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Memory as sensory modality, perception as experience of the past

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Response to Reviewers:	I have fixed the typos noted by the referee and also proofread the paper again. I've made two or three other very minor typographical changes, including setting off the long quote from Chalmers instead of keeping it in-line.

Runner-up for the philosophy of memory essay prize, invited to submit

Title: Memory as sensory modality, perception as experience of the past

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Memory as sensory modality, perception as experience of the past

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Abstract

Perceptual experience strikes us as a presentation of the here and now. I argue that it also involves experience of the past. This claim is often made based on cases, like seeing stars, involving significant signal-transmission lag, or based on how working memory allows us to experience extended events. I argue that the past is injected into perceptual experience via a third way: long-term memory traces in sensory circuits. Memory, like the receptor-based senses, is an integrated and constituent modality through which we experience the environment. Because of this modality, we experience the sensed properties of stimuli partly as they are now, but also partly as we encountered them in the past.

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1 Introduction

As you interact with your environment through senses like vision and touch, you experience what's immediately around you. The *here and now* intrudes into consciousness. I propose that you also experience the past. Along with spatiotemporally present sensory stimuli (particular objects, sounds, events, surfaces, etc.), the past finds its way into experience. Specifically, stimulus *properties* are experienced through the modality of memory. Properties are perceived partly as they really are, in the here and now, but also partly as they appeared when previously encountered.

By claiming that memory is a perceptual, or even *sensory*, modality, I mean that, akin to how the neural circuits projecting from our photoreceptors and mechanoreceptors afford distinct modes through which we perceive the environment (vision vs touch), so too memory within those circuits affords its own distinct perceptual mode. Perception partly involves experience of the past because memory is a modality, integrated with our receptor-based senses, through which we perceive the environment.

There are several kinds of memory: multiple short-term working memory buffers used in different kinds of processing, along with long-term episodic, procedural, and semantic memory. Each has a neural basis which supports certain kinds of psychological processes or states and manifests in certain behavioral performances. When I propose that memory is a sensory modality, I'm referring to the long-term mnemonic mechanisms integrated into the neu-

ral circuits originating at sensory receptors, along with the physical memory traces they leave during sensory interactions. I'm excluding whatever enables working memory buffers (Zylberberg and Strowbridge 2017) and instead have in mind mechanisms such as long-term potentiation and long-term depression of synapses (Feldman 2012).

Memory, as I use the term, should be distinguished from the psychological process of *remembering*. We often *use* traces left by past sensory interactions thanks to long-term mnemonic neural mechanisms *for the purpose of* calling to mind some past event, object, or bit of information. My claim is not that this functionally defined psychological process is a sensory modality. I'm not proposing that you're engaging a perceptual modality when you recall, in a "re-experience" (Tulving 2002, 6), your first job or yesterday's breakfast. My claim is about mnemonic neural mechanisms and the traces they facilitate.[1]

The idea that memory is involved in perception has a long history, back to William James and Immanuel Kant. It's supported by empirical results, theoretical considerations, and introspection. I summarize this work in section 2. The upshot is that memory, in the sense of long-term mnemonic neural mechanisms and the traces they facilitate, is an integral part of sensory processing. While this point has recently received more uptake from philosophers (e.g. Munton 2021), no one has yet taken the step of suggesting that it implies perception involves experience of the past.

[1]I'll leave open whether perceptual systems sometimes *remember*, in the functionally defined sense of recall-process, in their effort to interpret sensory input.

In section 3, I distinguish my thesis from the claims that signal-transmission lag and short-term working memory introduce the past into present experience. For example, we see the sun as it was approximately eight minutes ago and our extended present experience of the moment (the "specious present") includes not only what happens in the objective durationless now,[2] but what's unfolded over the last second or two. My claim is different from these two points.

In section 4, I discuss what I take to be the default view: Perceptual processing relies on long-term memory traces, but these traces merely facilitate perception of the here and now, without introducing the past into experience. For example, Jessie Munton (2021) has argued that memory allows us to see some invisible things, e.g. momentarily occluded objects or parts of objects falling out of your field of view. I agree that long-term mnemonic mechanisms in sensory neural circuits serve this function. It's unlikely that memory introduces *particular past-perceived objects and events* into perceptual experience. Perceptual experience is dominated by the present objects and events our sensory systems function to track. Still, as I argue in section 5, the default view ignores (i) the experience of *properties* and (ii) how properties are experienced through perceptual modes. For example, we not only perceive particular baseballs, but also their roundness, and our experience of

[2]The relativity of simultaneity entails that there is no such objective durationless "now". Still, within the local spacetime of our sensory interactions with the environment at their low relative speeds, observer discrepancies won't affect how we interpret experience and its spatiotemporal content.

that roundness depends on whether we're seeing or touching them. I argue that long-term memory traces constitute their own perceptual modality. Like other perceptual modalities, these traces shape the experience of properties, with the net effect being that we experience properties in part as they were encountered in the past.

When I use the term 'experience', I always mean phenomenal consciousness. I'm referring to subjective, potentially introspectable mental happenings or states with phenomenal character. There's another common use of the term 'experience' without connotations of phenomenality, e.g. as when we say that a pitcher has a lot of experience throwing baseballs. I'll use terms like 'past sensory interactions' and 'previous encounters' when I mean to speak of experience in this latter sense. Authors I quote generally blur the distinction, but I won't comment on their usage.[3]

You might press that we experience neither "the present" nor "the past", but instead a *percept*, i.e. a kind of mental representation encoded in neural activity. I will assume, and talk as if, what we experience are distal sensory stimuli and properties themselves, not intermediaries like percepts, sense-data, or other "mental images". Even if you do hold that we experience intermediaries and not distal stimuli themselves, you can still reframe my discussion as a discussion about what these intermediaries represent. Do they represent only present distal stimuli, or do they also, in some way,

[3]By using different terms, I don't mean to suggest the two are exclusive (they are not). I use different terms merely for clarity.

represent the past?[4]

2 Memory in perception

The idea that perception involves memory goes back to the start of psychology. William James (1892, 334) writes that when we use our senses, "the *brain reacts* by [nerve-fiber] paths which the previous experiences have worn, *and which make us perceive the probable thing*, i.e., the thing by which on previous occasions the reaction was most frequently aroused." Another nineteenth-century psychologist, Ewald Hering, thought that we experience size constancy because we "replace the current experience of [an object's] size with the experience [we] remember having had when [we were previously] in the optimal condition", i.e. the optimal viewing distance (Kelly 2010, 147). Hering held a similar view of color, coining the notion of a "memory-color", i.e. the remembered typical color of an object type, e.g. bananas being yellow (Witzel and Gegenfurtner 2013). Hering appealed to memory-colors in his explanation of color constancy (Bruner et al. 1951, 225), an idea with some empirical support (Hurlbert and Ling 2005).

More recently, Wilder Penfield, based on his clinical work doing temporal lobotomies in severe epileptic patients between 1930 and 1960, speculated that the functional role of the neural circuits immediately downstream of the

[4]My view is that even if experience is fundamentally a representation, we still experience stimuli themselves, not intermediaries. As Fred Dretske (2003) and others point out, even if experience is a representation, *what* we experience is what's represented, not the representation(al vehicle) itself (see also Crane 2006; Genone 2016).

primary sensory cortices is to access memories from past sensory interactions and interpret the current input based on those past encounters (Penfield and Perot 1963). He drew this conclusion from how direct electrode stimulation of these areas would, in a small percentage of patients (7.7%), induce audio-visual hallucinations of past-perceived objects, people, voices, and events.

Across James, Hering, and Penfield, the idea is that present perceptual experience is the result of using long-term memory to interpret sensory input. While not a dominant point of contemporary theorizing, this connection between memory and perception has found its way into current work. Thomas Albright (2012, 237–39), building on work from others (e.g. Kosslyn 1994), suggests that the neural activity responsible for visual experience results from a mix of bottom-up input originating in the retinas and top-down feedback from the inferior temporal (IT) cortex. Through something like Hebbian learning, past encounters with coinstantiated features leads IT responses to these features to wire together. The IT cortex does pattern completion when met with incomplete or noisy input, filling gaps with previously coinstantiated features. This mechanism would explain why, for example, viewing an object in low (mesopic) light and other color-distorting conditions (e.g., semiopaque film) leads to an experience of its color skewed in the direction of its remembered color—an effect known since at least Hering and his discussion of "memory-color" (Bruner et al. 1951; Siple and Springer 1983; Hansen et al. 2006).

Within Albright's discussion is the idea that the neural bases of percep-

tion, memory, and imagination overlap. This idea isn't new (e.g., see Farah 1985; Kosslyn 1994, 2005; Horikawa and Kamitani 2017; Bone et al. 2020). Within research on episodic memory (Tulving 1983), there's now strong consensus that a *single* neurocognitive system underlies our ability to both remember actual, and imagine future and counterfactual, episodes, i.e. events (Tulving 2002; Buckner and Carroll 2007; Schacter and Addis 2007; Suddendorf and Corballis 2007; Michaelian 2016; Beaty et al. 2019). Recently, Donna Addis has proposed that this single system assembles experience (or, that is, the neural representations responsible for experience) across not only memory and imagination, but also perception.[5] She says:

> During perception, various streams of incoming sensory information are processed and continually interact with relevant schemas to form an emerging simulation supported by higher-level DMN [default mode network] regions. Importantly, schemas also guide the incorporation of pre-existing elements into the simulation of present experience, such as previously-perceived elements (depending on associative strength with activated elements) and conceptual knowledge, to fill in gaps in perception, provide deeper levels of meaning, and so on. (Addis 2020, 252)

As Addis uses the term (2020, 244), a *schema* is an "associative network"

[5]The idea that perception, imagination, and memory share neural mechanisms isn't without controversy. It's challenged by how brain lessons seem able to doubly dissociate perception and imagination (see Brogaard and Gatzia 2017). Space precludes me from responding to this concern. These ideas are well-enough supported that a discussion taking them for granted is still valuable.

of neural connections "that organizes lower-level representations", a network "acquired gradually via the abstraction of elements (and their interrelationships) that feature commonly across multiple experiences".

Common to these proposals is a mechanism for how memory influences perceptual processing. Past sensory interactions, via long-term mnemonic neural mechanisms like synaptic plasticity, prime sensory neural circuits to repeat past patterns of firing (e.g. Jackson 2013). This pattern priming takes for the form of something like Addis' schemas, or what I'll call long-term memory traces: associations between neurons set by strengthened (or weakened) synaptic connections. Current sensory input, instancing bits and pieces of these patterns, reactivates them. The neural activity responsible for experience at any given moment (the neural correlate of consciousness) lies somewhere in the middle: a pattern of activity driven both by receptor input and reactivated long-term memory traces.

The dependence of the neural correlates of perceptual experience on not only a cascade from sensory receptors, but also feedback via a kind of pattern completion, has not gone unnoticed by philosophers. In a recent paper, Munton (2021, 14) points to how ambiguity in sensory input is resolved by perceptual priors (presumably stored in long-term memory traces) as an example of memory being used in perceptual processing. She gives the example of memory-colors. She also notes the phenomena of boundary extension, "the way in which subjects falsely report having seen beyond the edges of an image in a picture, or the limits of their own visual field" (2021, 14). Since

boundary extension seems to require long-term memory resources, yet still happens at the ultra-fast speeds on online perception, it seems to be a case of memory being used in perceptual processing.

Munton aside, philosophers often construe this feedback contribution not in terms of *memory*, but instead in terms of *imagination*. This connection goes back at least to Immanuel Kant (1787), who famously held that experience is not passively receptive, but instead is an active synthesis of sensory input plus additional ingredients from imagination (Brown 2018, 138–39). Here a central problem was how we get experience of enduring objects from a series of transient sensory interactions. P. F Strawson (1970), following Kant, proposed that "imagination contributes past or possible perceptions to occurrent perceptions and thereby helps imbue the latter with a sense of endurance or object-sameness" (Brown 2018, 143).

Although philosophers often frame the issue in terms of imagination, it's clear that they have in mind the same sort of memory phenomena I've mentioned above. Consider, for example, the account from Derek Brown (2018, 147–48) and Fiona Macpherson (2012) of memory-colors. According to Brown and Macpherson, long-term memory stores associations between object types (e.g., banana) and colors (e.g., yellow). These memories trigger states of imagination (presumably states of imagining the associated color) which are combined with perceptual states to yield a seamlessly integrated phenomenology. Notice that although Brown focuses on the role of *imagination* in this process, for him and Macpherson, imagination is a mechanism

for meshing a reactivated memory trace into current perceptual experience.

Related to Munton's discussion of boundary extension, Bence Nanay (2010) proposes another case, arguing that amodal completion (experience of parts of objects that are out of view, e.g. objects' backsides or their occluded parts) involves imagination filling incomplete perceptual input (see also Kind 2018). Macpherson (2018, 3) notes that the resolution of ambiguous figures in perceptual experience, like the Necker cube, might also be accomplished through imagination. These ideas from Brown, Nanay, and Macpherson, and more broadly the idea that a kind of (imaginative) "imagery" fills impoverished sensory input, have their roots in work from Stephen Kosslyn (1994), who made seminal proposals on the integration between long-term associative memory, mental imagery, and perception.

Philosophers perhaps construe the feedback contribution to perceptual experience in terms of imagination, instead of memory, because they might want to limit memory to a certain functional role. They presumably will acknowledge that the input to perception from imagination takes the form, at the neural level, of input generated by reactivated memory traces. But, as Addis and others (e.g. Michaelian 2016) who see memory and imagination as a single system point out, memory traces (e.g., networks of neurons "wired" through past activity to co-fire) provide the raw material of a neurocognitive system which can reactivate and constructively (re)combine them for different purposes, e.g. as a means of recalling the past, imagining scenes, or supplementing sensory input. When this system reactivates these traces to

supplement sensory input, it's not (these philosophers might want to press) reactivating them for the purpose of recalling the past. Hence, the input into perception isn't "memory". These philosophers may suggest that when the system reactivates traces to supplement sensory input, it is realizing a process of imagination.[6]

For my purposes, it doesn't matter how we construe the *psychological process* being realized by the feedback contribution to perception. It's enough for my purpose that one acknowledge the role of mnemonic neural mechanisms, and the traces they leave, in this feedback. It's fine for my argument below if this trace-based feedback is best characterized as realizing a functional process of imagination (but see Briscoe 2018).

A real problem for the argument below would come from those who want to construe perception very narrowly, so that any contribution beyond the bottom-up receptor cascade is nonperceptual cognition. Munton (2021, 13) cites Thomas Reid (2011) and Elizabeth Spelke (1988) as advocating for this narrow understanding of perception. Space precludes me from responding fully to this view, to which Munton herself gives a response, but I think it should be rejected.[7] First, if perception is tied to experience (as I think

[6]Addis and others who see memory and imagination as a single system likely don't think there's a substantive question as to whether it's imagination, or memory, which affects perception.

[7]As I'll note below in section 5, the effects of long-term mnemonic neural mechanisms are a form of perceptual learning. Some have objected that perceptual learning is cognitive, not genuinely perceptual (e.g. Pylyshyn 1999, 359). These objections often come in debates over cognitive penetration. I disagree; this paper presupposes that these effects are perceptual. Space prevents me from responding to this debate, but relevant defenses in the neighborhood of what I'd pursue include Vetter and Newen's (2014) oft-cited paper

it should be), then it seems clear that perception goes beyond bottom-up input, since perceptual experience (phenomenology) is shaped by top-down feedback. Second, if perception is limited to the bottom-up receptor cascade, then it might turn out that we perceive almost nothing—surely a counter-intuitive result. Although my examples so far, like memory-color, involve feedback which supplements impoverished receptor input, as I'll discuss below, long-term mnemonic neural mechanisms (and hence "feedback") pervade all levels of sensory processing (even down into V1) and explain even basic phenomena like color and shape constancy.

3 Clarifying the thesis

So, the neural cascade starting in our sensory receptors which results in our experience of the environment is shaped by long-term memory traces. From this I want to argue that perceptual experience at least partly involves experience of the past. This is a claim not about memory *per se*, i.e. not about how to type the psychological processes or states involved in perceptual experience. Instead, it's a claim about the *content* of those processes or states, about *what* is experienced in perception. Specifically, it's the claim that what's experienced in perception is not limited to spatiotemporally present stimuli, but includes things from the past as well.

My claim is not that some of what we experience in perception is experi-

and Kevin Connolly's (2019) recent book on perceptual learning.

enced *as past*, i.e. *as being from the past*. When I now look at the pencil I'm holding, nothing intruding into my experience (the pencil, its color and shape, etc.) introspectively strikes me as if it's actually from the past. I experience it all as spatiotemporally present (Taylor 1938, 226). Still, that doesn't preclude that some of what I'm experiencing may not actually *be present*. Early modern and early twentieth century philosophers were impressed with the temporal delay due to the finite speed of light, sound, and neural signals. Some were also gripped by the idea that the "specious present" of experience (James 1892) extends temporally a few moments back before the present instant in time. They thus inferred that much (or all) of what we presently experience is actually in the past (Laird 1920, 45–48).

The claim I will defend here isn't the well-known claim that stars and other distant objects we see and hear are actually in the past, i.e. that we now see and hear them as they were some time ago. I want to focus on *typical* cases of object experience: e.g., I look now at the pencil I'm holding, you watch a cyclist ride past you while walking down the street, or a batter tracks a ball pitched at him. Unlike seeing stars or hearing far-off thunder, these cases involve experiencing what is more or less spatiotemporally present. Because experience isn't a durationless snapshot, but an extended window of a second or two, in these cases working memory allows us to compensate for the short (0.05–0.5 second) lag due to signal transmission and neural processing. Experience itself may be delayed (objective timing), but it presents,

or represents, the correct timing (subjective timing).[8]

In addition to experience of the past which derives from lag in signal transmission (e.g., the finite speed of light or action potentials), claims are often made about how working memory introduces the past into perception. Assuming we really do experience a present extending over a second or two, what intrudes into experience are unfolding events that stretch back that second or two in time. This extended present is supported, presumably, by whatever mnemonic neural mechanisms underlie the working memory of our sensory processing (Zylberberg and Strowbridge 2017).

It's not too controversial to point out that working memory infuses typical object experiences with content extending into the past. A batter doesn't just see the pitched ball's current position, but its whole past spatiotemporal trajectory. In the cutaneous rabbit illusion (Geldard and Sherrick 1972), you (inaccurately) feel each tap as a member of a temporal sequence of "hops" running up your forearm. A perceptual phenomenology of "instants" without the temporal context of the extended subjective present would be a jarring departure from actual experience, and it's working memory which saves us from it.[9] This too is not my claim.

[8]Echos provide a fascinating transmission lag case. At least on some views (e.g. O'Callaghan 2007), a reflecting sound wave (as in an echo) allows you to re-encounter, and so re-experience, the sound causing it. Hence, experiences of echos are actually experiences of a disturbance or vibrational event a few seconds in the past, one and the same event you already experienced as the "primary" sound.

[9]Set aside questions about the ontology of experiences, e.g. whether experiences themselves are the kind of entity which have an objective duration, or how the objective duration of an experience relates to the duration felt by the subject having the experience. My point is that if, at some arbitrary instant, you could somehow catalogue what was be-

My claim that perception involves experience of the past is that (i) some of what we experience is in the past, outside the extended window of time presented in experience as the present, and (ii) this experience of the past is not due to signal-transmission lag, but rather to mnemonic neural mechanisms. Because this experience of the past isn't due to signal-transmission lag, it's not like the case of seeing stars. Because what's experienced is outside the extended window of the subjective present, it's not like those cases easily explained by working memory.[10]

Notice that I'm neutral on a theory of experience. For all I've said, perceptual experiences can be representational states (Anscombe 1965; Harman 1990; Dretske 1995; Burge 2010), or relations to stimuli (Austin 1962; McDowell 1986; Campbell 2002; Martin 2004; Fish 2009). When I talk about *experiencing something from the past*, I'm neutral on whether this should be understood as (a) being in a state which represents that thing from the past, or (b) standing in the relation of conscious perception to something from the past. What we perceive might "intrude" into experience by being represented (Clark 2012), or that intrusion might be more literal, e.g. with the perceived

ing presented to a subject in their experience at that instant, you would find the content outstripped what could actually happen in an instant, and contained a temporal stream including elements in the past.

[10]The line between short-term working memory and long-term memory is not sharp, either in terms of temporal duration or neural mechanisms. For example, the mnemonic neural mechanisms responsible for the waterfall illusion (Addams 1834) are probably more like the neural mechanisms which allow us to track moving objects in real time than the mechanisms which associate colors and shapes, but the waterfall illusion is an effect which extends beyond the specious present. I'll set aside these intermediary cases and focus on stable, long-term effects like color-shape associations.

thing becoming a literal constituent part of your mental state (Hellie 2014). Alex Moran (2019) has argued that relationalism can't accommodate perception involving experience of the past, specifically signal-lag cases like seeing stars. Similarly, the conclusions of this paper may challenge relationalism. I will leave the issue open, so as not to get caught in tangential issues.

4 The default view

As discussed in section 2, sensory circuits include mechanisms of long-term associative memory, mechanisms like long-term potentiation and long-term depression of synapses (e.g. Albright 2012; Feldman 2012). The effects of past sensory interactions (memory traces, or "schemas") shape present processing of receptor input. I will argue in the next section that these mechanisms and traces suffice to inject past elements (from outside the extended subjective present) into current perceptual experience.

This claim is opposed to the default view on the involvement of long-term memory traces in perceptual processing.[11] This default view says that traces from past interactions guide the present processing of input without introducing the past itself into experience. After all (so the default view reasons), sensory systems function to track *present* stimuli, to track how things are here and now, in the space around you. The relevant stimuli are *particular* objects, surfaces, arrangements, sounds, events, and other things

[11] Thanks to an anonymous referee for pointing out what is the default view.

we might bump into. Along with guiding physical action, the aim of sensory systems is to *sort* or *classify* these particulars (Matthen 2005), e.g. by color, shape, motion direction, or category. That is, these systems aim to attribute properties to particular stimuli (Dretske 2003; Burge 2010). Sensed stimuli have a nested structure, e.g. objects consist of their surfaces and parts, and events consist of changing objects. Sensory systems also function to work out this structure, e.g. to work out mereological, causal, temporal, and spatial relations between structure elements (Addis 2020).

According to the default view, the integration of long-term mnemonic mechanisms into sensory processing shows merely that past encounters affect how sensory circuits track, sort, and structure *present* stimuli. For example, in the memory-color case, memory traces produced by these mechanisms affect a property (color) attributed to particular stimuli, but attributed properties are still attributed to the spatiotemporally *present* particulars being tracked. Properties (as opposed to their instances) are abstract, and hence *atemporal*. So, in the memory-color cases, what we experience through our senses are only the spatiotemporally present particulars with which we're now interacting, along with the atemporal properties (colors) our sensory systems attribute to them. Nothing *from the past* finds its way into experience.

To take a second example, memory traces likely affect how we organize a perceived scene. As Addis (2020) would put it, these traces form "schemas" which guide not only what properties we attribute to stimuli, but also how we experience the mereological relations between stimuli and how we experi-

ence the causal, temporal, and spatial relations between objects in unfolding events. Still, the default view presses, *what* we experience is limited to the spatiotemporally present (particular) stimuli being organized. The various structures into which schemas organize these stimuli are themselves abstract (see Addis 2020, 244), and hence atemporal. Nothing from the past intrudes into perceptual experience. Memory traces facilitated by long-term mnemonic mechanisms merely affect perceptual experience causally, partly determining the (atemporal) structures into which present stimuli are organized.

It's worth mentioning one flaw in the reasoning behind the default view, even though it won't ultimately help us see how past elements are introduced into *perceptual* experience. The default view misses the point that long-term memory affects more than just how we track, sort, and structure stimuli. As noted in section 2, it can *fill in* missing elements. Consider amodal completion. Sensory systems use patterns stored in memory traces to enable experience of whole objects, despite only having input from some of their parts (e.g., from facing, nonoccluded surfaces). Similarly, Addis (2020, 252) suggests that schemas don't just help in organizing given elements, but also fill in missing elements. As a third example, consider a case raised by Albright (2012). If a person tosses a ball into the air multiple times but then palms it while still accurately miming the toss motion, many observers will "see" the ball fly up on the fake toss.

To defend my position, a tempting reply would be to point to these

cases and propose that the element added by memory is something from the past. This suggestion would be a rather strong interpretation of Addis's remark that "schemas also guide the incorporation of *pre-existing elements* into the simulation of present experience, such as *previously-perceived elements*" (2020, 252, emphasis added).

This reply to the default view faces several challenges. Amodal completion is unhelpful because it doesn't involve adding a *missing* element, just *completing* an incomplete one. That is, amodal completion allows us to experience whole (3D) distal objects even when we only receive input from some of their parts, but (you may think) it doesn't allow us to experience the missing part. For example, when vision amodally completes the backside of an object, it's not as if you experience some backside (which we might suppose is a past-perceived backside); instead, you merely experience the spatiotemporally present object as having an (unexperienced) backside.

Albright's vanishing ball trick faces an initial problem. It's reasonable to suppose that the experience is supported by short-term working memory, and so in that way falls outside the scope of my thesis. It's not a good candidate for experience of the past generated by long-term mnemonic neural mechanisms.

We might fall back more generally on Addis' idea that long-term memory traces can inject missing elements into experience, but both this claim and Albright's trick face two other, more serious problems. First, even if we wanted to suppose that the added elements are past-perceived stimuli, you

might think we face the challenge of specifying *which* past-perceived stimulus is injected into experience. For example, say my friend always wears the same red hat. I see him one day, but for whatever reason input from his hat fails to be processed by my visual system. So, my schema for this friend injects a previously seen instance of the hat into my experience, to fill the gap. *Which* past-perceived hat instance does it inject? Schemas are supposed to be general or abstract patterns, not mechanisms for achieving reference back to past-perceived particulars.[12]

There is one way you can respond to this worry, at least if you endorse a representationalist account of experience. The reply goes that even if there is no determinate, past-perceived instance of my friend's hat which I experience in this case, it does not follow that what's experienced is not in the past. Consider, for example, how you might paint a scene depicting your mother as she was in your childhood, without necessarily painting any one particular past scene or painting your mother as she was on any one particular past day. You can successfully paint (represent) something from the past, without successfully referring to either a particular scene or to a particular day-length time-slice of your mother. A representation can represent a *past particular* without being determinate as to which past particular is being represented.

[12]My opponent may not actually want to press this problem. Yes, it is a problem for those who want to claim that pattern completion by long-term memory traces injects experience of past-perceived objects into current sensory experiences (e.g. Barkasi 2020). But my opponent faces their own version of the problem: How is it that the activation of a schema, or general pattern, abstracted from past experience, allows me to perceive the *current instance* of my friend's red hat? So, the problem arises independent of any attempt to find the injected element in the past.

So, a representationalist might be able to sidestep this challenge, although they would need to say much more to fill out this brief sketch.

Even if this reference-fixing problem could be solved, a second problem arises. Both Albright's trick and Addis' added schema elements seem to involve *hallucinatory* experience, not *perceptual* experience. The vanishing ball on the fake toss, or Addis' injected elements, are hallucinated, not perceived. A proponent of the default view can grant that sensory processing which fails to put us in contact with the spatiotemporally present environment can generate all sorts of weird experiences, including experience of the past (e.g., see Weir 2004; James 2014; Manzotti 2019; Barkasi 2020). What's at issue is what happens when perceptual processing *succeeds at its function* of tracking, sorting, and structuring spatiotemporally present sensory stimuli. What I take to be the counterintuitive claim to which the default view is opposed is the claim that long-term mnemonic neural mechanisms introduce experience of the past (outside the extended subjective present), even when all is going well and our sensory systems are successfully tracking, sorting, and structuring spatiotemporally present stimuli.[13]

We can grant to the default view that the function, or purpose, of percep-

[13] Brown (2018) raises a similar issue for the question of whether perceptual experience is ever infused with imagination. He points out that it's uninteresting and trivially true that we can, for example, imagine a lamp in the corner of a room we can see to be empty; the interesting question, for him, is whether normal, successful perceptual experiences involve an imaginative component. Similarly, it's not radical to claim that, when sensory input is incomplete, it can be filled by a hallucination of a past-perceived stimulus. The interesting question is whether normal, successful perceptual experience involves experience of the past.

tion limits perceptual experience to spatiotemporally present particular stimuli, atemporal properties attributed to these stimuli, and atemporal structures into which these stimuli are organized. Second, we can grant that memory traces facilitated by long-term mnemonic neural mechanisms in sensory circuits causally shape how these present stimuli are tracked, sorted, and structured, and grant that that causal process itself does not introduce the past into perceptual experience. Third, while long-term memory traces might introduce particular past-perceived stimuli into current perceptual experience, these are likely hallucinated, not perceived, elements. Does this leave room for long-term mnemonic neural mechanisms to introduce experience of the past (outside the extended subjective present) into experience of successfully tracked, sorted, and structured spatiotemporally present stimuli? I'll argue in the next section that it does.

5 The perception of properties

In this section, I argue that long-term mnemonic neural mechanisms introduce the past into successful perceptual experience through the way in which the traces they facilitate shape experiences of properties. Granted, properties are atemporal. Still, properties don't intrude into experience true to their ideal, Platonic, or objective nature. As David Chalmers says metaphorically:

> In the Garden of Eden, we had unmediated contact with the world. We were directly acquainted with objects in the world

> and with their properties. Objects were simply presented to us without causal mediation, and properties were revealed to us in their true intrinsic glory. (Chalmers 2006, 49)

But Eden is not our world. We're stuck accessing objects and properties through causal intermediaries, including (most relevantly for my purposes) patterns of neural firing. Even granting, as I do, that we experience the objects and properties themselves (not the intermediary encodings), these intermediaries, or *modes of access*, still shape our experiences. We experience properties under these various modes, i.e. modalities, e.g. the same shape intrudes into visual and haptic experience differently.

Memory, I suggest, is its own mode for experiencing properties. Given the development and wiring of our sensory systems, we perceive stimuli through not only receptor-based modalities like vision and touch, but also (necessarily) through this modality of memory. Like any other modality, memory shapes the experience. In particular, properties experienced through the modality of memory are experienced not only as they are in the here and now, but also partly as they've been encountered before in past sensory interactions. That's the argument, in brief.

Let's start by seeing how the argument takes form in the example of memory-colors. As I look, in dim light, at the pencil I'm now holding, I experience its shape through both vision and touch. Similarly, I experience its color through both vision and memory. I experience its color through memory because my visual system is reactivating a memory trace in order

to complete, or interpret, the degraded color signal currently propagating up from my retinas. By reactivating the trace, my visual system is using that pattern and identifying the current stimulus as a new instance of it.

Why think this involvement of traces introduces *the past* into my pencil experience? The experienced color—a shade of cadmium yellow—does not itself have a temporal location. Merely experiencing that color as a common pattern instanced by previously seen stimuli does not obviously introduce any temporal flavor to the experience, aside from perhaps diffuse feelings of mild *déjà vu*. The key point for introducing the past into experience is that the reactivated trace, storing the pattern, is not static. It, and the pattern it encodes, is shaped (and reshaped) by each sensory interaction (each perception) of cadmium yellow. The current pattern, being reactivated as I look at my pencil, is shaped by all my previous encounters with cadmium yellow. This current interaction will shape future reactivations of the pattern. Because my experience of the color is dependent on this neural activity, as I look now at my pencil in dim light, I don't experience its color, cadmium yellow, as it really is in the moment. Instead, I experience cadmium yellow in part as it was (or appeared, or struck me) in the past, on previous encounters.

So, as I look now at the pencil I'm holding, it's true that my perceptual experience does not reveal to me some past region of (space)time. Past-perceived stimuli (e.g., other particular pencils I've used) are not intruding into my experience alongside the pencil I'm now holding. Thus, perception is different from episodic memory, which you might think really does

involve particular past-perceived events intruding again into consciousness (e.g. Aranyosi 2020; Barkasi and Rosen 2020). Still, the past shows up in my current perceptual experience via the mode through which I experience the pencil's properties.

In what way does the above reasoning cast memory (long-term mnemonic neural mechanisms and the traces they facilitate) as a perceptual mode, akin to vision or touch? To start, note that memory need not make my experience inaccurate. It's not that I experience the *wrong* property. We can suppose that my visual system correctly classifies the pencil I'm holding by color, i.e. it attributes the right color property. The issue driving the above argument is that my visual system *accesses* that color via memory. Just as different neuroreceptor pathways (e.g., vision vs touch) afford different (but equally accurate) modes of access, registration, or encoding (to think of it in three different ways) to one and the same property, the use of memory is its own mode of access. To take shape as an example, a certain pattern of neural firing across the retina is one encoding of roundness. A different pattern of neural firing across mechanoreceptors and proprioceptors can encode that same roundness in a different way. Similarly, memory traces in the cortex provide a third encoding. Perception of a property, like cadmium yellow or roundness, requires access to, or registration of, that property via some such encoding. When I propose that memory is a perceptual modality, what I have in mind is the idea that (like vision, touch, and the other receptor-based senses) memory affords a means (or mode) of accessing stimuli and

their properties deployed for perception.[14]

It's precisely because memory affords a mode (or means) of perceiving that it introduces the past into experience. How we experience a property clearly depends on the means through which we access it, i.e. on its encoding. What it's like to experience a property through touch is not the same as what it's like to experience that same property through vision; likewise, we should expect that there's some way in which it's like to experience a property through memory. Different neuroreceptor pathways introduce into experience aspects of their own nature, or (more precisely) their own encodings. Memory encodings of a property—the traces left by past sensory interactions by long-term mnemonic neural mechanisms—are something like an average (informally speaking) of all the previous neural patterns prompted by that property. In sensory circuits, long-term mnemonic neural mechanisms not only leave pattern-storing traces for later reactivation, but continually reshape those traces on each encounter. Thus, the neural pattern registering a present sensory encounter with a property is always a pattern reflecting previous encounters with that property. So, we would expect properties ex-

[14] As I understand it, claiming that memory is a perceptual modality is not quite the same as claiming that it's a distinct *sense*. There are, of course, differences between the "full-fledged" senses like vision or touch and memory, most conspicuously that memory lacks a proprietary suite of receptors. Memory also seems dependent on the other senses in important ways, e.g. (when used in perception) it lacks its own proprietary phenomenology and instead seems to shape the phenomenal character of the other senses. These features put memory outside the bounds of standard classifications of the "senses" (e.g. Macpherson 2011, 2014), but don't diminish it as its own unique mode of accessing stimuli. Notice that memory would not be the only sensory modality without proprietary receptors. Our ability to perceive flavour is generally thought of as a perceptual capacity routed in encodings that draw from both olfaction (smell) and gustation (taste) (O'Callaghan 2019).

perienced via memory to be experienced in a certain way, specifically, partly as they were previously encountered.

How is the past itself involved? Each time we encounter a property, that encounter shapes, or refines, our neurosensory representation of that property. As Addis puts it, schemas get updated.[15] Hence, stored representations capture properties not as timeless abstractions, but as they've been encountered in the past.[16] For each property, there is a way it has "appeared" on average in the past, or across many past interactions. When a property is introduced into present perceptual experience via memory, it doesn't appear as it might were an ideal perceiver to access it without any memory. Instead, its appearance is a skewed blend of its actual current appearance and its "average" past appearance.

At this point, a second version of the hallucination objection might be raised. It might be objected that remembered properties are only introduced into perceptual experience in special cases, like the memory-color (mesopic light) case I've been discussing. These cases, the objection goes, aren't genuine perception, but are somehow defective. Were the sensory input more complete, memory would not get involved, and we would experience the

[15]This updating might be given a computational gloss, like that found in predictive processing. Here I'm sticking to a basic neurobiological perspective: What's being updated are the literal primed patterns of neural activity; they are updated via changes in synaptic strength, changes produced via mechanisms like long-term potentiation and long-term depression.

[16]You might object that, as Addis herself says, the trace or scheme-forming process *is* a process of abstraction; hence, the results *are* timeless abstractions. This objection assumes that neural circuits make idealized abstractions. In practice, both constrained by sample data and physical electrochemical noise, the brain never manages perfect abstractions.

property as we presently encounter it.

In response, memory does play a larger role when the upflowing receptor signal is especially incomplete or otherwise defective. Still, (i) the signal coming up from receptors is *always* incomplete, even in cases that count as successful perception, and (ii) memory plays other roles aside from filling gaps in incomplete input. These two points are deeply connected.

Regarding the first point, consider just how little input is needed for amodal completion. In a quick glance, you can see a nearby object as an extended solid, despite not having had the time to fully explore how the 2D projections of its facing surfaces change with perspective. This is not an aberrant or defective case of perception. As is often pointed out (e.g. Fodor and Pylyshyn 1981, 173), proximal sensory input is *always* impoverished. For example, the image on the retinas underdetermines the 3D shapes of the distal objects being projected.

The sparseness of perceptual input is one reason to posit, like Helmholtz did in the nineteenth century, that perception is an *inferential* process, or to posit, like David Marr (1980), that it's a *computational* process. The computational theory of perception itself makes clear the pervasive use of memory in perception. *All* perceptual experience is the result of transformations of receptor input as that signal propagates through sensory neural circuits. Those transformations (understood as inferences, computations, or something else) are facilitated by synaptic connections set by the mnemonic mechanisms of long-term potentiation and long-term depression. Hence, a

form of long-term memory, often described as *perceptual learning*, is constantly at work in perceptual processing.

This leads naturally to the second point. To perceive a property at all, even given complete and perfect sensory information, the brain must still organize or extract that information—it must transform preliminary encodings (e.g., in receptors) into usable encodings in the cortex. Detection of a property requires not only that receptor responses carry enough information, but that the system can extract that information or recognize it. The work of Addis and others suggests that long-term mnemonic neural mechanisms play a key role in this process. Even if we ignore high-level associations in IT cortex of the sort that Addis and Albright have in mind, sensory circuits are constituted by synaptic connections set via long-term mnemonic mechanisms. At all levels of the processing hierarchy, sensory circuits exploit and depend on long-term mnemonic mechanisms to extract information about distal stimulus properties from proximal input (Cooke and Bear 2014). Memory is deployed pervasively throughout genuine, successful perception as a means of interpreting input so as to sort stimuli, i.e. attribute properties to them.[17]

The view I'm proposing has it that the multimodality of perception (O'Callaghan 2019) includes not just the receptor-based senses, but also memory. Perceptual experience presents to us properties not only accessed through the different receptors (vision, touch, audition, etc.), but also ac-

[17] Brown (2018, 154) argues that perception is pervasively infused with imagination, and his argument likewise makes use of these points about the pervasiveness of input processing.

cessed through long-term memory. Memory might even play a fundamental role. While our perceptual access to a given property might be mediated at different times to varying degrees by vision, touch, and the other senses, memory is *always* a component. While some properties (e.g., color) may be accessible only through one sensory modality, memory is required to access any stimulus properties at all. In this way, perception is not only experience of the here and now, but also of the past.

To conclude, consider an interesting objection the responses to which clarify my view.[18] Consider someone who has just seen their first round shape (a coin), and saw it from an oblique angle so that it appeared oval. Alternatively, imagine someone who has (by bad luck) only ever seen circular objects from oblique angles. Now imagine that this person sees a circle head on. Doesn't my view predict that the circle's roundness will appear oval to them, and isn't that implausible?

First, my view is not that current input is discarded and replaced with a previously stored pattern. The view is that what's experienced is a blend of current input and matching stored pattern—weighted on many factors, like the strength of the current input. Second, if someone really has only seen one circle, and saw it from an oblique angle, or really did only ever see circles from oblique angles, it seems doubtful that their visual system would (at first glance) recognize a circle viewed head-on as the same shape as the circles viewed obliquely. We would have a case of either incomplete perceptual

[18]This objection is from a very helpful referee.

learning, or extremely distorted perceptual learning. A not implausible guess is that this person would experience the roundness of the head-on circle very differently than they experienced the roundness of the oblique circles, as their visual system has not yet learned to identify circles from different angles.

6 Conclusion

Let's summarize my proposal. What past elements, outside the extended temporal window presented as present, intrude into perceptual experience? The past elements intruding into present perceptual experience are "appearances" of properties. For example, when I look at the pencil I'm holding, whether under mesopic or normal lighting conditions, I don't experience its cadmium yellow entirely as it *really is*, in the here and now. To varying degrees depending on the viewing conditions, I experience that cadmium yellow (in part) as it struck me in the past, across previous viewings. In a similar way, all perceptual experience of properties—e.g., hue, shape, texture, pitch, along with high-level properties like causation, kind, and gestalt organizational properties—is, to some degree, experience of those properties as they were encountered in the past.

Why think those elements intrude into perceptual experience? The only way we have of sorting sensory stimuli, i.e. of extracting property information and attributing it to particular objects and events, is through some process of perceptual learning. Long-term mnemonic mechanisms are found

throughout sensory neural circuits. These include both high-level associations, in IT cortex and elsewhere, of the sort Albright and Addis discuss, as well as more local synaptic connections closer to the receptors which shape the signal cascade on its initial feed-forward sweep. These more local connections and their effects are James' nerve-fiber "paths" that are "worn" by previous experience (1892, 334). In this way, memory is a modality through which the environment is accessed and interpreted, akin to vision, touch, and the receptor-based senses.

It's not too controversial that perceptual experience includes experience of the past. Signal-transmission lag and short-term working memory introduce elements outside the extended moment experienced as present. I've argued here for what I take to be a more controversial and interesting claim: Long-term mnemonic neural mechanisms within sensory circuits introduces the past into present experience. The idea isn't that perception is like episodic memory, giving us experience of past-perceived particular objects and events situated within some past region of spacetime. Instead, the idea is that we perceptually experience properties partly as they were encountered (perhaps on average) in the past. Long-term memory traces are their own sensory modality, akin to vision or touch or audition, through which we perceive the spatiotemporally present environment. Just as we are forced to experience the world through our sensory receptors, we are also forced to experience it through our memories.

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