Beyond Space and Time: An Initial Sketch of Formal Accounts to Non-Spatiotemporal Conceptual Sensory Primitives

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Abstract

Derived from the embodied cognition hypothesis, image schemas are conceptual primitives thought to capture the spatiotemporal relationships underlying human conceptualisations. However, many embodied experiences are not spatiotemporal but rather based on the different sensory modalities. In order to provide a more comprehensive perspective of conceptual primitives, this paper looks at the traditional five senses and sketches an initial perspective of how some conceptual primitives could be systematically approached.

Keywords

Image schemas, Conceptual primitives, Sensory-perception, Conceptual spaces

1. Introduction

Embodied cognition proposes that all human thought stems from the embodied interactions with their environment [1]. This is a powerful position as it offers a concrete grounding of meaning and conceptual spaces to the tangible world. However, the cognitive relationship between the "real world" and the mental representation remains unclear even within this theoretical framework.

Taking a cognitivist approach, in which the mind is thought to function as an abstract information storage and processor, the embodied experiences must be translated into some cognitive components that can be processed and used efficiently. One possible solution to explain the demonstrated efficiency is to assume that these components take the format of generalised semantic "building blocks". Such building blocks are likely rich in embodied grounding while having a broader (or vaguer) application format to adapt to particular situations. Motivations of how conceptual information is represented as smaller compositions are found in a range of scientific disciplines including early and highly influential work such as gestalt principles [2], universal grammar [3] and the transcendental schemata [4]. Frege [5]'s principle of compositionally is also important for conceptual primitives, as it demonstrates how, by combining the sense (or meaning) of smaller components, different meanings can emerge due to the particular composition.

From the perspective of past discoveries in cognitive linguistics [6] and developmental psychology [7], the representation of the embodied experience is thought to take the format of "image schemas." They are commonly defined as cognitive patterns that are semantically rich generalisations of early experiences and perceptions. Importantly, they are proposed to be atomic cognitive gestalts that underlie large parts (if not all) of the conceptualisation of the world. Image-schematic notions such as CONTAINMENT, LINK and SOURCE_PATH_GOAL form relational notions can be found in a range of linguistic expressions as well as abstract representations such as *"getting out of a depression"* and *"life is a journey"*. In this fashion, they also capture the functional and descriptive relationships between agents, objects and environments. For instance, it is possible to be "inside a house" or to "be linked to each other through marriage".

The Eight Image Schema Day (ISD8), 25–28 November 2024, Bozen-Bolzano, Italy
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While there are a different perspectives (likely due to the elusive and hard-to-study nature of the image schemas), definitions are often based on spatiotemporal experiences grounded in the Euclidean experience of space and the linear experience of time and how that information can be mapped onto conceptual structures [8, 9]. However, many sensations and foundations of conceptual spaces are (in a direct sense) neither spatial nor temporal. Human sensory experiences are rich and are founded on a range of sensory experiences which may or may not be spatiotemporal. Think, for instance, of the experience of eating sun-warm strawberries picked directly from the plant. Following the conceptual framework where spatial and temporal descriptors are applied to conceptual structures, one might express the taste experience as being "round" in flavour or that it "lingers." Yet, ultimately, the experience itself is not of a prototypical image-schematic nature. Properties such as taste, size, texture and temperature play a larger role in the experience of the situation and using these more "precise" descriptors would be a more accurate way to capture the semantics of the experience. However, even without a foundation based on spatiotemporality, it is important to note is that other "sensory primitives" are still intended to function on a higher level of abstraction and generalisation, just like the image schemas. In comparison to the systematic work on formally approaching image schemas (e.g. the previous work by the authors [9, 10]), there is (to the author's knowledge) no method to holistically describe the conceptual spaces of the non-spatiotemporal primitives. As a consequence, many conceptual metaphors are based on image-schematic terms and spatiotemporal relationships. Thus, relying on linguistic convention and embodied inference as a means to describe the conceptual experience of the situation.

Traditionally in cognitive linguistics, this has been used to *a posteriori* motivate the role image schemas play in our conceptualisation. By looking at the usage of spatiotemporal metaphors for embodied experiences we can explain increasingly more complex notions and temporal changes [11]. However, it is equally interesting to look at the embodied experiences themselves and see how this translates into conceptual primitives in their own right. The hypothesis is that while image schemas may lay the foundation for (some) conceptualisation, embodied experiences can be sorted into conceptual primitives in their own right - simply perhaps with lesser established conceptual spaces.

Dealing with these non-(obviously-)spatiotemporal conceptual primitives, this paper attempts a preliminary, high-level analysis of some sensory primitives.

2. Multimodal Sensory Experience and Possible Primitives

One of the main pillars of embodied cognition is that cognition stems from embodiment. Simultanously, embodiment is based on multimodal sensory experiences [1]. In consequence, the sensory experiences are what constructs cognitions. Most commonly we speak of five traditional senses, but there are a number of other sensors and embodied inputs that likely play a central role when constructing a conceptual understanding of the world. However, as a preliminary starting point, in this paper, we restrict ourselves to the traditional five senses: *vision*, *taste*, *olfactory*, *hearing* and *touch*.

The experiences from the senses come in a few different forms and structures. Some are heavily influenced by categorisation and different classification formats. Others act as binary experiences. Yet others, are more dependent on the context and the individual objects in the scene/experience.

2.1. Vision

Most human experiences are heavily based on vision. A prototypical human visual experience is a 3D perception of percepts such as shape, colour, size, depth and shades. Out of these, two are particularly important for the identification of objects: *colour* and *shape*.

Colour: Analysing colour as a conceptual primitive is of particular interest when it comes to metaphorical uses. Many expressions rely on colour metaphors to describe certain emotional states. Consider expressions such as *"being green with envy"*, *"having the blues"* or *"seeing in red"*, all using a colour

Figure 1: RGB colour cube

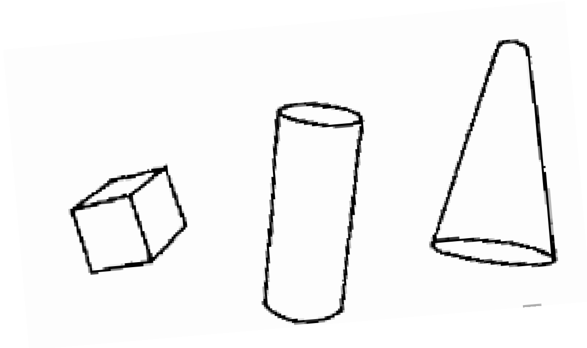

Figure 2: Geon examples.

code to describe an emotional state. Despite being a complicated relationship, there is a documented semantic connection between colours and concepts and [12] even introduces a conceptual inference system based on colour associations. While many conventional colour associations are likely culturally enforced, there is also empirical support that colours results in embodied reactions such as alterations in blood pressure [13] and simulate hunger [14]. These changes in physiological states further support the idea that there is an embodied relationship between colour and semantic annotation.

That colour plays a central role in how we identify objects is clear. We regularly identify objects based on iconic colours; consider, for instance, bananas, stop signs and marble. It is less clear how it would be possible to formally define and represent a conceptual primitive based on colours. Using the primary colours would be too reductionistic and simultaneously neither detailed nor specific enough to capture the impact of colour. Instead, possible perceptual description ranges from everything to numerical descriptions as found in web colours - a hex triple representing the primary colours, and regional representations such as that seen in conceptual spaces [15]. One could imagine a conceptual space of colours designed based on a 3D matrix based on the RGB colour cube, see Figure 1.

Shape: Not only are prototypical bananas associated with the colour yellow, they are also famous for their elongated bent shape. For shape and spatial descriptors, many metaphorical and abstract uses exist. Consider expressions like *"getting square with someone"* or *"why the long face?"*, both relying on shape descriptors. Shapes are also interesting with respect to how they influence our conceptualisation and emotional reaction to the object itself [16]. As many artists or architects might tell you, the shape of an artefact influences our perception of the object and its interpretation.

One highly influential theory for how shapes can be treated as compositional primitives is the theory Recognition by Parts [17]. This is partially supported by seminal neurological research that shows that certain cortical columns react to particular shapes and lines with distinct orientations [18]. Recognition by parts proposes that all objects can be decomposed into a limited set of basic geometric shapes called *geons*, see Figure 2. These shapes are things like spheres, cubes and pyramids that in different combinations and constellations form increasingly complex constructions.

Geons are strongly connected to the notion of spatiotemporality in that they are so spatial. However, the interesting thing about them is not how they occupy space in isolation, but rather how they combine to form larger contexts.

2.2. Taste and Texture

Taste and the experience of food are likely the hardest sense to discuss with respect to reasonably formulated conceptual primitives. This goes against the importance of it from an embodied perspective, as the experience of food is both highly embodied and important for meaning attribution in daily life.

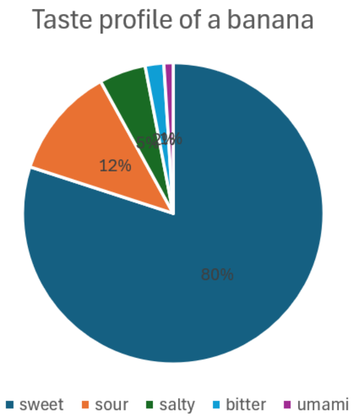

Figure 3: Taste profile example

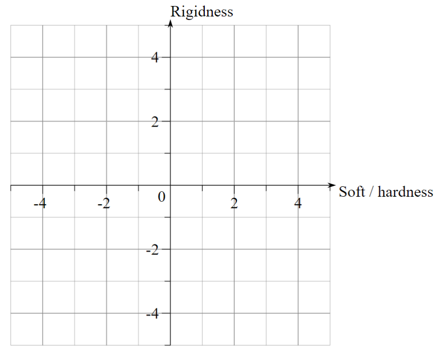

Figure 4: Texture graph example.

Taste: Taking a direct approach to conceptualising taste, we have five main proposed flavours: *salt*, *sweet*, *sour*, *bitter* and *umami*[1], that (roughly) correspond to particular nutritional macros or, as in the case with bitterness, potential danger.

While we experientially think of an apple as having "apple taste" and mulled wine as one of the metaphoric flavour of "Christmas", there is no particular taste receptor that corresponds to things like apples or Christmas. Instead, all different tastes are a unique combination of chemicals that to different degrees activate the sensation of the main five tastes. For instance, (guessing entirely) the flavour of banana might be a combination of 80% sweet, 12% sour, and the remaining 8 spread on salty, bitter and umami. In comparison, the flavour of a steak might be 95 per cent umami and 4 per cent salty. The perception of the taste is then reinforced with the identification of what the other senses (primarily vision and smell) are telling you you are eating.

Therefore, it is possible to base the taste primitive on a conceptual space consisting of a vector with 5 dimensions for taste where each dimension corresponds to a value of one of the main flavours, see possible representation format in as a pie chart in Figure 3. It is also possible that the strength of the flavour plays a large role, which could be interpreted as a higher dimension of the chart.

Texture: While texture is perhaps not a flavour in itself, it plays a central role in the experience of taste. Interestingly enough from a conceptual direction, there is a correlation between crunchy and sharp flavours such as sparkling water and Maltesers with hard-sounding letters and words (e.g. kiki) and with softer flavour/texture sensations like water and brie cheese with soft wounding words (e.g. bouba) [20]. This is an example of "sound symbolism" which will be mentioned in more detail in the next section. However, the interesting takeaway concerning culinary texture is that the physical sensation has a direct relationship with the conceptualisation. There might not be a clear-cut distinction between textures but it is reasonable to assume that different properties should exist on different axis, see possible representation format in Figure 4.

2.3. Olfactory

Our sense of smell is likely the hardest sense for humans to understand and finding reasonable conceptual primitives is a challenge. In some ways, smell is an experience that accompanies, or enhances, taste. Consider how bland food tastes when you have a cold. In fact, some researchers propose that up to 95 per cent of what you taste, is based on smell [21]. This is great news for the perfume industry but complicates things from a formal and conceptual perspective.

Physically speaking, humans are estimated to have some 400 different odorant receptors [22]. This corresponds to the ability to identify an estimate of up to 1 trillion (!) different odours [23]. This provides

[1] There is also a growing hypothesis that fat corresponds to yet another flavour but it has yet to be empirically ascertained [19].

a remarkably diverse and rich experience compared to taste (especially considering the overall human preference for eating over smelling). It would be unfeasible to introduce 400 conceptual primitives for smell, and any methodology for designing primitives that can capture up to 1 trillion different odours will undoubtedly fail.

Due to the complexity and vastness of smells, any conceptual approach to model a primitive perspective on the sense of smell requires a rather complex representation format. Therefore, an ontological approach is likely the most suitable for grouping the smells into categories. Here the distinctions can be based on shared perceptual experiences where categories and subclasses of smells can be constructed based on shared features. For instance, on a high-level one could distinguish between "good/bad" smells and divide them into subcategories like "floral" and "fruity" that each could contain the individual smells that prototypically fit within that smell-character. Likely, most smells would fit into more than one category, constructing a complex network and knowledge graph of primitives and their members. Some work has been done to introduce such ontologies for odours based on different perspectives. [24] looks at categories based on perceptual categories, and [25] introduced an ontology for smells. However, with some 1 trillion smells to be identified any categorical division needs serious consideration. From the perspective of conceptual primitives, only the upper categories would likely be of any interest.

It is tempting to disregard the olfactory sense when modelling a framework for embodied conceptual primitives due to its immense complexity. However, our sense of smell is conceptually important in that it is highly associated with categorisation through activation of nostalgia and memory retrieval [26], situational comprehension (consider the smell of smoke and what conclusions one can draw from that) and even (implicit and explicit) decision making[2].

2.4. Hearing

Similarly to smells, sound is something that entirely surrounds us. Meaning that while we can hear (and smell) where particular sounds come from, we experience sound from a more regional spatial perspective. It is also experienced as a scale that changes over time, and there are a lot of spatial requirements to how we hear things. Consider an echo, how sound is distributed in a concert hall and the time it takes for thunder to accompany the lightning. Excluding loudness (which can be thought of as a magnitude scale much like with the intensity of tastes), in an instant, sound waves are exclusively experienced as tones with pitch.

One interesting conceptual phenomenon associated with sound is the theory referred to as "sound symbolism." Sound symbolism proposes that there is a systematic relationship between the way a word sounds and its meaning. As mentioned with taste and textures, certain experiences are highly connected to particular sounds and this is inferred to other domains as well. Consider the sound of glass shattering and the associated feelings we have when hearing the sound even when there is no glass around.

Unfortunately, sound symbolism is generally disregarded as scientifically solid. Despite that, there is research shows some correlations between the perception of sound and the assigned meaning (e.g [27, 28]). It is simply likely that this relationship is not bidirectional but emerged as a feature of how language developed from embodied associations. Regardless, the interesting thing about it is that the phenomenon does support the idea of embodied primitives from a much richer perspective than previously established.

Sound primitives are likely to be structured as olfactory primitives: as ontological categories. Many of the taxonomies of sounds focus on human categories (e.g. [29]). However, for any approach looking at embodied conceptual primitives, the core features are likely better related to the physical principles of sound waves stemming from the prototypical features of objects and the sound they produce/reflect.

2.5. Touch

The final sense is the most embodied in that it is the sensation of physical touch. Thus, it feels rather intuitive to think of touch as rather spatial as an experiential component. After all, the body occupies a

[2]Consider the epic quote from Lord of the Rings, where Gandalf tells Merry: *"When in doubt, always follow your nose."*

spatial region and the skin is a form of a curved and connected plane. However, with the exception of "where" the touch is felt, there is rather little about touch that is directly spatial. Looking at the sensory receptors on human skin, there are only four main sensations that can be experienced: *pressure*, *hot*, *cold*, and *pain*. Pressure has multiple types of sensory receptors but overall is it simply a matter of the sensation of force on the skin, so here we treat it as one primitive category.

Temperature: The importance of temperature as an experiential conceptual primitive exceeds the sensation of touch as temperature is something that extends outside of our bodies and "surrounds us" and is associated with the objects themselves (e.g. tea, snow man and sunshine). In a simple form, temperature can be represented as a binary relationship[3]: either hot or cold, alternatively as the relational: hotter or colder. In many conceptual situations, temperature does not need to be better specified. However, from the physical perspective, temperature can also be considered a scale, as in how we measure temperature with a thermometer. The temperature itself is only so interesting as the experience of temperature also depends on other factors (that we may or may not be able to detect) such as humidity, air pressure, wind and shade.

Pain: While perhaps being the most important sense from an evolutionary perspective, pain is actually rather simple as a conceptual primitive[4]. Pain acts as a scale from "a little bit of pain to increasing amounts of pain." Other than asking people to self-assess the level of pain, there is really no means to measure it. It is an entirely internal experience. Interestingly enough, there is no such thing as a receptor for pleasure.

Pressure: From the perspective of assigning conceptual primitives, pressure is the most interesting component under touch. This is because of the strong correlation of pressure with forces.

Taking this perspective, touch primarily appears to be a type of force schema. It is the sensation that allows us to feel pushed in a direction or the sensation that we experience as we push (or bump) into something. Developmental psychologist Mandler calls this primitive UMPH [30]. In recent work [10], we separated the UMPH primitive into two variants: *a*-UMPH (active) and *p*-UMPH (passive), to distinguish between the situations in which the self is actively causing the sensation of pressure to the body from the sensation in which an external force is pressured onto the physical body.

3. Compositionality of Conceptual Primitives

Designing a systematic overview of conceptual primitives is interesting in its own right. However, the greatest benefit lies in the possibilities of what happens when conceptual primitives are combined to represent a bigger picture.

Argued to be one of the most influential ideas in linguistics, Frege's principle of compositionality [5] proposes that the meaning of a proposition is a combination of the meaning of the parts and how they are combined. For theorists working on image schemas as the conceptual foundation for events and conceptualisations, the notion of "image schema profiles" is familiar [8]. These are groupings of image schematic relationships that take part in the conceptualisation of a particular scenario or concept. Consider for instance a situation like *"going to the beach"*. It has a range of image-schematic components: *"going to"* is a member of the SOURCE_PATH_GOAL family [31], the beach is associated with concepts like "swimming" which can be thought of as BEING_CONTAINED in water, etc. These image schema profiles have further been subdivided based on the type of combinatorial process that is involved [32] and investigated to describe the conceptualisation behind events through conceptual segmentation [33, 10].

[3]With a possible additional neural state, that is only ever experienced when queried. Consider lukewarm water/air - it cannot be felt unless you realise it is there.
[4]Completely disregarding the whole range of emotional pain here.

While such profiles capture highly semantically relevant components of these conceptualisations they are far from complete. A situation such as *"going to the beach"* is also conceptualised based on the conceptual primitives that are not necessarily spatiotemporal, but rather sensory-embodied: e.g. the temperature of the sun, the sensation of sand between your toes, the sweetness of ice cream, and the perceptive experience of objects like beach balls, parasols and bathing suits, and emotional components like 'having fun' or the stinging pain from sunburns.

A truly representative conceptual space for the conceptualisations of something like *"going to the beach"* is required to take a much more holistic perspective into account for it to make the concept justice. It is only in this complete combination of conceptual primitives that we can learn to understand that the unique compositions actually tell us about the concepts themselves.

4. Discussion and Future Work

Established conceptual primitives such as the spatiotemporal relationships of the image schemas are inherently embodied, yet little work has been done to establish the sensor-perceptive primitives from a multimodal perspective.

In this short paper, a few possible directions for how to identify and approach conceptual primitives from the (traditional) five senses have been introduced. While this study does not attempt to solve any of these issues, nor introduce a complete set of primitives, it is intended as a perspective piece that may spark inspiration on how such non-spatiotemporal conceptual sensory primitives could be defined, formalised and utilised in a larger setting.

Being one of the prominent promoters for image-schematic research to lay the foundation for conceptual structures, it feels important to point out that this is not intended to replace image-schematic-like conceptualisations formats but rather to enrich them with more conceptual primitives.

Passionate about this idea space, future work includes taking a closer look at what different types of primitive candidates such as those presented in this paper could look like formally and empirically. The main goal is to approach an ontologically structured formal theory for conceptual primitives that more holistically can describe the mental components involved in the realisation of thought and the conceptualisation of experience.

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