forthcoming in *Journal for the General Philosophy of Science*

Maturationally Natural Cognition, Radically Counter-Intuitive Science, and the Theory-Ladenness of Perception*

Robert N. McCauley
Center for Mind, Brain, and Culture
Emory University

Abstract:
Theory-ladenness of perception and cognition is pervasive and variable. Emerging maturationally natural (MN) perception and cognition, which are on-line, fast, automatic, unconscious, and, by virtue of their selectivity, theoretical in import, if not in form, define normal development. They contrast with off-line, slow, deliberate, conscious perceptual and cognitive judgments that reflective theories, including scientific ones, inform. Although culture tunes MN systems, their emergence and operation do not rely on culturally distinctive inputs. The sciences advance radically counter-intuitive (RCI) representations that depart drastically from MN systems' deliverances. Extensive experience with RCI scientific theories can result in a practiced naturalness with their perceptual and cognitive consequences; nevertheless, automatic MN verdicts persistently intrude. Fodor suggests that the *uniformity* of the biases MN systems introduce can serve as a theory-neutral means for adjudicating scientific disputes. Findings about vision challenge Fodor's proposal for circumventing problems that MN theory-ladenness presents. These considerations indicate that RCI scientific ideas are difficult to learn, master, and deploy; consequently, the corrective import of science's social and institutional arrangements plays a critical role in its epistemic stature.

Keywords: theory-ladenness, perception, cognition, maturational naturalness, dual systems

1. Introduction

How far theory-ladenness extends depends, in part, on how the notion of the theoretical is construed. Arguably, considering the influence of theoretical biases on *perception*, in particular, *presumes* a liberal conception, since perception is so unreflective, typically, even in scientific research. A liberal conception of the theoretical includes within its purview biased perceptual responses that depend on a perceiver's cognitive dispositions -- regardless of their origin. Such a liberal account of the theoretical exposes epistemically relevant continuities between the place of perception in sophisticated, professional science and in the most mundane forms of getting about in the world and between the influence of explicit, formal theories on careful, conscious, scientific observation and the influence of maturationally natural dispositions of mind on automatic, unconscious, inarticulate perception.

Humans' maturationally natural proclivities undergird a theory-ladenness of perception that is inescapable. That alone, though, need not jeopardize the rationality of science, as some philosophers of science recognize. Failing to appreciate how much material and cultural circumstances influence maturationally natural aspects of perception, however, does threaten some proposals, specifically Jerry Fodor's (1990), for surmounting the challenges of the theory-ladenness of perception.

Section 2 presents some philosophical and psychological preliminaries. Section 3 delineates maturationally natural dimensions of perception and cognition as one species of automatic, unconscious, mental activity. Commensurate with dual process theories in cognitive science, this broadly intuitive mentation contrasts with more reflective, conscious forms of thinking and perceiving, but also with another form of fast intuitive perception and cognition, acquired after extensive experience or practice. Section 4 examines the relationship of these maturationally natural dimensions of perception and cognition with the perceptual and cognitive demands of theoretical science. Sooner or later, science involves representations that fail to square with the deliverances of humans' maturationally natural capacities and that are, in this regard, radically counter-intuitive (RCI). Section 5 considers how maturationally natural verdicts about the world automatically intrude in perception and thought and impede learning and mastering science. Section 6 briefly reviews Fodor's proposal for managing the theory-ladenness of perception rooted in maturationally natural aspects of vision. Then it outlines findings from cross-cultural experimental research bearing on the cultural infiltration of maturationally natural dimensions of visual perception that pose a problem for that proposal. Section 7 argues that the persistence and invisibility of maturationally natural influences on individual scientists' perceptual judgments pose challenging, but not insurmountable, problems for science education and for accounts of science's epistemic prominence. Various social and institutional arrangements in science play a decisive role in correcting for the possibility of individual scientists' limitations.

2. Naturalism and the Selectivity of Theories

One thing that even the most lingua-focal philosophers, the most phenomenologically-oriented philosophers, and the most naturalistic philosophers can agree about is that explicitly formulated, *scientific* theories are made up of concepts. What the first and the third disagree about is what concepts are. (See, for example, Machery 2009). What the second and the third disagree about is how broadly and how deeply theories and their concepts apply (Churchland 1989). These disagreements are not peculiar to concepts but are, instead, born of broader differences about methods. Naturalists are more liberal, at least in the sense that they include all of the methods of these other philosophers *and more*.

Comparatively, naturalists are less impressed with philosophical methods overall. The history of Western philosophy, in the Modern era especially, is a history of philosophical speculations spawning sciences, which return, not much later, as contributors to understanding topics, on which philosophy had presumed it held a proprietary claim. Many philosophers (and humanists, generally) find these scientific proposals presumptuous, pushy, and offensive; by contrast, naturalists welcome them. Naturalists differ among themselves in how prominent a role they accord scientific accounts of things, but they all agree that philosophical tools and pronouncements possess no inherent superiority over the hypotheses, methods, and discoveries of modern science concerning empirical questions.

Naturalists' methodological liberalism inclines them to adopt comparably liberal conceptions of theories. Whatever philosophers take scientific theories to be, from logically integrated sets of sentences (Hempel 1965) to patterns of connection strengths in neural networks (Churchland 1989), one thing all agree about is that theories are speculative in that they *select* among what we experience, perceive, and know. They choose particular items, features, events, processes, or relations, from amongst the limitless possibilities of what might bear on some explanandum. Theories are conjectures about what does and does not matter, any appearances to the contrary notwithstanding, for obtaining explanatory understanding about phenomena.[1] They often reveal hitherto unrecognized patterns. Theories instruct us about which variables to manipulate in order to predict or control outcomes. In all of these respects and more, theories highlight what we should attend to.

For any perceptual or cognitive system, then, to select among inputs is, in effect, to *theorize*. To select systematically is, functionally, to entertain a theory, whether or not that selection is conscious and whether or not the entertained theory is formulated linguistically. Perceptual and cognitive mechanisms that carry out such systematic selection *embody* theories, irrespective of those mechanisms' novelty or complexity or of those theories' origins. If, for example, theories are patterns of connection strengths in neural networks, as Paul Churchland (1989, pp. 188-89) proposes, then

> . . . no cognitive activity whatever takes place in the absence of some theory or other.
>
> This perspective bids us see even the simplest of animals and the youngest of infants as possessing theories . . . The difference between us and them is not that they lack theories. Rather, their theories are just a good deal simpler than ours, in the case of animals. And their theories are much less coherent, less organized, and less informed than ours, in the case of infants. . . . But insofar as there is cognitive activity at all, it exploits whatever theory the creature embodies, however useless or incoherent it might be.

Naturalists contend that from the standpoints of perceptual and cognitive processing, of underlying mechanisms, and, therefore, finally of theoretical *form*, nothing of epistemically-principled importance differentiates the influence -- with regard to perception, judgment, and inference -- of humans' maturationally natural perceptual and cognitive proclivities from that of the painstakingly acquired command of professional sciences' most esoteric theories. As Churchland stresses, the major difference between maturationally natural theoretical commitments and those of professional science concerns their comparative sophistication. This paper argues that they also differ with respect to the ease with which human minds utilize them and with respect to their vulnerability to interference and to decay.

Since Norwood Russell Hansen's *Patterns of Discovery* (1958), philosophers of science have wrestled with the epistemic implications of theory-impregnated perception and cognition in science. On the naturalists' liberal account of the theoretical, the theory-ladenness of perception and cognition comes in at least two varieties. These correspond broadly to two types of cognitive processing that cognitive scientists have been differentiating for nearly forty years (Schneider and Shiffrin 1977; Shiffrin and Schneider 1977; Kahneman 2011).[2] Dual process theories distinguish between slow, reflective, conscious cognition and fast, intuitive[3], unconscious cognition. Since the former involves deliberate, conscious, articulable thought, it is described as *off-line.* By contrast, intuitive cognition is *on-line,* because it occurs automatically and, typically, without verbal representation. The discovery and illumination of the latter has especially set the theories and findings of the cognitive sciences off from both commonsense and most philosophical conceptions of the mind.

Since Chomsky's claims in the 1960s about speakers' tacit knowledge of their grammars, cognitive scientists have examined the myriad ways that perception, thought, and action reflect humans' thorough-going familiarity with and use of vast bodies of knowledge about scores of matters that they are usually just as thoroughly unaware that they possess (Reber 1993). While philosophers squabbled about whether these capacities merited the label “knowledge” (Harman 1974), cognitive scientists plunged ahead with explorations in dozens of domains of the representations and processes of these fast, automatic perceptual and cognitive systems.[4]

At least since Thomas Kuhn’s (1970) discussion of experimental participants’ initial failures to correctly identify the suits of anomalous playing cards (e.g., red spades), philosophers of science have recognized that influences of theories on perception and cognition need not be readily available to consciousness. With intellectual work, such implicit influences can be brought to consciousness. The study that Kuhn discussed suggests that sufficient experience with stimuli can also incite conscious reflection from the bottom up. After multiple trials with the anomalous playing cards participants began to sense that something was amiss. After further presentations of the cards, many could eventually articulate what was wrong.

The influence of implicit theoretical commitments should worry philosophers of science. Those commitments are, after all, unrecognized and unconscious, and, thus, far less likely to undergo conscious scrutiny, compared to the explicit scientific theories people entertain and debate. Kuhn’s example indicates how unlikely people are to detect anomalies in everyday experience, which does not normally involve plentiful presentations of the same stimuli that would push their tacit theoretical understandings up to the level of consciousness as candidates for critical examination.

By contrast, Churchland (1979, 2012) has examined the sometimes laborious intellectual task it is to learn to perceive the world in terms of the frameworks that explicit scientific theories provide. What is particularly noteworthy is that Churchland focuses on a theory to which everyone assents yet which seems to influence almost no one’s normal perception. In short, he examines how difficult it is to see the sky as a Copernican (addressed in Section 5 below.)

To make sense of the cognitive processing that informs theory-ladenness in these and other cases requires introducing a distinction between two sub-types of fast, intuitive processing. Differentiating these two kinds of intuitive processing will clarify but also complicate the underlying educational and epistemological issues science occasions.

3. Two Kinds of Intuitive Processing

Proponents of dual process theories distinguish slow reflective perception and cognition from the fast intuitive varieties. With this intuitive mode humans seem to perceive and know things instantly; consequently, it has been characterized as “cognitively natural” (McCauley 2000). Exhibiting a couple of key features will ordinarily suffice to ignite such intuitive processing. Though humans normally presume the soundness of these intuitions, in fact, they are woefully underdetermined by the evidence. Those automatic verdicts seem *so* natural that people normally fail to realize *that* they even know such things, let alone *how* they know them or that what they presume amounts to conjectures.[5] Humans routinely draw conclusions about individuals’ emotional states on the basis of their facial expressions, tones of voice, or bodily comportment, and they do so with little, if any, explicit awareness of what informed those inferences. Cognitively natural, fast intuition, whether it concerns perception, cognition, or action, comes in two forms.

3.1 The Practiced Naturalness of Some Intuitive Processing

A common English idiom describes some capacities as becoming "second nature." Perception, thought, and action become second nature after people have extensive experience in some domain, often supplemented by explicit instruction. After a great deal of practice in some area, perception, cognition, and action gradually shift from conscious, arduous, and deliberate to unconscious, easy, and automatic. Labored, unnatural cognition can become natural cognition – second nature -- with practice, yielding an (oxymoronic) *acquired naturalness* (McCauley 2013). Depending upon the complexity of the patterns or pursuits, this transition might take years, as in the procurement of sophisticated skills, like those bench scientists acquire. Recognizing the species of a fossil, assessing the consistency of two hypotheses, planning effective moves in chess, or throwing the discus, once challenging, begin to feel natural by virtue of frequent and extended reflection, observation, experience, participation, or practice. Each is a domain in which humans can develop *expertise*.

Experts have ready intuitions about what they master; however, expertise need not be esoteric. Sometimes, experts are rare (e.g., in high energy physics), but expertise can also be widespread (e.g., negotiating London's mass transit system). Perception, thought, and action that have become second nature enjoy a "practiced naturalness" (McCauley 2011). Human beings attain practiced naturalness in different domains, and those domains are largely a function of their culture and time period. Proficiency driving cars seems ubiquitous in societies where many people can afford them, but *no one* possessed this skill in the ancient world.

3.2 Maturationally Natural Intuitive Processing

Talk of 'second nature' presumes forms of perception and cognition that are *first nature*. First nature is comparably unconscious, easy, and automatic, but it requires neither tutelage nor any culturally distinctive inputs. Prominent discussions have underscored such systems' putative innateness, modularity, or both (e.g., Fodor 1983). If cognitive systems are innate or modular in the senses that Fodor or the evolutionary psychologists (Buss 2005) have advanced, they would certainly qualify as maturationally natural systems. For more than fifty years language has been the prime candidate, however promising alternative accounts eschewing strong nativist and modular claims exist (e.g., Christiansen and Chater 1999). Other putative cognitive modules that would qualify as maturationally natural systems address domains such as the basic physics of solid objects (Spelke et al. 1992), contamination avoidance (Rozin et al. 1995), face recognition (Duchaine and Nakayama 2006), and theory of mind (Baron-Cohen 1995). Since both these systems' innateness and the modularity (at least in Fodor's sense) are controversial (e.g., Barrett and Kurzban 2006) and since neither is necessary for characterizing maturationally natural systems, the focus here shall be on other facets of these systems, without commitment concerning their putative innateness and modular status (*whatever* each of those attributions are taken to entail[6]).

The stress on innateness arises partly from the fact that such systems *address fundamental problems* for human survival. Whether it is perceptual recognition of objects, cognitive discrimination of syntactic distinctions, or action responses to environmental contaminants, maturationally natural cognition speaks to basic problems humans must handle to get by in the world. Many maturationally natural systems (concerning perception and locomotion, for example) are intimately connected not only to human evolution but to other species' evolution too. Unlike cultural practices, e.g., dance, or the technologies with which humans can achieve practiced naturalness, *no one invented* maturationally natural capacities.

Especially when considering the theory-ladenness of perception and cognition, the most notable features of maturationally natural operations are that they are nearly always *automatic* and *fast*. That comports with the claim that these systems address matters fundamental for survival. It is sometimes unwise to insist on the highest standards of evidence. If a predator is lurking, fleeing, rather than striving for corroboration, is the better course. Consequently, satisfying a few diagnostic cues, their occasional fallibility notwithstanding, is enough to trigger maturationally natural dispositions. Systems that rely on only a couple of fairly reliable cues, though, are not terribly sophisticated.

Recall Churchland's comment about the relative simplicity of animals and young children's theories. In most domains most adults do not entertain any substantial alternatives to the maturationally natural theories acquired in childhood. Simple, fast acting, maturationally natural perceptual and cognitive systems jump to conclusions at which the available evidence only hints. Participants cannot help interpreting some movements of dots on a screen as motions of animate agents, pursuing or fleeing from one another (Scholl and Tremoulet 2000). These relatively unsophisticated systems' penchants for acting on relevant but slight evidence render us *susceptible to illusions*. When stimuli mimic cues that activate some maturationally natural system, it issues false-positive outputs, generating a perceptual or cognitive illusion. The deliverances of visual perception when people watch movies are an obvious illustration. Changing patterns of light on a screen suffice for people to see entirely different worlds, which collapse to the mere flickering of light on a flat surface when seen from one of that surface's edges. The key point is that, typically, *we cannot help ourselves* from reacting according to these systems' dictates.

Most maturationally natural capacities *appear early* and are active by the time humans reach school age. This is why 'school age' is fairly uniform across cultures. By six years of age, humans can perceptually discriminate objects and events as well as agents and their actions, hypothesize plausibly about those agents' mental states, move smoothly and efficiently through their environments, perceive, comprehend, and produce language, etc. Maturationally natural capacities are also in operation before humans realize that they are. Humans have *no recall of learning* to walk or talk or read minds or when and how they got their accents, as opposed to when they learn to ride a bicycle or to read and write. Across cultures the emergence of maturationally natural capacities virtually *constitutes normal development*.

No culturally distinctive support is required for the appearance or development of maturationally natural capacities. Culture certainly infiltrates and tunes maturationally natural systems, but the same infants in a French speaking community who learn to speak French are no less able to learn Finnish, if they had been raised among Finnish speakers. The development of such capacities does not depend upon direct teaching or explicit instruction. Nor does it turn on special technologies or the preparation of special learning environments. No one needs to teach a normal child the language in which it is immersed. Maturationally natural capacities such as language, it will *acquire on its own*.[7]

Debate has raged over the origins of maturationally natural capacities. The relative specificity of the learning principles informing their emergence remains contentious. Few, however, dispute the fact that such systems are *domain-specific* capacities by the time they are up and running. What school age children (and adults, for that matter) think about biological kinds and their inferences about them apply to that domain. The underlying principles cannot be generalized to language any more than the principles of a language can be applied to thinking about biological kinds.

4. Radically Counter-Intuitive Science

Since maturationally natural systems address matters that are often decisive for the preservation of human life and limb and, thus, for human reproduction too, the biases that inform those systems' selectivity among inputs must, at least, prove good enough for humans to get by. They may well do better (Papineau 2000). Still, when the exacting standard of the epistemic credentials of science is the topic at hand, good-enough-to-get-by or good-enough-to-assure-reproduction are unlikely to be good enough.

The sciences advance, usually sooner rather than later, representations that are *radically* unlike the deliverances of humans' maturationally natural cognitive systems. The sciences traffic in RCI representations that imply that the world is not as our maturationally natural perception and cognition suggest. In short, the world is not as it appears. Science's RCI representations not only improve upon our maturationally natural conceptions, they also account for when and why those conceptions work when they do.

Scientific theories and concepts reorder and re-categorize things by presenting new, *unobvious* regularities based, in psychology and social science no less than in the physical and biological sciences, on what are often mechanisms and forces that are not manifest to our unaided senses (Bechtel 2008). The sciences offer more penetrating explanations than maturationally natural folk physics, folk biology, and folk psychology or our lame attempts at folk sociology by personifying societies and groups (Contreras et al. 2013). Scientific theories do not just make sense of the familiar world; they also have implications for how things work in exotic environments. This gives scientific claims theoretical depth. They must be extended to circumstances either inexplicable before, inaccessible before, or, often, unimagined before. Scientists invent technologies for gaining access to such extraordinary circumstances. Experimental investigation of scientific theories' implications in unexplored settings is a pivotal means for testing them and extending knowledge.

Such endeavors inevitably result in representations that diverge drastically from maturationally natural conceptions of things. From the first ground-breaking proposal of modern science, viz. that the earth moves, to finding that the *biological* distinction between the sexes in humans is not discrete,[8] to the discovery of what seem to be conceptually impossible pathologies such as Anton's syndrome, i.e., blindness denial (Churchland 1983), to ascertaining, via the theory of relative deprivation, that the most oppressed peoples are not most likely to protest, the physical, biological, psychological, and social sciences generate findings about the world that defy maturationally natural intuition and, simultaneously, offer the most far-reaching explanatory accounts of the matters at stake.

More generally, modern science's advancing restriction on the domains in which appeals to agent causality are any longer deemed legitimate may well be its most significant divergence from maturationally natural presumptions. Infants' sensitivity to agents in their environment is only the first step in the rapid development of sophisticated, maturationally natural mind-reading and social skills (Rochat 2009). Humans' facility with agent explanation contributes not only to its over-extension but to experiencing some satisfaction from that over-extension (Dennett 2006; Mithen 1996). Both look to play some role in the unending appeal of religion to human minds (Barrett 2012). In nonscientific cultures, anything can be an agent, including heavenly bodies, the seas, the wind, and more. Maturing physical sciences have discredited and supplanted agentive explanations of wondrous celestial and geological events. (Oddly, most humans have much less interest in explaining the non-wondrous events in their everyday worlds.) The combination of Darwin's theory of evolution and the subsequent rise of cellular and molecular biology eliminated any need for appeals to agent causality in the biological realm. Vitalism, the notion that vital spirits were responsible for life, had taken its last gasps by the early twentieth century. Over the last fifty years, the cognitive and brain sciences have begun to weaken even the hold of appeals to conscious mental operations *within ourselves* as satisfactory explanations for much human conduct.

5. Maturationally Natural Perception and Cognition Impede Science

Since maturationally natural perceptual and cognitive operations are simultaneously selective, unconscious, and automatic, the problems of theory-ladenness that they introduce are acute, certainly for science education, if not for scientific practice as well. Specifically, maturationally natural perception and cognition tends to be cognitively invisible, intrusive, and tenacious.

5.1 Maturationally Natural Intuition is Invisible

Humans are alert neither to their maturationally natural intuitions (they have them, but they rarely, if ever, notice that they have them) nor to those intuitions' theoretical character. Humans not only *presume the soundness* of the intuitions born of their maturationally natural proclivities, they do so *unconsciously*. Under most conditions, maturationally natural intuition is *invisible* in the sense that it is the set of unnoticed internal lenses that humans perceive the world *through*; it is the set of unrecognized presumptions that humans know the world with. Knowledge that is this constitutional is, in effect, perceptually and *cognitively* invisible. It constitutes the default, background assumptions that both frame and enable humans' transactions with their physical and social environments. Churchland (1989, p. 282) comments that we ". . . suppress the important fact that the antecedent taxonomy provided by common sense is as richly theoretical, conjectural, and provisional as . . . " the taxonomies of science are. If knowledge is invisible, so is its theoretical status.

If humans do not realize that they operate with maturationally natural assumptions and if they do not realize that those assumptions involve tacit theoretical commitments, then they have few, if any, occasions to question them. Everyday interactions with medium sized, terrestrial objects, including organisms, rarely frustrate humans' maturationally natural expectations. Consequently, the systematic probing of the world that the sciences carry out, the often counter-intuitive findings their inquiries uncover, and the RCI theories and models that they advance to explain both those findings and commonplace phenomena jointly form the single most noteworthy challenge to the perceptual and cognitive supremacy of maturationally natural intuition.

5.2 Maturationally Natural Intuition is Intrusive

That scientists challenge the dominion of maturationally natural intuition by pursuing slow, conscious, deliberate cognition presents a problem. When scientists step forward from their reflections to meet the everyday world, maturationally natural dispositions intrude. When less experienced science students face ordinary, unremarkable environments, they feel the tug of maturationally natural intuitions that are inconsistent with their hard-won scientific knowledge. Since those maturationally natural systems operate *automatically*, neither explicit, reflective knowledge nor long histories of practice completely undo their operations. Given their transparency and their comparative theoretical simplicity, they mostly constitute obstacles to learning, mastering, and doing science.

Michael McCloskey and his colleagues (Caramazza et al. 1981; McCloskey 1983; McCloskey et al. 1983) showed that most naïve participants rely on maturationally natural physical intuitions when making judgments about relatively simple motions of objects. Their critical finding, though, was that roughly one quarter of participants who had successfully completed a high school or college course in basic mechanics reverted to their pre-Galilean folk intuitions when queried about objects' motions. Maturationally natural, folk physics intruded and overwhelmed reflectively acquired knowledge about mechanics, leading these participants to ignore such basic principles as inertia.

Elementary problems with which they are well acquainted do not mislead scientific experts, but since maturationally natural systems run automatically, experts' performance should, at least sometimes, manifest evidence of their intrusions. *Even an advanced scientific education does not stop the cuing of these systems*. Dennis Proffitt and David Gilden (1989) demonstrate that, without the opportunity to apply their explicit knowledge of the relevant formulae, expert physicists' intuitions about more complicated motions such as collisions are regularly incorrect too.

Such intrusions are not confined to folk physics. Recently, Deborah Kelemen and colleagues (2012) have shown that professional scientists are vulnerable to similar lapses in biological reasoning, when facing considerable demands on cognitive processing, for example, when handling tasks under time pressure. In such conditions "purpose-based" reasoning becomes their default stance in managing questions about biological structures. Their instantaneous maturationally natural deliverances, to the effect that any appearances of *design* depend upon agents' actions, take over. Whether operating with nonstandard problems or in unusual settings or working under cognitively stressful conditions, *erroneous maturationally natural assumptions can swamp educated human judgment*.

Over the past four decades experimental research has revealed that even experts can be suspect probabilistic thinkers, especially when contexts or problems are atypical. Probabilistic inference is, of course, often pivotal in scientific inquiry. Humans' intuitions about probabilities, which lead them to ignore base rate information, sample sizes, and patterns such as regression to the mean, violate the normative principles of probability theory (Kahneman, Slovic, and Tversky 1982; Gilovich, Griffin, and Kahneman 2002). People employ heuristics, such as representativeness, which holds that "like goes with like" (Gilovich 1991: 136). Using this heuristic can lead to mistakes, when similarity judgments are based on considerations that do not track objective probabilities. Tversky and Kahneman (2002: 20, emphasis added) hold that this and other fallible heuristics inform our "*natural* assessments" of probabilities.

Tversky and Kahneman (2002: 20) found "no effect of statistical sophistication" in how participants performed in assessing probabilities of conjunctions and their conjuncts. More than eighty per cent of their "highly sophisticated respondents" erred by following the representativeness heuristic. Not even monetary rewards for correct answers improve participants' performance (Camerer and Hogarth 1999). Tversky and Kahneman note that after being apprised of both the correct answer and understanding its rationale, the heuristic's incorrect answer still *feels right*.

Although issues of probability apply horizontally across domains, these heuristics otherwise exemplify the features outlined earlier for maturationally natural systems. They operate automatically, instantly, unconsciously, and intuitively. No one teaches the gambler's fallacy to children, and children have no recollection of when, why, or how they first deployed it. For everyday problems, most of these heuristics do well enough; however, they are biased and fallible. In the uncommon environments scientists explore or create in their experiments, though, these heuristics are utterly inadequate. Consequently, they are unsuited for scientific purposes, and their intrusions are unhelpful.

5.3 Maturationally Natural Intuition is Tenacious

As noted, expert knowledge is endowed with an acquired naturalness, achieved on the basis of towering amounts of experience in some domain. Thus, expert scientists may develop a complement of competing intuitions possessing a practiced naturalness (Papineau 2000). Even if exotic cases continue to pose problems for them, experts' perceptual and cognitive management of routine problems in normal environments, at least, becomes second nature.

Still, it appears that not even the pervasive, long-standing embrace of a well-established scientific theory with clear consequences for perceptual experience will always suffice to supersede maturationally natural dispositions influencing perception. Not even uncontroversial, long-held, widely accepted, thoroughly familiar scientific theories appear capable of readily eliciting corresponding changes in perception.

No scientific theory's fundamental tenets are any better known or more broadly accepted than the Copernican conception of the solar system. Yet the language of pre-Copernican conceptions pervades common talk, almost no one ever looks at the sky with the Copernican framework in mind, and when people do, it can be startlingly disconcerting (McCauley 2011; Churchland 1979 and 2012). Even experienced sky-watchers are no better. Stellar navigators, for example, are taught to envision themselves viewing the sky from Ptolemy's motionless earth.

Churchland (1979) proposed the assignment of viewing the evening sky as a Copernican. (See McCauley 2011, pp. 40-41 and figure 2-2.) The widespread adoption and cultural familiarity of the Copernican theory, notwithstanding, this exercise requires considerable intellectual work, including:

* keeping track of where the sun last appeared on the western horizon
* regarding the earth as a large, sphere rotating eastwardly, which is responsible for the sun's disappearance in the west
* identifying another planet in the sky

* recognizing the plane of the ecliptic on which both that planet and the earth revolve around the sun
* understanding both that one half of the moon is illuminated (some fraction of which is visible to the observer) by the no-longer-visible sun and that the moon is far closer to the earth and revolves around the earth

Churchland's original point was to demonstrate, first hand, how theoretical commitments can transform perception. Since this exercise requires considerable knowledge and concentration, since its perceptual effect is instantly erased by even the smallest distraction (for example, attending to some nearby, middle-sized terrestrial object), and since what it most readily induces is vertigo (as Churchland himself concedes), perhaps the deeper lesson is how tenaciously some maturationally natural dispositions grip human perception.

Whether a more sophisticated appreciation of Copernican theory and extensive practice, say, by an expert astronomer, would produce a practiced naturalness with this exercise and its desired perceptual consequences is an empirical question. Nothing, however, suggests that these experts go about their daily activities perceiving all of their own motions and the motions of things in the sky according to the Copernican view.[9]

6. Maturationally Natural Perception: Challenge or Opportunity?

Because he holds that humans' perceptual input systems are modularized, Fodor (1990) is unbothered by the theory-ladenness that their maturational naturalness entails. That is because his account (1983) of mental modules subscribes not only to the features by virtue of which they qualify as maturationally natural systems but to some decisive additional features as well.

Fodor holds, first, that humans' general-purpose, central cognitive systems have extremely limited access to perceptual input systems' inner workings. He notes (1983, p. 56), for example, that although humans must process utterances' phonemic, lexical, syntactic, and pragmatic features, what they recall, certainly after more than a dozen seconds or so and without tremendous mnemonic investments is, if anything, an utterance's semantic import – the gist of what was said. Representations employed at intermediate stages in perceptual input systems' processing are basically inaccessible and, thus, not candidates for conscious theoretical comparison.

Even more significantly, Fodor also maintains (1983, pp. 64f.) that perceptual input systems' operations are "informationally encapsulated"; they are mostly impervious to the feedback of information from central cognitive systems. He argues that systematically ignoring information that central systems possess enables perceptual input systems to be fast and to manage the unexpected perceptually. To be fast, these systems are stupid. They do *not* search through everything we know before offering a verdict. Activating one or two diagnostic cues is enough to trigger their operations. Assessing myriad confirmation relations is *not* part of their repertoire. These maturationally natural systems provide stereotypical deliverances to central cognitive systems about how the world appears. *Mastery of the sciences' RCI theories does not penetrate the operations of perceptual input systems*. Knowledge of scientific theories only exerts its influence at the levels of perceptual judgment and belief fixation, which are performed by central cognitive systems.

Crucially, Fodor's point is *not* that perceptual input systems are not theory-laden. He stresses, rather, that the relevant mental modules of *every* human have the *same* theoretical biases. Those modules' operations are overwhelmingly *indifferent* regarding the explicit theories humans are committed to reflectively, and, thus, they are "encapsulated enough to permit theory-neutral, observational resolution of scientific disputes" (1990, p. 255).

Fodor construes the apparent fixity of maturationally natural perception as offering not a challenge but an opportunity. He holds, ironically, that the theory-ladenness of maturationally natural, perceptual input systems provides grounds for managing the theory-ladenness of perception in science and for playing a prominent role in accounting for the scientific community's decisions between theories. Fodor's epistemological proposal for managing the problems, which the theory-ladenness of perception presents for accounts of scientific rationality, turns on the *uniformity* of humans' maturationally natural perceptual biases. On Fodor's view that uniformity in the theory-ladenness of perceptual systems purchases a theory-neutrality with regard to the assessment of any theories that humans entertain *reflectively*, including the theories of science, in the light of observational evidence.

A pivotal premise of Fodor's argument for this uniformity is that perceptual input systems are overwhelmingly indifferent to variability both in individuals' learning histories and in their social and material environments. Stability in perceptual input systems' deliverances over the life course (reflecting their "diachronic encapsulation") will undergird a "perceptual consensus" that will "survive the effects of the kinds of differences of learning histories that observers actually exhibit" (1990, p. 257). Fodor's proposal that such theory-neutral observation promises to aid the resolution of "almost all" theoretical disputes in science indicates that he thinks any diachronic penetration of input systems is modest and infrequent at most (1990, p. 254).

The single most important type of evidence Fodor cites in support of the informational encapsulation of perceptual input systems and, thus, of their uniform development, and, thus, of his proposal for managing the challenges theory-laden perception poses, is the *persistence* of perceptual illusions. What better evidence is there for the informational encapsulation of perceptual input systems, if perceptual illusions persist even after perceivers understand (a) that the stimuli elicit an illusion and (b) what the actual state of affairs is? If perceivers' knowledge could inform the operations of their modular input systems, it would, presumably, mitigate, if not eliminate, the illusion. But it does not -- at least not with the parade case that Fodor has *repeatedly* headlined, viz., the Mueller-Lyer illusion (McCauley and Henrich 2006). See Figure 1. Perceivers' conscious knowledge that the two horizontal

****

Insert Figure 1 about here

****

lines in this stimulus are the same length seems to have absolutely no impact on their inability to perceive them that way.

That is *unless* participants do not perceive them as different, which is to say, unless they are *not* susceptible to the Mueller-Lyer illusion at all! Given his conception of modular input systems, this is a possibility that Fodor basically ignores. He should not have. Unfortunately, mostly forgotten, decades-old, cross-cultural research (Segal et al. 1966) on susceptibility to the Mueller-Lyer illusion provides striking evidence not only of substantial variability in participants' responses to the Mueller-Lyer stimuli (as well as to some other standard visual illusions) across cultures but of entire groups that show *no* *susceptibility whatsoever* to the illusion. The leading hypothesis for explaining these findings is that these are people who have not spent their youths in carpentered environments, but for my purposes here, the pivotal point concerns the findings themselves. These experimental findings allow that regularities in responses among populations may exist, but they are, by no means, even the roughly uniform regularities *across* cultures that the theory-neutral perceptual consensus, which Fodor envisions, would require. Moreover, for some populations the Mueller-Lyer stimuli do not produce illusions at all, let alone ones that persist.

These have not turned out to be rare, isolated results. Recent research provides considerable evidence not just for imperviousness to familiar visual illusions among various people around the world but for significant cultural differences in visual perception generally (e.g., de Fockert et al. 2007). Experimental evidence suggests that the cultural infiltration of maturationally natural systems is far broader and deeper than most imagine and certainly than Fodor imagines about modular input systems. Visual perception is but one among more than a dozen maturationally natural systems (including such things as conceptions of fairness, folk biological reasoning, spatial cognition, moral reasoning, and more) for which new cross-cultural experimental evidence discloses substantial cultural penetration.[10] (This is in contrast to examples of maturationally natural systems, such as language and contamination avoidance, where cultural penetration was uncontroversial.) Such considerations have led many researchers to distinguish *cognitively* between the people of western, educated, industrialized, rich, democratic societies where the sciences flourish (i.e., WEIRD people and, in particular, late adolescents and young adults in America, who make up the majority of participants in experiments examining perception and cognition) and people from non-WEIRD societies (Henrich et al. 2010).

Whether the stronger claims about the atypical cognition of WEIRD people proves epistemologically significant, the cross-cultural experimental findings on visual illusions undercut the principal – very nearly, the sole -- form of evidence Fodor cites in behalf of the empirical assumption undergirding his proposal for dealing with the epistemological problems that the theory-ladenness of perception poses. The relevant empirical research points, if anything, in the opposite direction from what Fodor assumes. For many people in the world, the visual stimuli eliciting Fodor's favorite persisting illusion does not elicit the illusion, let alone a version of it that persists! Other cross-cultural research on visual perception indicates that this is one of many differences in visual processing that has been detected.

Maturationally natural perception is automatic, invisible, intrusive, and tenacious, but it is also *variable* depending upon "the kinds of differences of learning histories that observers actually exhibit." (See too Dunning and Balcetis 2013). Contrary to Fodor's contention, maturationally natural perception remains a challenge, not an opportunity.

7. Scientific Education and Scientific Rationality

Maturationally natural features of perception and cognition pose significant challenges for science education. Along with other research on the intellectual foibles of individual scientists, these findings about maturationally natural perception and cognition also raise nagging concerns about individual scientists' perceptual judgments and about their cognitive processing, more generally. Neither the pervasiveness nor the implacability of maturationally natural features of perception, though, jeopardize conceptions of scientific rationality that do not look to some *definitive* perceptual grounds for adjudicating theoretical disagreements.

The intrusions of maturationally natural proclivities of mind in human judgment readily triumph when they are not confronted by contrary inclinations associated with deeply ingrained scientific expertise. The experimental research on these matters shows that this is a pervasive problem for students across many sciences, not just physics (Carey 1986; Gregory 2009). Much of the relevant research examines what proves to be the dismal understanding of basic scientific matters among American undergraduate science students. Those students have a minimum of thirteen years of formal education and anywhere from four to eight years of formal science instruction and experience at the secondary and undergraduate levels. Those facts alone suggest that the amount of practiced naturalness, which people must acquire with scientific conceptions to forestall such intrusions with much consistency, probably requires educational achievements equivalent to doctoral level studies at least. That is a sobering conclusion for champions of democratic ideals that envision informed citizens wrestling thoughtfully with pertinent scientific findings about matters of public interest.

The situations that induce science students to revert to their maturationally natural perceptual and conceptual inclinations do not usually trip up scientific experts. Proffitt and Gilden's (1989) findings, however, intimate that even experts' intuitions routinely go awry with more complex problems. Those intimations and the maturationally natural features of mind that drive them, at least in part, combined, especially, with studies presenting the penchant of scientific researchers for confirmation bias (e.g., Mahoney and DeMonbreun 1977) but also with research that reveals individual scientists' weaknesses at deductive, probabilistic, and statistical reasoning,[11] suggest that any satisfactory account of scientific rationality should not turn on presumptions about the soundness of *individual* scientists' perceptual (or intellectual) judgments.

Clearly, the problems that individuals' maturationally natural dispositions of mind present for science education and for the enterprise of science, more generally, are *not* insurmountable. Science, after all, has progressed. Science has developed ways to manage these problems. The way around them, though, is not by looking either to perceptual verdicts of individual scientists or to uniform perceptual capacities across the species to establish some theory-neutral perceptual basis for adjudicating scientific debates. It is not to look to any account of scientific rationality that depends *essentially* on some perceptual basis (theory-neutral or not) for deciding scientific controversies. Scientific rationality does not rely on any intrinsic or uniform property of humans' perceptual capacities. More inclusive conceptions of its epistemic prestige that focus on science's social and institutional arrangements are preferable, in which individual scientists' perceptual judgments are but one among a number of considerations that play into how scientific *communities* sort through observational evidence and in which observational evidence is but one among a number of considerations, such as achieving overall explanatory coherence (Thagard 1992, 2012), that make for scientific progress.

References

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge: MIT Press.

Barrett, H. C., & Kurzban, R. (2006). Modularity in cognition: Framing the debate. *Psychological Review, 113* (3), 628-647.

Barrett, J. L. (2012). *Born Believers: The Science of Children's Religious Belief.* New York: Free Press.

Bechtel, W. (2008). *Mental mechanisms: Philosophical perspectives on cognitive neuroscience*. New York: Routledge.

Buss, D. (Ed.) (2005). *The handbook of evolutionary psychology.* New York: Wiley.

Caramazza, A., McCloskey, M., & Green, B. (1981). Naive beliefs in "sophisticated" subjects: Misconceptions about trajectories of objects. *Cognition, 9* (2), 117–124.

Carey, S. (1986). Cognitive science and science education. *American Psychologist* 41 (10), 1123-1130.

Christiansen, M.H., & Chater, N. (1999). Connectionist natural language processing: The state of the art. *Cognitive Science, 23* (4), 417-437.

Churchland, P. M. (1979). *Scientific realism and the plasticity of mind*. Cambridge: Cambridge University Press.

Churchland, P. M. (1989). *A neurocomputational perspective: The nature of mind and the structure of science*. Cambridge: The MIT Press.

Churchland, P. M. (2012). *Plato's camera: How the physical brain captures a landscape of abstract universals.* Cambridge: MIT Press.

Churchland, P.S. (1983). Consciousness: The transmutation of a concept. *Pacific Philosophical Quarterly, 64* (1), 80-93.

Contreras, J. M., Schirmer, J., Mahzarin, R. B., and Mitchell, J. P. (2013). Common brain regions with distinct patterns of neural responses during mentalizing about groups and individuals. *Journal of Cognitive Neuroscience* 25 (9), 1406-1417.

Coppola, M., & Newport, E. L. (2005). Grammatical subjects in home sign: Abstract linguistic structure in adult primary gesture systems without linguistic input. *Proceedings of the National Academy of Sciences*, *102* (52), 19249-19253.

de Fockert, J., Davidoff, J., Fagot, J., Parron, C., and Goldstein, J. (2007). More accurate size contrast judgments in the Ebbinghaus Illusion by a remote culture. *Journal of Experimental Psychology: Human Perception and Performance, 33* (3), 738-742.

Dennett, D. C. (2006). *Breaking the spell: Religion as a natural phenomenon*. New York: Viking.

Duchaine, B., & Nakayama, K. (2006). Developmental prosopagnosia: A window to content-specific face processing. *Current Opinion in Neurobiology, 16* (2), 166-173.

Dunning, D. and Balcetis, E. (2013). Wishful seeing: How preferences shape visual perception. *New Directions in Psychological Science* 22, (1), 33-37.

Evans, J.St.B.T., & K. Frankish (ed.). (2009). *In two minds: Dual process and beyond*. New York: Oxford University Press.

Fodor, J. A. (1983). *The modularity of mind*. Cambridge: The MIT Press.

Fodor, J. A. (1990). A reply to Churchland's "Perceptual Plasticity and Theoretical Neutrality." *A theory of content and other essays*. Cambridge: MIT Press (pp. 253-263).

Gilovich, T., Griffin, D. and Kahneman, D. (Eds.) (2002). *Heuristics and biases: The psychology of intuitive judgment*. Cambridge: Cambridge University Press.

Gregory, T. R. (2009). Understanding natural selection: Essential concepts and common misconceptions. *Evolution, Education and Outreach,* 2 (2), 156-175.

Hanson, N. (1958). *Patterns of discovery*. Cambridge: Cambridge University Press.

Harman, G. (1974). *On Noam Chomsky: Critical essays*. Garden City, New York: Anchor Press.

Hempel, C. (1965). *Aspects of scientific explanation*. New York: The Free Press.

Henrich, J., Heine, S. J., and Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences* 33 (2-3), 1-75.

Jablonka, E. and Lamb, M. (2005). *Evolution in four dimensions: Genetic, epigenetic, behavioral, and symbolic variation in the history of life.* Cambridge: MIT Press.

Jordan-Young, R. M. (2010). *Brain storm: The flaws in the science of sex differences.* Cambridge: Harvard University Press.

Kahneman, D. (2011). *Thinking, fast and slow*. New York: Farrar, Straus, & Giroux.

Kahneman, D., Slovic, P., and Tversky, A. (Eds.). (1982). *Judgement under uncertainty: Heuristics and biases*. Cambridge: Cambridge University Press.

Kelemen, D., Rottman, J., & Seston, R. (2012). Professional physical scientists display tenacious teleological tendencies: Purpose-based reasoning as a cognitive default. *Journal of Experimental Psychology: General* 142 (4), 1074-1083.

Keren, G., & Schul, Y. (2009). Two is not always better than one: A critical evaluation of two-system theories. *Perspectives on Psychological Science, 4* (6), 533-550.

Kuhn, T. (1970). *The structure of scientific revolutions* (second edition). Chicago: University of Chicago Press.

Machery, E. (2009). *Doing without concepts*. New York: Oxford University Press.

Mahoney, M. and DeMonbreun, B. G. (1977). Psychology of the scientist: An analysis of problem solving bias. *Cognitive Therapy and Research* 1 (3), 229-238.

McCauley, R. N. (2000). The naturalness of religion and the unnaturalness of science. In F. Keil and R. Wilson (Eds.), *Explanation and cognition* (pp. 61-85). Cambridge: MIT Press.

McCauley, Robert. N. (2011). *Why religion is natural and science is not*. New York: Oxford University Press.

McCauley, R. N. (2013). Why science is exceptional and religion is not: A response to commentators on *Why Religion Is Natural and Science Is Not*. *Religion, Brain & Behavior, 3* (2), 165-182.

McCauley, R. N. and Henrich, J. (2006). Susceptibility to the Muller-Lyer illusion, theory neutral observation, and the diachronic cognitive penetrability of the visual input system. *Philosophical Psychology, 19* (1), 79-101.

McCloskey, M. (1983). Intuitive physics. *Scientific American, 248* (4), 122-30.

McCloskey, M., Washburn, A., & Felch, L. (1983). Intuitive physics: The straightdown belief and its origin. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *9* (4), 636-649.

Mithen, S. (1996). *The prehistory of the mind: The cognitive origins of art, religion, and science*. London: Thames and Hudson.

Papineau, D. (2000). The evolution of knowledge. In P. Carruthers and A. Chamberlain (Eds.), *Evolution and the human mind: Modularity, language, and meta-cognition* (pp. 170-206). New York: Cambridge University Press.

Proffitt, D. R., & Gilden, D. L. (1989). Understanding natural dynamics. *Journal of Experimental Psychology: Human Perception and Performance*, *15* (2), 384-393.

Reber, A. S. (1993). *Implicit learning and tacit knowledge: An essay on the cognitive unconscious*. New York: Oxford University Press.

Rochat, P. (2009). *Others in mind – social origins of self-consciousness*. New York, N.Y.: Cambridge University Press.

Rozin, P., Nemeroff, C., Horowitz, M., Gordon, B., & Voet, W. (1995). The borders of the self: Contamination sensitivity and potency of the mouth, other apertures and body parts. *Journal of Research in Personality, 29* (3), 318-340.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing I: Detection, search, and attention. *Psychological Review, 84* (1), 1-66.

Scholl, B. J., & Tremoulet, P. D. (2000). Perceptual causality and animacy. *Trends in Cognitive Science* 4 (8), 299-309.

Segall, M., Campbell, D., & Herskovits, M. J., (1966). *The influence of culture on visual perception*. New York: The Bobbs-Merrill Company.

Senghas, A., S. Kita, & A. Özyürek (2004). Children creating core properties of language: Evidence from an emerging sign language in Nicaragua. *Science*, *305* (5691), 1779-1782

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing II: Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84* (2), 127-190.

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review, 99* (4), 605-632.

Thagard, P. (1992). *Conceptual revolutions*. Princeton: Princeton University Press.

Thagard, P. (2012). *The cognitive science of science*. Cambridge: MIT Press.

Tversky, A. and Kahneman, D. (2002). Extensional versus Intuitive Reasoning: The Conjunction Fallacy in Probability Judgment. In T. Gilovich, D. Griffin, and D. Kahneman (Eds.), *Heuristics and biases: The psychology of intuitive judgment* (pp. 19-48). Cambridge: Cambridge University Press.

* I am grateful to Ioannis Votsis and two anonymous referees for many helpful comments to Mark Johnson for valuable discussions about theories and concepts.

Endnotes

[1] "If perceptual recognition and explanatory understanding are . . . instances of the same form of cognitive achievement, as I have suggested . . . then it is proper to regard perceptual recognition itself as being just a case of *explanatory understanding at the sensory periphery*" (Churchland 1989, p. 228).

[2] This is not to imply either that all researchers draw the relevant distinction the same way (Evans and Frankish 2009) or that all endorse such a distinction, in the first place (Keren and Schul 2009).

[3] This paper uses senses of "intuitive" and "intuition" employed in the cognitive sciences, as discussed herein. Crucially, these terms can pertain to both perception and cognition (and will be used so here). These senses are, of course, distant on many fronts from the technical senses of these terms in Modern philosophy.
[4] This paper uses the term "knowledge" in the broad sense cognitive scientists do. Since it includes both knowing how (procedural knowledge) as well as knowing that (declarative knowledge), truth is not a necessary condition for knowledge on this view.
[5] Churchland holds that "even the humblest judgment or assertion is always a speculative leap . . . " (1989, p. 278).
[6] That skepticism seems particularly justified regarding claims about innateness, in a time when genetics is undergoing fundamental transformations (Jablonka and Lamb 2005) that virtually all of the parties to these debates ignore!
[7] Not only does establishing maturationally natural capacities not rely on culturally distinctive inputs, it may, in some cases, not even rely on any distinctively cultural inputs. What appears to be a spontaneous emergence of a collective sign language at a Nicaraguan school for the deaf suggests that such capacities may emerge from basic social interaction (Senghas et al. 2004; Coppola and Newport 2005).
[8] See the discussion in Jordan-Young (2010) of complete androgen insensitive (CAIS) females who are genetic males, i.e., they possess X and Y chromosomes, but who are to *all* external appearances morphologically female and who respond, if anything, as *more* feminine than average genetic females on most psychological measures.
[9] If this comment elicits an incredulous response, *that,* at least in part, is the point.
[10] For an extensive review of this research, see Henrich et al. 2010.
[11] See McCauley 2011 for a general discussion of these matters.

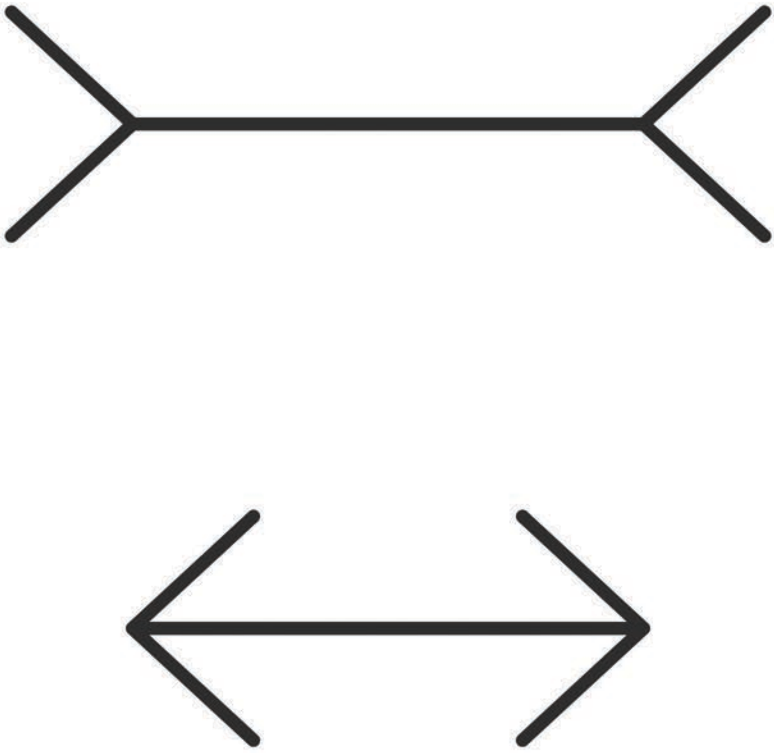

Fig. 1
the Muller-Lyer illusion