modern Formal Logic. Oxford: Clarendon Press.

Lyons, J., 1996. Linguistic Semantics: An Introduction. Cambridge: Cambridge University Press.

Mattessich, R., 1998. FROM ACCOUNTING TO NEGATIVE NUMBERS: A SIGNAL CON TRIBUTION OF MEDIEVAL INDIA TO MATHEMATICS. The Accounting Historians Journal. 25(2), 129–145.

Paradis, C., Willners, C., Jones, S., 2009. Good and bad opposites Using textual and experimental techniques to measure antonym canonicity. The Mental Lexicon. 4(3), 380–429.

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

Raykowski, W., 2015. Conceptual Duality of Mathematical Expressions. ResearchGate.

Raykowski, W., 2013. Conceptualising Experience: What Human Expressions Suggest about Cognition [Doctor of Philosophy Thesis]. Brisbane: Queensland College of Art, Griffith University.

Raykowski, W., 2019. Is There Such a Thing as Orthogonyms? Cognitive Semantics. 5(2), 201–223.

Raykowski, W., 2018. Layers and Levels: What a Column of Water Tells Us About Human Cognition. Cognitive Semantics. 4(1), 104–134.

Raykowski, W., 2022. Sensory Schema: From Sensory Contrasts to Antonyms. Cognitive Semantics. 8(2022), 240–268.

Reddy, M.J., 1979. The conduit metaphor: A case of frame conflict in our language about language. In: Ortony, A. (Ed.). Metaphor and Thought. Cambridge: Cambridge University Press. pp. 284–310.

Rhoades, R., Pflanzer, R., 2003. Human Physiology, 4th ed. Thomson Brooks/Cole.

Sangster, A., 2016. The Genesis of Double Entry Bookkeeping. The Accounting Review. 91(1).

Schwartz, B.L., Krantz, J.H., 2017. Sensation and Perception. SAGE Publications. Available online: https://us.sagepub.com/sites/default/files/upm-assets/128235_book_item_128235.pdf (accessed on 1 January 2024).

Shapiro, S., Kissel, T.K., 2024. Classical Logic. In: Zalta, E.N., Nodelman, U. (Eds.). The Stanford Encyclopedia of Philosophy (Spring 2024 Edition), Available online: https://plato.stanford.edu/archives/-spr2024/entries/logic-classical/ (accessed on 1 January 2024).

Skinner, B.F., 2014. Science and Human Behavior. The B. F. Skinner Foundation. Available online: https://-www.bfskinner.org/newtestsite/wp-content/uploads/-2014/02/ScienceHumanBehavior.pdf (accessed on 1 January 2024).

Wilson, M., 2002. Six views of embodied cognition. Psychonomic Bulletin & Review. 9(4), 625–636.