Perceptual Learning

Zoe Jenkin
Washington University in St. Louis

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Abstract: Perception provides us with access to the external world, but that access is shaped by our own experiential histories. Through perceptual learning, we can enhance our capacities for perceptual discrimination, categorization, and attention to salient properties. We can also encode harmful biases and stereotypes. This article reviews interdisciplinary research on perceptual learning, with an emphasis on the implications for our rational and normative theorizing. Perceptual learning raises the possibility that our inquiries into topics such as epistemic justification, aesthetic criticism, and moral knowledge should include not only an examination of cognition but also of perception.

Key Words: Perception, Epistemology, Cognitive Science, Philosophy of Mind, Knowledge

I. Introduction

A radiologist and a patient look at an x-ray. The radiologist sees a cancer lesion, while the patient sees only a disorganized muddle of grey and white. What explains this difference? The answer is perceptual learning.[1] Perceptual learning comprises long-lasting changes to perception, typically caused by repeated experience with a stimulus-type over time (Gibson, 1963, p. 29).[2] As radiologists undergo training and practice, their visual systems change. They acquire not only beliefs about which patterns indicate which prognosis, but also perceptual abilities for fine-grained discrimination and categorization.

Radiology is just one domain among many about which our perceptual systems can learn. Other well-studied domains of perceptual learning include chess (Chase & Simon, 1973), dog breeds (Diamond & Carey, 1986), color (Burns & Shepp, 1988; Goldstone, 1994; 1995), music (Burns & Ward, 1978), chicken sexing (Biederman & Shiffrar, 1987), car models (Curby & Gauthier 2014), language (Smith & Haviland, 1982), pattern recognition (Gibson & Gibson, 1955), and tennis (Farrow & Abernathy, 2003). Perceptual learning is a fundamental and widespread feature of human minds.

Perceptual learning is on the one hand a topic for scientific investigation. Neuroscience can tell us which brain areas develop over the course of learning (e.g., Weinberger & Bakin, 1998; Gauthier et al., 2000; Bushnell, 2001; Gilbert, Sigman, & Christ, 2001; Rossion & Gauthier, 2002; Li, Piëch, & Gilbert, 2008; Tanaka & Curran 2001; Bilalic et al., 2011; Gilbert & Li 2012; Astorga et al. 2022). Psychology can tell us how training procedures affect perceptual learning (e.g., Biederman & Schiffrar, 1987; Goldstone, 1994; Jarodzka et al., 2013), how much time, effort, and practice are required for expertise (e.g., Ericsson et al., 1993, Macnamara & Maitra 2019), and how the perceptual skills of experts and novices differ (e.g., Chase & Simon, 1973; Abernethy 1990). Psychology can also help explain the structure and function of the mental representations acquired during perceptual learning. Computational models can predict patterns of perceptual learning and test theories of their underlying mechanisms (e.g., Poggio et al., 1992; Petrov, et al. 2005; Jacobs 2009).

Perceptual learning is also a topic for philosophy. Careful interpretation and analysis of the empirical data is required to determine the contours of perceptual learning.[3] Theorizing about perceptual learning can shed light on some of the most fundamental issues in philosophy of mind, such as the content and format of perceptual states, the relationship between perception and cognition, and the role of attention in our mental lives. Perceptual learning influences the rational role of perception, including the quantity and quality of the evidence our perceptions provide. Perceptual learning also enables us pick up on aesthetic and moral properties in our environments, making representations of normative value available for reasoning and decision-making.

The scientific and philosophical investigations of perceptual learning are intertwined. Empirical research can guide us toward areas ripe for philosophical theorizing, and philosophical questions can set psychological research agendas. In the rest of this article, I discuss several strands of this interdisciplinary research on perceptual learning. In section II, I review the history of the study of perceptual learning, as well as some of its basic psychological forms. In section III, I examine the impacts of perceptual learning on the epistemology of perception. In section IV, I consider the pragmatic, moral, and aesthetic implications of perceptual learning. Perceptual learning also connects with several issues in philosophy of mind that I do not have space to discuss fully here, such as the nature of skill, the phenomenology of experience, and the function of perception. I focus on perceptual learning's rational and normative implications because they are especially fertile ground for new research.[4]

II. The History and Nature of Perceptual Learning

Some of the earliest writing on perceptual learning focused on the idea that one's concepts can shape one's perceptions. The Stoics of the 3rd century B.C.E. held that experts and non-experts can have different perceptions of the same object, depending on their conceptual repertoires (Annas, 1992; de Harven, 2018; Shogry, 2019). For example, when listening to the same piece of music, a trained musician's concept of intervals might allow him to hear a quartal harmony, while a musical novice who lacks the concept of intervals might only hear a pretty melody. On this kind of picture, acquiring a new concept need not always change perception, but in many important cases it does.[5]

In the Early Modern period work on perceptual learning took a more scientific turn as the Rationalists and Empiricists debated whether the psychological mechanisms underlying perception are innate or learned. The Rationalist "optic theorists" such as Descartes and Malebranche held that perception is governed by innate principles (Descartes, 1637/2001). In contrast, Empiricists held that perception is governed by simple learning mechanisms. For example, Berkeley argued that we learn to see spatial properties such as distance and magnitude through a "language of vision" that connects visual and tactile representations (Berkeley, 1709/2008; Atherton, 1990; Copenhaver, 2014). Reid introduced the idea of 'acquired' perception, which we gain through our habits of observation and inference (Reid, 1764/1997; Van Cleve, 2004; Copenhaver, 2010; Quilty-Dunn, 2013). Acquired perception is a learned sensitivity to complex properties ranging from geometrical form to personal identity to artistic style. Reid's thorough and scientifically oriented treatment of acquired perception can be seen as a precursor to our contemporary models of perceptual learning.

In the 1950s and '60s, Eleanor and James Gibson established the contemporary psychological research program on perceptual learning (Gibson & Gibson, 1955; Gibson, 1963). They not only conducted dozens of field-changing experiments, but also synthesized their results into the Ecological Theory of perceptual learning, which emphasizes the relationship between a creature and her environment. According to the Ecological Theory, perceptual learning involves extracting information from the environment for the purpose of guiding action.

Eleanor Gibson's work with infants and animals made progress on the debates between Rationalists and Empiricists over which perceptual capacities are innate and which are learned. Gibson's influential "Visual Cliff" experiment, in which infants refused to crawl onto a clear glass surface revealing a drop below, provided evidence that depth perception is innate (Gibson & Walk, 1960). Gibson also conducted visual cliff experiments on newborn chicks and goats, and dark-reared rats and kittens, finding roughly the same patterns of results as she found in human infants (Gibson, Walk, & Tighe, 1959, Walk & Gibson, 1961). These experiments demonstrated that we have a core of innate perceptual capacities that are shared with other animals.

Gibson also investigated how visual systems can learn beyond their innate structures. One of her central focuses was *differentiation*, a form of learning in which we learn to perceive fine-grained differences between stimuli (Gibson, 1969). In some of her most important experiments, Gibson showed that with practice, both children and adults can learn to detect subtle differences between scribbles (Gibson & Gibson, 1955) and letter-like shapes (Gibson et al., 1962) that they had initially found indistinguishable. According to Gibson, differentiation allows each person's perceptions to become attuned to her specific needs and environment (Gibson, 1992).[6]

In the last 60 years, psychologists have continued Gibson's research program, showing that perceptual differentiation occurs in a variety of domains, including color (e.g., Burns & Shepp, 1988), phonemes (e.g., Lively et al., 1993), faces (e.g., McGugin et al., 2011), and flavor (e.g., Ishii et al., 2007). These experiments demonstrate differentiation in sensory modalities beyond vision, including audition and gustation. Philosophers and psychologists have also built on Gibson's theoretical groundwork. Goldstone (1998) developed an influential taxonomy of perceptual learning, which I draw on here. This taxonomy describes four central forms of perceptual learning: differentiation, unitization, intentional weighting, and stimulus imprinting (Goldstone, 1998).[7]
First, following Gibson, differentiation is a process of creating new smaller perceptual units. These units might consist of atomistic features or continuous dimensions.[8] For example, on a featural account, one might learn to see a shade of red as crimson. On a dimensional account (Goldstone & Hendrickson, 2010; Folstein, Gauthier, & Palmeri, 2012; Jones & Goldston, 2013; Burnston, 2017a; 2017b), one might learn to see the same shade of red as having particular values along dimensions such as hue, saturation, and brightness. Featural and dimensional accounts may each be correct for

different types of perceptual differentiation (Goldstone, 1998). The distinction between featural and dimensional learning applies to several of the forms of perceptual learning.

The second form of perceptual learning, *unitization*, creates larger, more complex perceptual units (Goldstone, 2000). Just as we can learn to remember acronyms like NATO and BYOB as single entities rather than as strings of letters, we can learn to perceive stimuli with multiple co-occurring features or dimensions as individual units rather than merely as sets of feature or dimensions. Examples of unitization include word perception (O'Hara, 1980), perception of chess pieces (Chase & Simon, 1973), and perception of dog breeds (Diamond & Carey, 1986). We can also learn to unitize entirely new forms, such as families of "Greebles," which are figures that differ in the shape and orientation of their parts (Gauthier & Tarr, 1977).

The third form of perceptual learning is *stimulus imprinting*. In stimulus imprinting, specialized receptors are developed for detecting particular stimuli, features, or dimensions of stimuli (Goldstone, 1998). For example, receptors for tone frequency are developed in the primary auditory cortex (e.g., Weinberger & Bakin, 1998) and receptors for faces are developed in the fusiform face area (e.g., Rossion & Gauthier, 2002). The outputs of these specialized receptors can be combined in later perceptual processing to create complex object and scene representations (Goldstone, 1998; Schyns, Goldstone, & Thibaut, 1998).

The fourth form of perceptual learning, *attentional weighting*, involves learning how to direct your attention (Goldstone, 1998). The study of the role of attention in perceptual learning dates back at least to William James, who described how perceptual systems can be trained through selective attention and practice (James, 1890/1981). More recent psychological research has focused on how attending to features or dimensions of stimuli enhances our ability to detect and discriminate those stimuli (e.g., Weidner & Müller, 2009; Rangelov, Muller, & Zehetleitner, 2012).[9] One especially interesting type of attentional weighting involves changes in perception across category boundaries.

When we learn that stimuli belong to categories, we begin to attend to the distinguishing features and/or dimensions of those categories. This not only enhances our ability to discriminate stimuli across categories, but can warp our perception, exaggerating central category features or dimensions because they are weighted so highly in processing. This kind of category-driven perceptual learning occurs widely, including with respect to phonemes (e.g., Swan & Myers, 2013), brightness, and size (e.g., Goldstone, 1994).[10]

These different forms of perceptual learning can work together. For example, a radiologist may simultaneously use visual differentiation to pick up on low-contrast aspects of images (e.g., Sowden et al., 2000) and visual unitization to pick up on tumors or lesions (e.g., Brennan et al., 2018; Johnston et. al 2020; Sha et al., 2020). These kinds of learned perceptual skills underwrite perceptual expertise, enabling remarkable feats of perception such as accurate medical diagnosis and musical virtuosity. But perceptual learning also has more mundane practical uses, such as helping us identify our friends and family, navigating our commute to work, and allowing us to tell when food is properly cooked.[11]

While humans may be unique in their ability to develop social events and professions around perceptual expertise, perceptual learning itself— and even the deliberate training of perception—is present throughout the animal kingdom. Pigeons and mice can learn to visually discriminate artistic styles, picking out Renoirs from Picassos (Watanabe, 2011, 2013). Dogs can learn to smell low blood sugar through training as diabetes alert dogs (Rooney et al., 2019). Guppies can learn color and shape discrimination (Lucon-Xiccato, Manabe, & Bisazza, 2018). Human infants also display impressive capacities for perceptual learning. 3.5-month-old infants can learn to visually differentiate faces that vary in spatial configuration (Galati, Hock, & Bhatt, 2016). Infants can also learn to improve their auditory word segmentation (Thiessen, Hill, & Saffran, 2005) and phoneme categorization (Werker et al., 2007) through exposure to infant-directed speech. The presence of perceptual learning in infants and animals indicates that while perceptual learning does sometimes draw on cognition, as in the domains of chess (Chase & Simon, 1973) and mathematics (Landy & Goldstone, 2007, Kellman, Massey, & Son, 2009), perceptual learning does not require the presence of sophisticated cognitive systems.

These experiments on infants and animals only provide behavioral evidence of perceptual learning. So, one might wonder what precise kinds of perceptual changes underly the various improvements in infants and animals' discriminatory capacities. Are these changes to perceptual content, format, phenomenology, or only to the link between perception and action?[12] This question must be considered for each experiment individually, so I do not have the space to answer it fully here. For my purposes, I understand perceptual learning permissively, so that it encompasses all the above types of changes to perception. This is in the spirit of Gibson's definition of perceptual learning as long-lasting changes to perception caused by repeated experience with a stimulus-type over time (Gibson, 1963, p. 29).[13] These long-lasting changes might be to the content, format, phenomenology, links to action, or any other features of perceptual systems.[14]

III. Perceptual Learning and Epistemology

One significant philosophical impact of perceptual learning is that it pushes us to consider whether epistemic concepts such as rationality, justification, expertise, and knowledge apply beyond cognition. Traditionally, cognition is taken to be the primary locus of these concepts. Cognitive states and processes such as beliefs, judgments, and reasoning patterns are the topic of both most everyday discussions of rationality and most mainstream epistemology. Yet perceptual learning highlights that perceptual states and processes share many of the central features that underlie our epistemic evaluations, such as reliance on stored bodies of information and sensitivity to new reasons.

A classic picture of perception is as a modular, innately specified input-output system that relies on a proprietary information store (Fodor, 1983; Pylyshyn, 1999). On this picture, while perceptual states vary depending on the stimuli one encounters, they cannot be synchronously influenced by cognitive states such as beliefs, desires, and expectations. Perception is thus dubbed 'cognitively impenetrable' (Pylyshyn, 1999). This fixed model of perception is antithetical to deliberative thought, in which beliefs, expectations, desires, and other broadly cognitive states regularly influence each other. If perception is insensitive to our rationally considered beliefs, it is hard to see how perception could be rationally evaluated as justified or unjustified. Instead, it seems outside the realm of rational evaluation.

Some philosophers and psychologists have argued that contra this classic picture, perception is cognitively penetrable, and our beliefs, desires, and expectations can influence perception (e.g., Prinz, 2006; Lupyan, 2015; Block, 2022). The possibility of cognitive penetration fuels arguments that perceptual experiences can respond to reasons provided by cognitive states, and are thereby rationally evaluable (Siegel, 2011, 2017). Given both the controversy over whether cognitive penetration occurs and the rich epistemic implications of perception responding to reasons, it is worthwhile to look for additional ways perception might respond to reasons, irrespective of cognitive penetrability.

Perceptual learning introduces one such way. The existence of diachronic perceptual learning is far less controversial than the existence of synchronous cognitive penetration. Even Fodor allows that perceptual systems can be slowly and gradually influenced by environmental stimuli or by the agent's background beliefs, albeit in a limited way (Fodor, 1984).[15] While some forms of perceptual learning involve responses to information stored in cognition, perceptual learning is typically not classified as a form of cognitive penetration because it occurs diachronically rather than synchronically (Fodor, 1983; Ransom 2020b).[16] In contrast, some philosophers have argued that perceptual learning should be understood as form of cognitive penetration (thus impugning modularity), because perceptual learning shows that perception and cognition do not have truly independent information stores (e.g. Churchland, 1988; Stokes, 2014). Whether perceptual learning is ultimately a form of cognitive penetration or not, the important point for epistemology is that compared to synchronous cognitive penetration, perceptual learning is a significantly less psychologically controversial way in which perception might be sensitive to our reasons.

How might perceptual learning display sensitivity to reasons? When beliefs or inference patterns repeatedly occur in conjunction with a perceptual stimulus-type, the relevant information can be gradually transferred to perception. For example, through extensive experience perceiving chess boards and contemplating available moves, chess players learn to visually unitize the pieces on the board into chunks (Chase & Simon, 1973; Gobet & Simon, 1996; Leone et al., 2014). The unitization is driven not only by visual stimuli, but also by knowledge of the rules and strategy of the game.[17] It is a substantive philosophical question whether this unitization is a rational response to the reasons provided by the chess master's experience and knowledge or merely a brute causal response.[18] At the least, such examples demonstrate that perceptual learning shares the flexibility and sensitivity to new information that is typical of reasoning in cognition.

Bayesian models of perceptual learning further support the idea that perception has much in common with reasoning. According to Bayesian models of perception, perception's basic processing structure is Bayesian updating. This idea originated with the 19th century psychologist Hermann von Helmholtz, who held that perception is comprised of a series of learned probabilistic inferences (von Helmholtz, 1867).[19] This picture has continued to flourish in contemporary research on Bayesian models of perception (e.g., Brainard & Freeman, 1997; Knill & Richards, 1996; Geisler & Kersten, 2002; Yuille & Kersten, 2006; Rescorla, 2015; Zhao et al., 2021). Bayesian models of perception state that perceptual learning consists of updating environmental priors in response to data from experience, in accordance with Bayes' Theorem (e.g., Knill, 2007). Bayesian updating is a paradigmatically rational mode of reasoning (Teller, 1976; Jeffrey, 1983). While perceptual Bayesian models may draw on different databases of priors from cognitive Bayesian models, they nonetheless share a core processing structure that is typical of rational belief revision.[20]

The rational impacts of perceptual learning also extend to the justification perception provides for beliefs. Perceptual learning can influence our perceptual states, and thus the beliefs they justify. On some views, perceptual learning is best characterized by a change in our capacities to identify and discriminate objects (Markie, 2006; Brogaard & Gatzia, 2018; O'Callaghan, 2019). On this kind of view, when we have learned to identify objects or features on the basis of a particular experience-type, we become justified in identifying objects or features on that basis (Markie, 2006). On other views, perceptual learning is best characterized by a change in the content of our perceptual states (Connolly, 2014, 2019a; Chudnoff, 2017). On this kind of view, the change in perceptual content induces a corresponding shift in the beliefs the experience justifies. For example, in color differentiation subjects learn to discriminate between similar colors (Goldstone, 1994), indicating that the content of their perceptual experience shifts from e.g., <yellow> to <canary yellow>.[21] This new perceptual experience justifies a new set of beliefs, such as the belief that canary yellow is lighter than Dijon yellow. Other forms of perceptual learning such as unitization, stimulus imprinting, and attentional weighting can similarly change the contents and capacities of perception. Some of these forms of perceptual learning can incorporate information across sensory modalities, generating new multisensory perceptual contents and capacities, such as rhythm or flavor perception (Connolly, 2019a; O'Callaghan, 2020). When perceptual learning alters perception in these various ways, it shifts the beliefs perception justifies.

Through these sorts of changes, perceptual learning offers a potential psychological route to rich (or high-level) contents of perceptual experience. Vision uncontroversially has thin (or low-level) contents, which include properties such as shape, color, texture, motion, luminance, and spatial relations (Pylyshyn, 1999). Some philosophers argue that visual experience also has rich contents, which include properties such as natural kind membership, personal identity, emotions, action affordances, and moral status (e.g., Siegel, 2006, 2010; Bayne, 2009; Masrour, 2011; Nanay, 2011, 2012; Block, 2014; Werner, 2016; Green, 2017; Toribio, 2018a).[22] It is a natural thought that if perception has rich contents, they make their way into perception through cognitive penetration. For example, your belief that a dog is an Australian Shepard might cause you to see the dog as an Australian Shepard. However, as noted earlier, it is controversial whether this kind of synchronous cognitive penetration occurs.[23] Additionally, many plausible cases of rich perceptual content occur when the subject lacks this a relevant simultaneous cognitive state (e.g., one might visually perceive a ball landing in a potted plant as causing the lights to go out despite believing the two events are unrelated (Siegel, 2010, p. 122)). So, arguments for rich contents are on firmer ground if they posit alternative ways to enrich the contents of perceptual experience beyond cognitive penetration.

Perceptual learning provides one such alternative. For example, an experienced dog groomer might see learn to see dogs as Australian Shepherds or Border Collies. On a featural account, this learning would involve visually unitizing each dog breed's co-occurring features, such as size, head shape, eye color, and coat length, texture, and pattern (Diamond & Carey, 1986). On a dimensional account, this learning would involve placing each breed in a space across various continuous dimensions, such as small to large body, pointy to rounded head, dark to light eyes, long to short coat, rough to smooth coat, and solid to variegated coat pattern (Folstein, Gauthier, & Palmeri, 2012; Burnston, 2017a; 2017b).[24] Either way, the rich contents acquired through perceptual learning enhance what we can justifiably know based on our perceptual experience.[25] For example, your perception of a dog as an Australian Shepherd justifies your belief that the dog is an Australian Shepherd, as well as your belief that the dog requires a lot of exercise.

Perceptual learning not only influences what perception justifies, but also calls into question the source of that justification. Epistemic Internalists typically take perception to be an 'unjustified justifier', meaning that it provides justification for beliefs without itself being epistemically evaluable as justified or unjustified (Chisholm, 1977). On this picture, perception provides justification in virtue of its phenomenal character, rather than in virtue of any inherited justificatory status (Pryor 2000; Bengson, 2015). In contrast, belief provides justification in virtue of its own justificatory status, which typically derives from the way it is formed and maintained. The idea that perception is an unjustified justifier is appealing if one thinks of perception as a polished mirror reflecting the world, but the psychology of perceptual learning illustrates that perception can also reflect back our own past experience and knowledge.[26] Some perceptual experiences that result from perceptual learning are formed in response to stored perceptual information, much in the same way that beliefs are formed in response to supporting beliefs. For example, when a chess master perceives a Queenside castling on the board, her visual experience is formed in response to not only her early visual representation of the locations of the rook and king, but also the stored information from visual unitization that if the rook and king are in these locations, there is a Queenside castling. These states are not only causal antecedents of the perceptual experience of the castling, but also plausibly epistemically justify it, given that their contents, structures, epistemic dependency relations, and degree of flexibility in light of new information are strikingly similar to those of paradigmatic justified beliefs (Jenkin, forthcoming). Perceptual learning jeopardizes the role of perception as an unjustified justifier and raises the possibility that the scope of epistemic justification may extend into perception (cf. Ransom, 2020b).[27]

The considerations discussed in this section so far indicate that perceptual learning has the potential to epistemically enhance perception in a variety of ways, including in the beliefs perception justifies, perception's ability to respond to reasons, and perception's justificatory status. When perceptual learning is especially successful in enhancing perception, it leads to perceptual expertise (Kellman & Massey, 2013; Connolly, 2019a; Chudnoff, 2020; Ransom, 2020b). Expertise is not only a psychological notion but also an epistemic one. Experts have special connections to truth, evidence, or knowledge. While there are various theories of what exactly constitutes expertise, it is widely thought to manifest in an individual's beliefs (e.g., Goldman, 2016). An expert on medieval literature will have beliefs about medieval texts that are unlike those of nonexperts. Through perceptual learning, though, expertise can manifest in perception rather than (or in addition to) belief. For example, through olfactory training perfumiers' olfactory systems become different from those of non-experts as they learn to differentiate and classify odors (Royet et al., 2013; Barwich, 2017).[28]

Just as there are various theories of cognitive expertise, there are various theories of perceptual expertise. These theories of perceptual expertise graft onto theories of perceptual learning itself, specifically theories of whether perceptual learning involves learning new facts or new capacities. On the view that perceptual learning involves perceptually learning new facts, perceptual expertise involves a substantive or special acquisition of these new facts (Chudnoff, 2017; Chomanski & Chudnoff, 2018). For example, an expert perfumier knows that jasmine smells sweeter than gardenia, as well as facts about the relative sweetness of many other flowers. She accesses these facts through experiences with corresponding representational contents. On the view that perceptual learning involves learning new perceptual capacities (Brogaard & Gatzia, 2018, O'Callaghan, 2019), perceptual expertise is constituted by a substantive or special set of perceptual capacities. For example, an expert perfumier has the capacity to differentiate the scent of jasmine from that of gardenia, and the capacity to rank floral scents according to sweetness. On this view, perceptual expertise need not be contained in an experience's representational content, but is instead manifests in how an agent can use her experiences.

These two views are not mutually exclusive. As Chomanski & Chudnoff (2018) note, perceptual expertise might involve both representing new facts in experience and acquiring new capacities. Along these lines, Chudnoff (2020) argues that perceptual expertise involves a capacity for forming impressions that is grounded in search strategies for a particular domain. These impressions are perceptual experiences with unique representational contents that are not achievable by novices. For example, a radiologist might deploy expert search strategies when look at an x-ray and thereby have a perceptual experience as of a lesion that would be unavailable to a non-expert. On this view, the acquisition of new capacities and changes to representational content go hand in hand.

Whichever of these accounts of perceptual expertise turns out to be correct, these recent theories of perceptual expertise demonstrate that the epistemology of expertise is equally rich in the perceptual domain as in the cognitive.

IV. The Pragmatic, Moral, and Aesthetic Impacts of Perceptual Learning

Perceptual learning is not only of epistemological interest but is also relevant to other areas of philosophical inquiry. In this section, I survey some of these connections.

First, perceptual learning has many pragmatic uses that can help us achieve our goals. One such use is transforming perception to fits the needs of cognition and action (Goldstone, 2015). For example, learning to differentiate phonemes in a new language facilitates both linguistic understanding and speech production (Lively et al., 1993; Bradlow et al., 1999; O'Callaghan, 2011). Perceptual learning can also free up cognitive resources such as attention and memory so that they are available for other tasks (Connolly, 2019a).[29] For example, when we learn to auditorily differentiate phonemes automatically, rather than through deliberate cognitive examination, we free up attention to formulate a reply. Perceptual learning can also help compensate for sensory impairments, such as presbyopia (decreased ability to focus one's eyes) (Deveau & Seitz, 2014) and amblyopia (weakness in one eye) (Levi & Li, 2009; Astle, Webb, & McGraw, 2011; cf. Zhang et al., 2014). Perceptual learning can also enable the use of sensory substitution devices, by helping subjects direct their attention toward the aspects of the stimulus (Connolly, 2019a, 2019b).[30] Perceptual expertise is essential to a variety of professions such as radiology, medicine, engineering, vehicle mechanics, construction, product testing, architecture, landscaping, and more.

In the moral domain, perceptual learning can help us pick up on morally relevant properties. For example, learned distributions of perceptual attention might aid in detecting deliberate mispronunciations of foreign names or dismissive body language that constitute microagressions. Here, perceptual learning helps detect descriptive properties (such as the accuracy of phonetics or the shape of visual gestures) that ground moral properties (such as moral goodness and badness). This form of perception is often labeled 'indirect moral perception.' Some philosophers have argued that perceptual learning can also help us directly perceive moral properties. This idea dates back to Aristotle (1999), who stressed the importance of the "apparent good" in our moral psychology (Moss 2012). The idea of moral perception is still very much alive among contemporary philosophers (e.g., Murdoch, 1970; Audi, 2013; Cowan, 2014; Werner, 2016; McGrath, 2018).[31] Audi (2013) argues that not only do we perceive moral properties, but moral perception supports (or at least fits especially well with) a version of metaphysical realism about those moral properties.[32] I remain neutral on the metaphysics of moral properties here, but any account of moral perception should be able to explain moral perception's objects and correctness conditions.

How might we acquire the capacity for direct or indirect moral perception? It is certainly possible that at least the core of moral perception is innate. However, the high degree of individual variance in the accuracy and sensitivity of moral perception indicates that it is influenced by learning. Some philosophers have argued that moral perceptual learning is a kind of cognitive penetration in which perception becomes inflected with preexisting moral knowledge (e.g., Cowan, 2014). Wholly bottom-up processes are also psychologically plausible for some forms of moral perceptual learning, but when combined with direct views of moral perception they face the question of how perception could directly represent abstract moral properties absent cognitive influence. Indirect views of moral perception avoid this question because they only require that we learn to improve our detection of the descriptive grounds of moral properties. The descriptive grounds of moral properties are typically properties we already grant can be represented without cognitive influence.

In the aesthetic domain, perhaps the most striking appearance of perceptual learning is in its artistic and narrative depictions, which provide a window into the phenomenology of learned perception. In *Gulliver's Travels*, Swift describes Gulliver's return home to England after four years in the kingdom of Brobdingnag, where the grass is as tall as trees and the inhabitants as tall as skyscrapers. Gulliver's visual experience has adjusted to these colossal sizes, so human-sized objects now appear miniscule: "I saw his dishes of the size of a silver three-pence, a leg of pork hardly a mouthful, a cup not so big as a nutshell," (Swift, 1726/2005, p. 136). While such literary depictions may not be psychologically accurate, they allow us to inhabit the perspectives of individuals whose perceptual learning histories are very different form our own.

Equally important is perceptual learning's role as a locus of artistic and critical skill. Just as radiologists can learn to see lung cancer on chest scans (Sha, 2020), painters may learn to see subtle differences in types of brushstrokes. Music critics may learn to hear allusions to classic works or rich aesthetic properties such as gracefulness.[33] Aesthetic perceptual expertise often manifests in attention. Psychological studies show that trained artists can better attend to important structural and abstract features of artworks, whereas novice devote their attention to objects and figures (Antes & Kristjanson, 1991; Vogt & Magnussen, 2007). This kind of educated allocation of attention plausibly underlies the expert critical taste that Hume influentially described in *Of the Standard of Taste* (Hume 1757). Hume argues that with sufficient practice evaluating and comparing aesthetic objects, everyone's taste will ultimately converge with that of the ideal critic. While Hume leaves it unclear as to what exactly such practice consists in, perceptual learning is plausibly one of its central components.

Some forms of perceptual learning call into question whether our critical practices latch onto objective aesthetic truths. The mere exposure effect is a form of perceptual learning in which repeated exposure to a stimulus-type (i.e., an artistic style, technique, or subject matter) enhances our liking and evaluation of that stimulus-type. This is because exposure increases perceptual fluency (the ease with which a stimulus is processed), and greater fluency leads to greater positive affect (i.e., easy processing feels good). This positive affect is then misattributed to the work of art perceived (Reber et al., 1998). If our positive aesthetic evaluations are a function of internal processing dynamics rather than external features of artworks, beauty seems in some sense to be in the eye of the beholder (Reber et al., 2004).[34]

While perceptual learning is beneficial across domains of philosophical inquiry, it also has its downsides. Perceptual learning often tracks statistical regularities, so statistical abnormalities lead to perceptual illusions. These illusions have negative epistemic consequences. For example, through multisensory speech perception, we learn to expect certain mouth movements to co-occur with certain sounds. When these signals fail to co-occur and different syllables are presented to vision and audition, we experience illusory perceptions that match neither syllable (McGurk & MacDonald, 1976; Mitchel et al., 2014). Such illusions undermine our knowledge of the external world. They also have negative pragmatic implications. For example, when experiencing an illusion of speech perception we may be unable to fulfil our practical aims of understanding and communicating.

Perceptual learning can also encode harmful biases and stereotypes. Concepts such as black and crime can become associated through e.g., media portrayals, and subsequently function as "visual tuning devices," biasing visual attention toward black faces after the concept of crime has been primed (Eberhardt et al., 2004).[35] These visual biases may contribute to unjust and disproportionate arrests of black men. They may also further solidify the stereotypic associations that drive them, in a self-perpetuating cycle. Such perceptual manifestations of bias have prompted philosophers to question whether statistical generalizations are always justified (Gendler, 2011; Munton, 2019). Cases of perceptual biases plausibly constitute both moral and epistemic failures.[36]

Another moral downside of perceptual learning is the possibility of expert sadists or moral deviants.[37] If we can learn to perceive moral properties, some agents might learn to see moral goodness and badness in the wrong circumstances due to social structures, upbringing, or individual ill will. For example, in Dickens' *Great Expectations*, Miss Havisham raises Estella under a moral system that disvalues displays of emotion and values mocking and tormenting men (Dickens, 1860). We might imagine parts of this moral system manifesting in deviant moral perception. For example, Estella might see displays of emotion as morally bad and men's torment as morally good.[38] Real world versions of such miscalibrated moral perception might occur when individuals are raised in sexist, racist, or homophobic communities. As Goldie (2007) points out, the fact that a perception feels phenomenologically immediate (as states that result from perceptual learning typically do) does not guarantee its accuracy or justification.

In the aesthetic domain, one surprising downside of perceptual learning is that it can sometimes diminish our aesthetic pleasure. When we learn to differentiate the good from the bad, our enjoyment of the bad often suffers. A coffee drinker who learns the difference between the taste of high- and low-quality beans may start to actively dislike the latter, when previously they were pleased at every cup. Film critics who have learned to attend to every aspect of cinematography, directorial choice, and production design may find themselves so attuned to these details that they are unable to appreciate the film as a holistic work.

These negative impacts bring out the limits of our control over perceptual learning. We cannot directly determine which regularities our perceptual systems pick up on, when learning starts and stops, or when learning will transfer to similar contexts. But there are several things we can do: we can alter the stimuli we are exposed to, we can deliberately focus our attention, and we can reward effective learning (Seitz et al., 2009; Zhang et al., 2018; Tamaki et al., 2020). These techniques provide hope for some degree of indirect control over perceptual learning in both its positive and negative respects.

V. Conclusion

Perceptual learning motivates an extension of many of our philosophical inquiries into the perceptual domain. Justification, expertise, statistical reasoning, artistic criticism, moral knowledge, and more are not merely constituted by our beliefs and actions, but also branch into perception. These branches are just beginning to be explored, but they hold the potential to transform our picture of perception from a mere informational input system into a system written through with rationality and normative import.

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Endnotes

[1] For evidence that radiologists undergo perceptual learning, see Krupinski (1996), Sowden et al. (2000), Sheridan & Reingold (2017), Brennan et al. (2018), Alexander et al. (2020), Johnston et al. (2020), Richter et al. (2020), and Sha et al. (2020).
[2] This is a paraphrase. Gibson's own wording of the definition of perceptual learning is, "any relatively permanent and consistent change in the perception of a stimulus array, following practice or experience with this array" (Gibson, 1963, p. 29).
[3] E.g., Connolly (2019a) draws on empirical data to defend the philosophical claim that perceptual learning leads to genuine changes in perception.
[4] For additional overviews of perceptual learning, see Goldstone (1998), Kellman & Massey (2013), Goldstone & Byrge (2015), Connolly (2017, 2019a), Seitz (2017), and Prettyman (2018).
[5] The 14th century Nyāya philosopher Gangesha Upadhyaya holds a similar view according to which some of our perceptions are nonconceptual whereas others are conceptually laden (Phillips, 2012).
[6] For an overview of Gibson's theory of perceptual learning, see Adolph & Kretch (2015).
[7] Goldstone (1998) presents these four forms of perceptual learning in a different order from the one I use here. This taxonomy is developed in Goldstone & Byrge (2015). For additional discussion of the taxonomy of perceptual learning, see Prettyman (2018) and Connolly (2019a).
[8] I thank an anonymous reviewer for suggesting I highlight this distinction and for pointing me to the citations of the dimensional account.
[9] I thank an anonymous reviewer for sharing these two citations. For further discussion of attentional weighting, see Connolly (2019) and Ransom (2020a).
[10] For arguments that categorical perception involves locating an object within a region of dimensional space, see Burnston (2017a, 2017b).
[11] In one of the earliest examples of perceptual learning, Aristotle discusses the example of a baker who has learned how to see a loaf of bread as done when it is ready to come out of the oven (*De Anima*, 1112b33-1113a2).
[12] I thank an anonymous reviewer for raising these questions.
[13] While Gibson's 1963 definition of perceptual learning is stated permissively, at certain points in her career she held more restrictive views about the definition of perceptual learning. In her 1969 book she held that perceptual learning involves learning about distinctive features of objects—a kind of change in content (Gibson, 1969). In her 2000 book, she held that perceptual learning involves learning affordances for action (Gibson & Pick, 2000). See Adolph & Kretch (2015) for discussion.
[14] While the notion of perceptual learning I use here is relatively permissive, others have argued for more restrictive definitions of perceptual learning. For further discussion, see Goldstone (1998), Goldstone & Byrge (2015), Watanabe & Sasaki (2015), Connolly (2017, 2019a), Prettyman (2018), Chudnoff (2020).
[15] I thank an anonymous referee for emphasizing this point. See Connolly (2017, section 3.4) for further discussion of the debate between Fodor and Churchland over whether perceptual learning is a form of cognitive penetration.
[16] See Quilty-Dunn (2020a) for arguments that the notion of cognitive penetration permits of diachronic cognitive influence, while the notion of informational encapsulation does not.
[17] Other domains of perceptual learning that may be partially driven by cognition include Greebles (Gauthier & Tarr, 1997), radiology (Krupinsky, 1996), and phonemes (Lively et al., 1993).
[18] For arguments that perceptual learning does involve rational responses to reasons, see Jenkin (forthcoming).
[19] See Westheimer (2008) for discussion of the continuity between Helmholtz's writings and the contemporary Bayesian project.

[20] For discussion of the extent of the similarities between perceptual and cognitive Bayesian updating, see Orlandi (2014) and Rescorla (2015).
[21] I use angle brackets to denote contents.
[22] See Mandelbaum (2017) for arguments that the outputs of vision are basic-level concepts. This view is more permissive than a view that posits exclusively thin contents, but it also puts significant restrictions on rich contents.
[23] For arguments in favor of cognitive penetration, see Prinz (2006), Lupyan (2015), Block (2022). For arguments against cognitive penetration, see Fodor (1983), Pylyshyn (1999), and Firestone and Scholl (2016).
[24] An anonymous reviewer helpfully notes that the possibility that perceptual learning enriches the contents of perceptions may be dependent on the format of perception (i.e., whether perception is iconic or discursive). If perceptual representations are iconic and cognitive representations are discursive, perceptual learning could enrich perception without the involvement of cognition by increasing the range of iconic features or dimensions represented. If perceptual and cognitive representations are both discursive, cognitive penetration may be necessary to generate new discursive symbols. The truth of this latter claim depends on theories of concept/symbol acquisition, as well as on what counts as cognitive penetration. For discussion of this set of issues, see Burnston (2017a, 2017b, 2020), Toribio (2018a, 2018b), Quilty-Dunn (2020b), Mylopoulos (2021), Shepherd (2021), and Ferretti & Caiani (forthcoming). I thank the anonymous reviewer for suggesting this list of citations.
[25] For further discussion of whether perceptual learning leads to rich contents of experience, see Siegel & Byrne (2017), Connolly (2019a), and Ransom (2020a, 2020b). For discussion of the idea that the information stored in cognitively impenetrable modules can change due to experience, see Scholl & Tremoulet (2000), Goldstone (2015), and Toribio (2018b).
[26] For a different kind of critique of the picture of perception as a mirror, see Rorty (1979).
[27] See Siegel (2017) for related arguments that cognitive penetration jeopardizes the role of perceptual experience as an unjustified justified. See Chudnoff (2017) for related arguments that perceptual learning gives us reason to think perception not only generates new justification, but also preserves justification derived from background beliefs (cf. Brogaard & Gatzia, 2018).
[28] Some forms of perceptual expertise may emerge without deliberate training. For example, Joy Milne, a rare "Super Smeller," spontaneously discovered that she could detect Parkinson's disease by odor with astonishing accuracy (Trivedi et al., 2019). In such cases, perceptual expertise may be innate or unintentionally learned.
[29] Connolly argues that freeing up cognitive resources is not only a practical implication of perceptual learning but also its function (Connolly, 2019a).
[30] Sensory substitution devices translate environmental information into novel formats so that it can be accessed by people with sensory deficits. For example, Bach-y-Rita's TVSS (Tactile-Visual-Sensory-Substitution) device for people who are blind or visually impaired converts visual information into tactile stimulation on a subject's back (Bach-y-Rita & Kercel, 2003). Eagleman's Neosensory Buzz wristband for people who are deaf or hard of hearing converts auditory information to vibrations (Perrotta, Asgeirdottir, & Eagleman, 2021). By learning to perceptually attend to the relevant properties of the sensory stimulation provided by the device, subjects can decode the meaning of the environmental information. There may also be significant cognitive involvement in this learning process (Deroy & Auvray, 2012).
[31] For critique and discussion of the limitations of moral perception, see Dancy (2010), Chudnoff (2016), and Reiland (2021).
[32] Audi (2018) clarifies that his 2013 view leaves open the possibility of anti-realist views of moral properties.

[33] A similar issue arises here as in the moral domain with respect to realism about aesthetic properties. One might think that the ability to perceive rich aesthetic properties such as gracefulness supports metaphysical realism about those properties. However, as in the moral case, the perception of rich aesthetic properties is compatible with anti-realist views of those properties so long as the anti-realist can offer a plausible story about their objects and correctness conditions.
[34] For criticisms of this argument, see Nanay (2017).
[35] For additional discussion of the implications of Eberhardt's results, see Alexander (2010, pp. 101-106), Siegel (2017, pp. 174-177), Brownstein (2018, pp. 35-36), and Munton (2019).
[36] For further discussion of the downsides of perceptual learning, see Connolly (2019a, pp. 2016-2017).
[37] I thank an anonymous reviewer for suggesting this possibility.
[38] This kind of perceptual learning may or may not be psychologically realistic. This is a hypothetical example meant to illustrate the impacts of this type of moral perceptual learning, if it does occur.