Independent Studies

On The Boundary Between Perception and Cognition

Draco(Yunlong) Xu
Department of Computer Science
Department of Mathematics
University of Rochester
yxu103@u.rochester

Advisor
Alison Peterman
Department of Philosophy
Department of Brain and Cognitive Science
University of Rochester

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1. Introduction

The distinction between perception and cognition is widely regarded as an a priori or common-sense notion across diverse disciplines, including philosophy, psychology, and cognitive neuroscience. Despite the widespread acceptance of this distinction and the assumption of a boundary between the two processes, as noted by Beck, relatively few studies have endeavored to explicitly define this boundary. Addressing this issue carries significant implications for two reasons:

(1) If we fail to identify a clear boundary or establish that no such boundary exists, we may need to reevaluate the foundational assumptions of numerous theories in philosophy, psychology, and cognitive neuroscience that depend on the inherent separation of perception and cognition.

(2) If a well-defined boundary does exist, it becomes essential for deepening our understanding of perception and cognition, thereby allowing us to more effectively examine their functions and interconnections.

In this paper, I will tackle the problem of defining the boundary between perception and cognition, building upon and extending Beck's work. To address this issue, Beck proposes the stimulus-dependence criterion, which posits that perceptual processes are directly and immediately influenced by sensory input, while cognitive processes primarily operate on stored information or mental representations, without direct influence from sensory input. However, two critical questions remain unresolved.

The first pertains to the definition of a stimulus: What constitutes a stimulus? For example, when observing a red apple, is the stimulus the electromagnetic waves, the apple itself, the color red, or the electrical signals produced when simulating neural responses in early cortex areas and directly transmitting them to the visual cortex? The second question revolves around the nature of dependence in this context: Are we discussing physical dependence, causal dependence, or another form of dependence?

Clarifying these two concepts is vital for a comprehensive understanding of the boundary in question. Consequently, this paper will begin with an overview of Beck's stimulus-dependence criterion, followed by an exploration of the definition of a stimulus and an examination of the concept of dependence.

2. The Criterion of Stimulus-Dependence

In the article ”Marking the Perception-Cognition Boundary: The Criterion of Stimulus-Dependence” by Jacob Beck [1], the author delves into the crucial distinction between perceptual and cognitive processes within the philosophy of mind and cognitive science. Beck proposes the criterion of stimulus-dependence as a tool to differentiate these two mental processes more effectively.

Beck critically evaluates previous attempts to demarcate perception from cognition, such as the cognitive penetration debate, and argues that these attempts have fallen short in providing clear criteria for distinguishing between the two processes. To address this issue, Beck introduces the stimulus-dependence criterion. This criterion posits that perceptual processes are directly and immediately influenced by sensory input, whereas cognitive processes primarily operate on stored information or mental representations without direct influence from sensory input.

Moreover, Beck confronts potential objections to the stimulus-dependence criterion, including the possibility of cognitive processes being influenced by sensory input or perceptual processes being influenced by stored information. In response to these concerns, he elucidates that the criterion emphasizes the primary differences in the way perception and cognition operate on information, rather than positing an absolute separation between the two processes.

Specifically, Beck proposes a promising idea that emphasizes the importance of current proximal stimulation in accurate perception. When you close your eyes, you don’t see objects but still have accurate beliefs and memories about them. Beck suggests defining a mental state as stimulus-dependent if it relies on proximal stimulation. Using this idea, Beck presents a simplified (though not perfect) formula for distinguishing perception and cognition:

S-D SIMPLE: A mental state α is perceptual if, necessarily, all veridical occurrences of α are stimulus-dependent (rely on proximal stimulation) ; otherwise, it is cognitive.

Here, α ranges over perceptual and cognitive state (event, process, etc.) types. Beck’s formula accounts for the fact that whole objects can be perceived through a medium and allows for perceptual states to have a time lag between distal and proximal stimuli. It also permits cognitive states to be influenced by proximal stimulation, but not necessarily dependent on it. For example, an electromagnetic helmet might cause a specific belief, but that belief could also exist without the helmet. In contrast, for accurate visual perception, Beck's formula requires proximal stimulation in all possible scenarios.

However, it could be hard to distinguish the demonstrative thoughts with the perception, especially for perceptually grounded demonstrative thoughts (PGDTs) which do plausibly have the function of being stimulus-dependent. Beck pointed out that whereas veridical perceptions are fully stimulus-dependent, veridical PGDTs are only partially stimulus-dependent. They both rely on a causal link to a distal stimulus through proximal stimulation. However, they differ in the stimulus-dependence of their attributive elements. Perceptual attributives are constrained by proximal stimulation, while conceptual attributives in PGDTs are not.

Beck offers two reasons to support the claim that conceptual attributives in PGDTs are not perceptually grounded. Firstly, conceptual attributives are not constrained by proximal stimulation in the same way as perceptual attributives. The example of a spotted sandpiper flying away illustrates that one can still attribute spottedness in a PGDT even when the spots are no longer perceptually discernible. Secondly, conceptual attributives in PGDTs are not limited to representing perceptible attributes; they are only limited by one's conceptual repertoire. Therefore, Beck proposes a revised version of the definition of perception:

S-D FULL: α is perceptual if, necessarily, all occurrences of all elements of α have the function of being stimulus-dependent; otherwise, α is cognitive.

Beck further addresses a concern regarding the stimulus-dependence of perceptual attributives for three-dimensional properties. He clarifies that stimulus-dependence requires an attributive to be causally sustained by some proximal stimulation, without any further requirement for a direct correspondence between the proximal stimulation and the attributive's content. This means that perceptual attributives can still indicate three-dimensional properties, as long as they have the function of being sustained by some proximal stimulation. In contrast, conceptual attributives do not have this function.

Anders Nes, Kristoffer Sundberg, and Sebastian Watzl [11] present two challenges to the criterion of stimulus-dependence: hallucinations and world-related cognition. The first challenge involves classifying hallucinations as either perceptual or cognitive mental states. The authors propose that although hallucinatory experiences are not stimulus-dependent, they may still result from a mechanism that generally functions as stimulus-dependent for perception. In successful cases, the mechanism operates as intended, while in cases of hallucination, it malfunctions. The viability of this response hinges on the plausibility of individuating mechanisms based on these functions.

The second challenge questions whether the world-relation is exclusive to perception. If certain cognitive states exhibit stimulus-dependence in the same manner as perception, then the world-relation is insufficient for classifying a state as perceptual. The authors concede that some cognitive states, such as perceptually grounded demonstrative thoughts, can be stimulus-dependent. However, they posit a difference between perception and demonstrative thoughts: in perception, the function to be stimulus-dependent applies to both the demonstrative and attributive elements, while in demonstrative thought, it applies only to the demonstrative component. Another example worth considering is whether the perceptual decisions that subjects make in cognitive science experiments constitute cognitive states.

An additional challenge that I would like to propose concerns the boundary of the stimulus. Neurons in our brains send and receive both chemical and electrical stimuli. This raises the question of how the stimulus should be defined, given that the distinction between perceptual and cognitive processes hinges on the nature of the stimulus. The definitions of stimulus and response used by psychologists were often too narrow, leading to inconsistencies and confusion [16]. For example, some researchers defined stimuli as physical events, while others included mental events like thoughts or emotions. However, there are researchers who pointed out that these inconsistencies made it difficult to establish a comprehensive understanding of behavior. Here, it is difficult for us to establish a comprehensive understanding of perception. A clear definition of the stimulus is necessary to maintain the integrity of the stimulus-dependence criterion, and this is an area where further research is needed. A key problem here is the role that context or the environment takes in defining the stimulus. As we mentioned before, if there is no red apple physically present, but a subject receives a simulated signal as if there is one, are we going to count it as a proximal stimulation of a red apple? Notice here that it is different from the illusory/hallucinatory experience, as it is usually defined as follows [15, 4]:

(A) In an illusory/hallucinatory experience, a subject is not directly presented with an ordinary object.
(B) The same account of experience must apply to veridical experiences as applies to illusory/hallucinatory experiences.
(C) Subjects are never directly presented with ordinary objects.

The reason is that, as ordinary objects are defined as ordinary mind-independent objects [4], here the neural stimulation is actually an object that is mind-independent. If you regard the signal itself as the object, then it is definitely directly presented. Therefore, it breaks the (A) and (C). If not, then what is the ultimate object, and what role does the signal serve? We will discuss this further in Section 3.

Beck argues that perception is causally sustained by present proximal stimulation. Consequently, when discussing dependence, he refers to causation and causal dependence. However, the role of causal notions remains unclear. There has been extensive discussion about causation in mental content [5, 17, 14] and in physics [7, 8, 9]. It is important to note that proximal stimulation is a physical stimulation, while α belongs to mental content as it ranges over perceptual and cognitive states. Thus, we need to further elaborate on causation and dependence. This is crucial not only because causation links physical and mental objects but also because the scope of causation plays a significant role in this context and could lead to confusion if not clarified.

Consider an example: A red apple is in front of you, and you are perceptually experiencing seeing a red apple. However, you cannot see it clearly because your visual acuity is poor, resulting from spending excessive time playing video games. Is the unclear perception of the red apple causally related to your previous experience of viewing video games on a screen? For another example, more formally, in psychophysics, there is a crucial fact that subjects accumulate stimulus input for perception and cognition. A subject cannot perceive dot motion if it is presented for a brief duration, such as 1 ms. However, a subject can perceive dot motion if it is presented for 1000 ms [2]. Then, at the exact point of the 1000th ms, is the perception causally related to the dot motion presented in the first ms?

It is essential to recognize the importance of defining what "present" means and what "previous" means. Since Beck argues that perception is causally sustained by present proximal stimulation, is there a minimal graininess to define presentness? What is the temporal range that can be defined as present? These questions will be key points to address in Section 4.

3. Stimulus

B. F. Skinner is among the first ones who research the definition of stimulus. In "The Generic Nature of the Concepts of Stimulus and Response," B. F. Skinner addresses the ambiguity and inconsistency in the definitions of stimulus and response as used by psychologists of his time [16]. He argues that a more precise and generic understanding of these concepts is necessary for the scientific study of behavior.

Critique of existing definitions: Skinner notes that psychologists' definitions of stimulus and response were often too narrow, leading to inconsistencies and confusion. For instance, some researchers defined stimuli as physical events, while others included mental events like thoughts or emotions. Skinner argues that these inconsistencies made it difficult to establish a comprehensive understanding of behavior.

Proposal of generic definitions: To address these issues, Skinner proposes more generic definitions for stimulus and response. He defines a stimulus as any event that changes the probability of a response and a response as any change in an organism's behavior resulting from a stimulus. By adopting these definitions, Skinner lays the groundwork for a more unified and coherent approach to studying behavior.

Temporal contiguity: Skinner emphasizes the importance of temporal contiguity (the closeness in time between a stimulus and a response) in understanding the relationship between stimuli and responses. He explains that when a stimulus consistently precedes a response, the organism is more likely to associate the two events and modify its behavior accordingly. This concept is central to Skinner's later work on operant conditioning.

Functional relations: Skinner highlights the significance of functional relations between stimuli and responses, referring to the way one event influences another. He notes that it's not enough to identify a stimulus and a response; researchers must also examine how these events are functionally related to understand the underlying principles of behavior.

Organism-environment interaction: Throughout the paper, Skinner emphasizes the need to consider the organism's interaction with its environment when studying behavior. He argues that focusing solely on stimuli and responses in isolation misses the broader context in which behavior occurs.

A stimulus is any event or situation that evokes a reaction or response from an organism. In this context, stimuli can be external, such as light, sound, or touch, or internal, such as thoughts, emotions, or physiological changes. Stimuli can be simple or complex, and they can produce a wide range of reactions in organisms.

A response, on the other hand, is the reaction or behavior exhibited by an organism in response to a stimulus. This can include actions, emotions, or physiological changes. Responses can be innate (e.g., reflexes) or learned through experience and conditioning.

The relationship between stimulus and response is fundamental to the study of behavior, as it offers insights into how organisms adapt to their environment and learn from their experiences. One of the most famous examples of this relationship is classical conditioning, as demonstrated by Ivan Pavlov's experiments with dogs [12]. Pavlov showed that when a neutral stimulus (e.g., a bell) is consistently paired with an unconditioned stimulus (e.g., food), the neutral stimulus eventually elicits a conditioned response (e.g., salivation) in the organism. In this section, we can discuss the definition of stimulus in a similar way, focusing on organism-environment interaction, functional relations, and temporal contiguity, with an emphasis on the first one.

3.1. Organism-Environment Interaction

J.J. Gibson challenges [6] the traditional view of stimuli in psychology and presents a new way of understanding how we perceive our environment.

Traditionally, psychologists have treated stimuli as simple, isolated events that trigger specific responses in organisms. This idea is based on the assumption that the relationship between a stimulus and a response is straightforward and direct. However, Gibson argues that this perspective is overly simplistic and fails to account for the complexity of our interactions with the world.

Gibson proposes a new concept called "affordances." Affordances are the potential actions or opportunities that an object or environment provides to an organism. For example, a chair affords sitting, a door affords opening, and a surface affords walking. These affordances are not just properties of the objects themselves, but also depend on the abilities and needs of the organism perceiving them.

Rather than focusing on isolated stimuli, Gibson emphasizes the importance of understanding the organism's relationship with its environment. He argues that we should study perception in terms of how organisms actively engage with their surroundings and pick up information about affordances.

Gibson's work challenges the idea that perception is a passive process where the mind simply receives and processes sensory input. Instead, he suggests that perception is an active, ongoing process in which organisms actively seek out and interpret relevant information in their environment. Gibson's paper argues against the traditional view of stimuli in psychology, suggesting that we should focus on understanding how organisms perceive and interact with their environment through the concept of affordances. This perspective emphasizes the active role of perception and the importance of the relationship between organisms and their surroundings.

Distal stimuli and Proximal Stimuli. From J.J. Gibson's perspective, examining the relationship between the environment and the perceiver is crucial for defining a stimulus. Gibson's work predates the modern psychophysics paradigm, which distinguishes between distal and proximal stimuli. While the affordances of proximal stimuli, such as the retina's ability to perceive electromagnetic radiation, are more readily understood, focusing on the visual consequences of electromagnetic radiation may overlook other potential perceptual effects. For instance, when electromagnetic radiation reaches our skin, it can trigger sensations like heat or cold. The perceptual effects of retina-electromagnetic radiation and skin-electromagnetic radiation differ in their associated distal stimuli: perceived color or brightness for retina-electromagnetic radiation, and thermal sensations for skin-electromagnetic radiation. This raises the question of whether the dominant definition of a stimulus could be more accurately characterized as distal stimuli, with distal stimuli as the ideal stimuli and proximal stimuli as their realization, potentially allowing for multi-realization.

To explore this question, we consider two examples: brain-computer interfaces (BCI) and color blindness. In the first example, a healthy subject's retina receives long-wave light with a wavelength of exactly 700 nm, resulting in the perception of the red color. Alternatively, the subject's V1 receives a direct stimulus, producing a subjective feeling of seeing red light. Although the distal stimuli are identical in both cases, the proximal stimuli differ significantly. In the BCI experiment, the V1 and all other involved areas' activity patterns should resemble those responding to real red light from the retina. If we regard V1 as the receiver, should the distal stimuli it receives from the retina or the BCI machine be the same? Please note that the BCI experiment discussed here is currently impractical. However, there is no theoretical barrier preventing us from realizing it in the near future, thanks to advancements in fields such as physics, materials science, neuroscience, bioengineering, and machine learning.

Addressing this question requires acknowledging that current BCI research cannot recreate the red-light experience experiment as described. Visual neural prostheses generate visual perception by directly stimulating the visual pathway using a camera to capture images, which are then converted into specific signals to stimulate the visual system. These stimulations create simple visual perceptions called phosphenes, used to construct more complex visual scenes. The stimulation site is chosen based on an individual's blindness pathology and aims to bypass damaged areas in the visual pathway. Current approaches target the retina, optic nerve, lateral geniculate nucleus, optic radiations, and visual cortices. Consequently, we do not know whether the distal stimuli must be the same. However, given the trial-to-trial variability in neural response, there should be at least some room for difference, although the extent remains unknown. If the distal stimuli must be the same, then there is no multi-realization in this sense.

In the case of color blindness, the distal stimuli of electromagnetic radiation remain the same; however, the proximal stimuli are altered due to differences in the photoreceptor cells in the retina. This example highlights the complex relationship between distal and proximal stimuli and the importance of considering the environmental and physiological factors that influence perception.

BCI stimulation is stimulus. Now, we address the question of whether Brain-Computer Interface (BCI) stimulation should be considered a stimulus, given that it is not directly from a present object. We argue that it should be counted as a stimulus because the subject cannot distinguish the signal from their perceptual experience. To illustrate this point, we consider the well-known thought experiment of the brain in a vat (BIV) [10]. If one were a BIV, their conscious experiences would be qualitatively indistinguishable from the experiences they have had throughout their mental life. However, if their computer-generated experiences led them to believe they had a body, they would be mistaken. In this case, all environmental information is contained within the signal.

One objection to this view is that an objective and physical variable, such as an apple, exists behind the light from a red apple, while no such variable exists behind the simulation. We counter this objection by first questioning why the apple cannot serve as the objective variable behind the simulation of the apple. When referring to the variable behind the light, we are discussing the distal stimulus. There is no requirement for the apple to be a natural item in this context. The concept of the apple stored as computer digits is no different from the apple we eat.

Secondly, we argue that the distal stimulus does not have to be, nor directly related to, physical items. For example, most people accept ”red” as a distal stimulus, even though it is not physical.

We recognize Putnam’s influential argument against the BIV hypothesis [18], which asserts that if the hypothesis were true, one could not meaningfully claim to be a BIV due to semantic externalism. This principle posits that the meaning of words and concepts is partially determined by factors external to the individual, linking our thoughts to the external world and shaping their meaning. For a BIV, their experiences and the words they use to describe them would lack any causal connection to the real world, resulting in a language distinct from that of a non-BIV individual. If the BIV hypothesis were true, a skeptic’s claim of ”I am a BIV” would be self-refuting. This is because if the skeptic were a BIV, their use of the term ”BIV” would not reference an actual brain in a vat, but rather a simulated concept within the computer program. As a result, the skeptic would be incapable of genuinely asserting that they are a BIV. This argument ultimately undermines the foundations of global skepticism and strengthens the notion that our experiences are connected to the external world.

Although we do not provide a direct counterargument to Putnam’s position, we contend that his argument would only pose a problem for counting BCI stimulation as a stimulus in the context of organism-environment interaction if there were no causal relationship with the world. If a BCI device were created for blind individuals, their interactions with the external world would be based on simulation input from the device, providing a causal relationship. Furthermore, even if the agent were manipulating the simulated world and not the external one, there would still be a causal connection to the external world as long as the simulation had an external stimulator.

Thus far, we have established that stimulation should be considered a stimulus, even from the perspective of organism-environment interaction, due to the broader scope of the environment under consideration. However, this raises questions about the limits of this scope. Are there any constraints we should impose? We will address this topic in the following paragraph.

3.2. Temporal Contiguity

In this section of our philosophy paper, let's begin by considering an example. Suppose there is a neuron in your brain that, once triggered by an external stimulus, continues to fire for 10 days. This neuron serves as a trigger for your perceptual experience. Is the initial external stimulus truly the stimulus for your perception on the 10th day? If someone argues that the neuron should be considered a receiver rather than a stimulator, let's consider a stronger example.

We know that the processing of light by the retina and brain forms the basis for visual perception. Photons are captured and converted into electrical signals by rod and cone photoreceptor cells in the retina. Now, imagine a drug that could delay or slow the processing of some photons, causing signal conversion to take 10 days. It seems that perception on the 10th day would depend on the stimulus the agent received 10 days earlier.

Beck contends that perception is causally sustained by present proximal stimulation. But what does ”present” mean in this context? In our example, the proximal stimulation is not there when the perception occurs. It is important to note that this example differs from viewing a star that is 10 light-years away. When watching a star, there is no temporal gap between the light it emits (which Beck defines as proximal stimulus) and the perception. However, in our case, such a gap exists.

From another perspective, is there a minimum resolution for time? If not, how can we correspond two events as ”present”? Therefore, instead of point-to-point temporal correspondence, there must be another suitable method to define the present in this context. We propose two possible alternatives: functional relations and temporal range.

First, let's discuss functional relations. The functional relationship between an external stimulus and perceptual experience might provide a more comprehensive understanding of the present. By focusing on the causal chain and the underlying mechanisms of perception, we could better explain how certain stimuli can still be considered relevant even when temporal gaps are present.

As for temporal range, which we will address in greater detail in section 4.2, it suggests that the present could be redefined as a range of time rather than an exact point. This would accommodate cases where perceptual experiences are delayed or prolonged due to various factors, such as the example of the drug affecting signal conversion. By taking into account a temporal range, we can better understand the complex nature of perception and its relationship with external stimuli.

3.3. Functional Relations

we aim to emphasize the importance of functional relationships rather than temporal correspondence when defining the 'present' of a stimulus. Let's suppose we have a stimulus s and a reaction r. We argue that $r = f(s)$, where f is the causal function from s to r, could be an effective approach for defining the present stimulus. To understand this, let us revisit the point-to-point temporal correspondence model.

Even if we accept that there exists a smallest unit for time, what we are doing in this model is setting $t_1 = T(s)$ and $t_2 = T(r)$, where T denotes the time of an event. If $t_1 = t_2$, then s is considered the stimulus for r. In this model, the only driving variable is time t, and the relationship between s and r lacks direction. This approach allows any other event occurring at the same time t to be indistinguishable from the stimulus-reaction relationship we are interested in.

By focusing on the functional relationship between s and r, we can establish a more meaningful connection between the stimulus and the reaction, as it reflects the underlying causal mechanism. This approach not only overcomes the limitations of the temporal correspondence model but also provides a better understanding of the stimulus-reaction dynamics in various perceptual scenarios. Actually if we look back to S-D FULL

S-D FULL: α is perceptual if, necessarily, all occurrences of all elements of α have the function of being stimulus-dependent; otherwise, α is cognitive.

We would like to further emphasize that there is no temporal proximity requirement for a stimulus. This clarification does not change the original meaning of Beck's argument. However, a potential issue may arise, as most events are causally related. For instance, the experience of viewing red lights might be causally related to a strong light stimulus that caused damage to your retina when you were a child. Alternatively, it could be related to a time when you ate a watermelon, and the weights of certain visual neurons may have been altered by the chemical components of the watermelon. One might ask, would this make the definition of a stimulus too broad?

The answer is indeed yes. For any occurrence x of any item of any α, adopting a broad definition makes it easy to claim that x has a stimulus-dependent function. This is because, if we consider any input with a functional causal relationship as a stimulus, then early-stage inputs (inputs experienced during infancy) will have a causal relationship with any x. These early-stage inputs significantly impact neural development during critical periods [3]. Consequently, all mental states would be considered perceptual, which is an incorrect conclusion. Thus, although there is no problem with the definition of a stimulus itself being functionally related, a more precise definition of dependence is necessary to define perception. To address this issue, we will rely on the dependence relationship and add a further constraint to it.

4. Dependence

The concept of dependence in this context is closely related to the problem of mental causation, as it represents an inverse problem. Therefore, it might be useful to examine mental causation first, using insights from it to gain a deeper understanding of how the external world affects the mental realm. Mental causation refers to the mind's ability to causally interact with the world and influence behavior, which is essential for our self-perception as agents. Descartes' mind-body problem continues to be a central topic in modern discussions of mental causation. He proposed that minds and bodies are distinct substances, with minds being unextended, thinking entities and bodies being spatially extended and incapable of thought. Despite these differences, Descartes believed in the causal interaction between the two. However, the challenge lies in explaining how such radically different substances can interact, a problem that remains relevant to this day.

Ontology explores the idea that to exist is to have causal powers, suggesting that the mental realm can affect the physical world. Metaphysics positions mental causation as central to the mind-body problem, examining how the two could possibly influence one another. Moral psychology emphasizes that agency, which is necessary for free will and moral responsibility, requires mental causation. Lastly, action theory posits that psychological explanation depends on the possibility of mental causation, as the mind's states, like beliefs and desires, should have a causal connection to bodily behavior [13].

While many psychologists accept the causal interaction between the mind and body, a growing number of researchers argue for epiphenomenalism. This theory states that mental occurrences result from physical events but do not exert any causal influence in return. Some empirical evidence supports this view, although the efficacy of mental states remains a complex issue that encounters both philosophical and empirical obstacles [19]. In the summer, I plan to conduct a comprehensive review of the problem of mental causation and to address how we could inverse the problem to obtain the starting point of dependence in this context. *However, since I haven't yet read enough on the subject and lack the time to explore it in depth at the moment, I plan to revisit this later.*

4.1. Causal and Physical Dependence

Causal dependence is a straightforward concept, and it serves as an appropriate candidate for the "dependence" aspect in our earlier definition of perception. However, as we noted, we must add constraints to the dependence relationship. Our plan is to incorporate the concept of physical dependence. Unlike causal dependence, physical dependence is not a well-defined term; it is most often associated with addiction. Nonetheless, the general idea is that dependence relationships should take into account that they are realized by our physical bodies, which have limitations. The following section will delve into a detailed discussion of capacity constraints. These capacity constraints help narrow the scope of dependence traces, thereby avoiding the issue we encountered in the previous section, where any occurrence appeared to be stimulus-dependent. *Further elaboration and examples will be added to this section later in the summer.*

4.2. Present: Temporal Range

The goal of this section is to introduce the idea that we could add a constraint to dependence by incorporating neurophysical capacity. Let's consider the example of a drug that could delay or slow the processing of some photons, causing signal conversion to take 10 days. The key component here is the processing time the photon needs. If the photon processing time is duration A, and the current time is t, then any input before $t-A$ should not be counted as dependence, if the photon is the only perceiver. The reason is that perception should not be involved with memory storage and access, and if the perceiver doesn't serve as a storer, then the information after processing should be cleaned out. It means that the capacity of the perceiver/sensor is bounded by the processing time of the perceiver/sensor. Only within this range, the dependence holds because out of the range, the information is either lost or is transited into other mental stages. So far, we may define the present temporal range as $\sigma = [t-A, t]$, where $A = \cup_i P_i$, and P_i the processing time of the i perceiver/sensor , t denotes the current time. Then we push the definition of perception from S-D FULL to S-D Time which could be seen below:

S-D Time: α is perceptual if, necessarily, all occurrences of all elements of α have the function of being stimulus-dependent of stimulus within the range of σ; otherwise, α is cognitive.

5. Summary

In summary, we address two main questions. The first pertains to the definition of a stimulus: What constitutes a stimulus? For example, when observing a red apple, is the stimulus the electromagnetic waves, the apple itself, the color red, or the electrical signals produced when simulating neural responses in early cortex areas and directly transmitting them to the visual cortex? The second question revolves around the nature of dependence in this context: Are we discussing physical dependence, causal dependence, or another form of dependence? To answer these questions, we delve into the philosophical concepts presented in our work concerning the nature of perception, stimuli, and their relationship to the external world. We explore the idea of Brain-Computer Interface (BCI) stimulation as a stimulus, using the brain in a vat thought experiment to illustrate that BCI stimulation can indeed be considered a stimulus. The importance of causal relationships between the environment and the subject is emphasized in this context.

We also address temporal contiguity, discussing the limitations of point-to-point temporal correspondence and proposing two alternatives: functional relations and temporal range. By focusing on the functional relationship between stimulus and reaction, we establish a more meaningful connection between them. Functional relations are further explored, highlighting the importance of the causal function between stimulus and reaction. Temporal range is introduced as a way to redefine the present in relation to perception, taking into account delays or prolonged perceptual experiences. We acknowledge the need for constraints on the dependence relationship and introduce the concepts of causal and physical dependence. By incorporating neurophysical capacity and temporal range, we refine the definition of perception.

In summary, our work presents a nuanced understanding of broader perception and cognition by examining functional relations, physical dependence, and temporal range. These concepts contribute to a more comprehensive understanding of the complex nature of perception and its connection to external stimuli.

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