

# Cognitive Styles in Two Cognitive Sciences

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## Abstract

Miller (1990) suggests that communication between linguistics and psychology is hampered for essentially cognitive reasons: linguists favor simplifying explanations while psychologists favor causal explanations. This paper reformulates this suggestion as three testable hypotheses. First, scientists vary in cognitive style from rationalist/nomological to empiricist/mechanistic. Second, linguistics is primarily a rationalist/nomological science, while psychology is primarily an empiricist/mechanistic one. Strikingly, even among nativists, linguistic and psychological research still contrast along the rationalist/empiricist dimension. Third, cognitive styles are relatively intractable, as suggested by empirical evidence that they are associated with intrinsic individual differences and by formal arguments that highlight their self-isolating nature.

**Keywords:** philosophy of science; epistemology; linguistics; psychology; individual differences.

## Introduction

Linguists and psychologists have often noted a persistent lack of mutual respect across their two disciplines (Johnson-Laird, 1987; Jackendoff, 1988; Miller, 1990; Carlson, 2003). Miller (1990, p. 321) ascribes this impasse to different ways of thinking, which we will call cognitive style:

What is holding up the free flow of ideas back and forth between linguists and psychologists? For what it is worth, my own view is that linguists and psychologists subscribe to different theories of explanation. Linguists tend to accept simplifications as explanations. [...] For a psychologist, on the other hand, an explanation is something phrased in terms of cause and effect, antecedent and subsequent, stimulus and response.

The present paper reformulates Miller's suggestion as the hypotheses in (1)-(3), then tests them.

- (1) Scientists vary in cognitive style from more rationalist and nomological to more empiricist and mechanistic.
- (2) Linguistics is primarily a rationalist/nomological science, while psychology is primarily an empiricist/mechanistic one.
- (3) Individual cognitive styles are relatively intractable.

By "cognitive style" we mean to cover both one's personal epistemology (theory of knowledge) and one's metaphysics (theory of reality). Rationalist epistemology emphasizes the role of reason in attaining knowledge, while empiricism emphasizes the senses. A nomological metaphysics explains

in terms of general laws, while a mechanistic explanation is expressed in terms of causal systems.

The overarching notion explored in this paper is that individual scientists tend to lean towards rationalism or empiricism, and towards nomological or mechanistic explanations, and that these leanings are reflected in their chosen scientific (sub)disciplines. Thus we expect to see reliable tendencies at both the individual and discipline level, but exceptions are not impossible.

Given the brevity of this paper and the ambitious nature of the hypotheses, this study cannot fully verify or falsify them. Obvious limitations include our focus on just two dimensions of scientific thinking (see, e.g., Hacking, 2002, for others), and the poorly understood relationship between individual and disciplinary styles (i.e., to what extent scientific styles are cognitive or social).

Each hypothesis is taken up separately. Support comes from published research in linguistics, psychology, and the history and philosophy of science.

## Cognitive Styles across the Sciences

Hypothesis (1) can be unpacked into three subhypotheses:

- (1a) Scientists vary from nomological to mechanistic.
- (1b) Scientists vary from rationalist to empiricist.
- (1c) Scientists in nomological sciences tend to be more rationalist, whereas those in mechanistic sciences tend to be more empiricist.

Regarding (1a), physicists favor nomological explanations, seeking the axioms underlying nature (exemplified in the Euclid-inspired style of Newton's *Principia*). Philosophers of physics sometimes write as if all science is inherently nomological (e.g., Scheibe, 2001), but in fact, physicists are atypical: chemists, biologists, geologists and other scientists generally concentrate on uncovering causal mechanisms, not general laws. As a typical example of a mechanism, Machamer, Darden, & Craver (2000) cite the transmission of chemical signals across a synapse, which involves entities (neurons, neurotransmitters) and activities (the releasing and binding of chemicals) in events that begin, progress, and end in space and time.

The ultimate reason for cross-disciplinary differences in explanatory metaphysics seems to be reality. The systems studied in fundamental physics are simple enough for simple laws to work well, and being fundamental, no lower-level causal explanation is possible. By contrast, chemical, biological, and geological phenomena merely need to be consistent with physics; historical contingences make them impossible to deduce from physics alone.

Yet there also seems to be a cognitive aspect to the preference for certain explanation types. Strikingly, scientists outside physics often demand mechanisms before accepting a pattern as scientifically significant, no matter how robust the observations. A classic example is the skepticism that greeted Alfred Wegener's theory of continental drift. This theory elegantly explained the fit between the coastlines of South America and Africa, among numerous other observations, but it was not accepted (revised as plate tectonics) until a plausible mechanism was discovered many decades later (Cohen, 1985).

As for (1b), cognitive scientists are used to thinking of rationalism as synonymous with nativism, but the focus here is instead on what Wole ski (2004) calls methodological rationalism (apriorism; nativism is genetic rationalism), as opposed to methodological empiricism (aposteriorism). Rationalism in this sense is associated with deduction from general axioms, while empiricism is associated with induction from specific tokens. More specifically, our focus is not on the views of professional philosophers, but the personal epistemologies (Muis, Bendixen, & Haerle, 2006) of practicing scientists.

Physicists are uncontroversially the most rationalist of scientists, having always tied their work to mathematics (as reemphasized by Galileo and Newton). Despite the physics-centric view of science among some philosophers, scientists in other disciplines view themselves quite differently. Surveys reviewed in Muis et al. (2006) find that while theoretical physicists group with mathematicians in scoring high for rationalist epistemology, chemists and biologists score high for empiricism.

The rationalist/empiricist contrast is not identical to the nomological/mechanistic contrast. Descartes claimed to use pure reason to deduce a theory of physics in which magnets attract via screw-like particles (Westfall, 1971). Similarly, natural selection has lawlike properties (Bock, 2010), even though arguments for it typically involve induction from masses of observations, as in Darwin's *Origin of species* (in sharp contrast to the deductive style of Newton's *Principia*).

Yet consistent with (1c), rationalists seem to have a natural affinity for laws and empiricists for mechanisms. Physicists since Newton have rejected mechanistic physics as question-begging, and biologists tend to see natural selection as a causal mechanism (Skipper & Millstein, 2005). More generally, while nomological approaches appeal to rationalists by being elegant and deductive, mechanisms appeal to empiricists because they are imageable as diagrams, posit causal interactions of the sort familiar from experience, and accommodate a diversity of induction-supporting observations through the cumulative elaboration of mechanical elements and architectures.

In a passage reminiscent of Miller (1990), Shapin (1996, p. 117) highlights the personal nature of cognitive styles:

Do you want to capture the essence of nature and command assent to representations of its regularities?  
Do you want to subject yourself to the discipline of

describing, and perhaps generalizing about, the behavior of medium-sized objects actually existing in the world? [...] The one is not necessarily to be regarded as a failed version of the other, however much partisans may defend the virtues of their preferred practice and condemn the vices of another.

Shapin illustrates this contrast with Newton and his contemporary Boyle, today known as the father of chemistry. When Newton first introduced his optical experiments to the Royal Society, he placed his observations in a deductive context: "I shall rather lay down the *Doctrine* first and then, for its examination, give you an instance or two of the *Experiments*, as a specimen of the rest" (quoted in Shapin, 1996, p. 114, italics in the original), adding that he had shown that the science of colors was "mathematical" with "as much certainty in it as any other part of optics," as "evinced by the mediation of experiments concluding directly and without any suspicion of doubt" (Shapin, 1996, p. 115). By contrast, Boyle's goals were simply to describe his experiments explicitly enough for others to experience them vicariously, if not replicate them and observe the results first-hand. Thus he wrote that he dared to "speak confidently and positively of very few things, except of matters of fact" (quoted in Shapin, 1996, p. 102). He even refused to express mathematically the gas law that today bears his name or to call it a law. Boyle also invented today's scientific reporting style, which clearly separates experimental description from interpretation.

### Cognitive Styles in Linguistics and Psychology

To paraphrase Shapin, we do not regard linguistic methodology as a failed version of psychological methodology, or vice versa. Rather, hypothesis (2) merely claims that there is a deep philosophical difference.

Miller (1990, p. 321) illustrates this difference as follows:

[A] grammarian who can replace language-specific rewriting rules with X-bar theory and lexicalization feels he has explained something: the work formally done by a vast array of specific rules can now be done with a simple schema. [...] To an experimental psychologist, X-bar theory is not an explanation; rather, if it is true, it is something to be explained.

More generally, linguistic explanations take the form of nomological grammars, which many linguists believe are themselves subject to universal laws. Evidence is slight by psychological standards, relying on a small number of clear cases; generality is assumed unless later shown otherwise. By contrast, psychological explanations take the form of processing systems, supported with empirical overkill by linguistic standards. Psychologists also follow Boylean reporting style, whereas linguists, like philosophers, freely interleave examples and analyses.

The contrasting philosophies underlying these practices are sometimes made explicit in rhetorical volleys aimed

across disciplinary borders. For example, Chomsky (2002, p. 102) claims that "the only field that has methodology courses, to my knowledge, is psychology," implying that psychologists still maintain the discredited notion of empirical discovery procedures. The psychologists Edelman & Christiansen (2003, p. 60) counter that linguists fail in their duty "to demonstrate the psychological (behavioral), and, eventually, the neurobiological, reality of the theoretical constructs," i.e., to demonstrate mechanisms.

Favoring mechanisms makes psychology an entirely typical science (outside of physics), but why does linguistics favor the nomological approach? Even though Chomsky is an easy target, linguists have always treated language nomologically. Bloomfield (1926) proposed a *Principia*-like axiomatic system for linguistic theory, and Chomsky (1966) links his own approach with Renaissance grammarians, who, in turn, built on the Aristotelian view of language as logic. Even before Aristotle and beyond Europe, Pāṇini developed an elaborate formal grammar of Sanskrit that presaged generative linguistics in important ways.

One motivation for nomological linguistics may be language itself: like physics, language is simple enough to be fruitfully described with simple laws. Yet unlike physics, a mechanistic approach to language is also fruitful, given that its processing involves causes and effects. Miller (1990, p. 321) tacitly admits the multifaceted nature of language when he addresses the question of why linguists and psychologists study it so differently, noting that "[s]ome have answered this question in terms of the competence-performance distinction: linguists and psychologists talk about different things," while "[o]thers have answered this question in terms of the structure-function distinction: linguists ask different questions of the same thing."

In fact, both of the alternative explanations he cites can be subsumed under cognitive style. Competence (grammar) is static linguistic knowledge, described in terms of structures; performance is language processing, described in terms of functions. Grammar is intrinsically atemporal, despite the confusion sometimes caused by the term "generative" (see Neeleman & van de Koot, 2010, for a computational argument that grammar must be atemporal). Hence grammar cannot be modeled mechanistically, since causal mechanisms necessarily operate in time (Machamer et al., 2000). This obligates grammarians to use nomological explanations, which, given hypothesis (1c), makes grammatical research particularly appealing to rationalists.

The central role of atemporality in nomological/rationalist approaches to language is highlighted by the turn that came with Saussure, the first modern linguist to explicitly advocate the primacy of synchronic grammar. The rise of structuralist linguistics in his wake was accompanied by a simultaneous rejection of psychological approaches to language, exemplified by the shift from the Wundtian philosophy of Bloomfield (1914) to the psychological agnosticism of Bloomfield (1933).

Since cognitive style is a property of individual scientists, methodological rationalists like Chomsky coexist in

linguistics with methodological empiricists like the corpus linguist Geoffrey Sampson. While Chomsky (2002, p. 102) praises "the Galilean move towards discarding recalcitrant phenomena if you're achieving insights by doing so," Sampson (2001, p. 1) asks linguists "to apply the same empirical techniques which have deepened our understanding of other observable aspects of the universe during the four centuries since Galileo." (Tellingly, both invoke Galileo: as noted by Shapin, 1996, scientists tend to take their personal cognitive style as defining science itself). Other non-rationalist approaches to linguistics include functionalism (e.g., Nichols, 1984), where causal mechanisms are central.

Psychologists also vary in cognitive style, with some attracted to nomological schools like rational analysis (Chater & Oaksford, 1999), or, earlier, Gestalt psychology. Yet other psychologists are quick to criticize such approaches for being insufficiently mechanistic, as seen in the peer commentary on Oaksford & Chater (2009), or in the comment by Bruce, Green, & Georgeson (2003, p. 127) that Gestalt laws have left us "with a set of descriptive principles, but without a model of perceptual processing."

The difference in cognitive style between (grammar-oriented) linguists and (most) psychologists is highlighted by the surprising fact that even when psycholinguists are genetic rationalists, they remain methodological empiricists. Compare Chomsky's nativism with that of the psychologist Steven Pinker. The poverty of the stimulus argument (Chomsky, 1986) deduces nativism from the premises that knowledge is rich but input to the learner is poor. This is a rational argument: Chomsky ascribes it to Plato, implying the irrelevance of two millennia of evidence. Moreover, contrary to a common misunderstanding (see, e.g., Chomsky & Katz, 1981), Chomsky does not induce universal grammar from grammatical universals.

By contrast, the prominence of these two arguments is exactly reversed in Pinker (1994). Pinker does rehearse a version of the poverty of the stimulus argument, but immediately afterwards he adds, "Chomsky's claim was tested in an experiment..." (p. 42). The remainder of Pinker's book is a long catalog of empirical evidence for nativism from a variety of sources, including cross-linguistic universals, in a style more like *Origin* than *Principia*.

The Chomskyan Jenkins (2000, p. 31) confirms that even if "no converging evidence at all of the kind Pinker detailed in his book [...] had turned up yet", we would still "be justified in accepting Chomsky's arguments that the 'basic design of language is innate,' to use Pinker's words", since "the argument from poverty of the stimulus [is] strong enough".

### The Intractability of Cognitive Style

Hypothesis (3) is supported by two independent arguments. For the benefit of different types of readers, one is empirical and one is rational. The empirical argument is based on evidence that cognitive style is associated with intrinsic individual differences. The rational argument is based on

formal analyses demonstrating the impossibility of choosing between cognitive styles either empirically or rationally.

### Individual Differences in Cognitive Style

The polarization of disciplinary styles can be explained in part by the social and cognitive factors driving group polarization more generally (Isenberg, 1986). Yet scientists do not merely absorb the cognitive style of their mentors and peers.

For example, the physicist Max Planck (quoted in Scheibe, 2001, p. 69) wrote:

What led me to my science and what fascinated me from a young age was the, by no means self-evident, fact that our laws of thought agree with the regularities found in the succession of impressions we receive from the external world, that it is thus possible for the human being to gain enlightenment regarding these regularities by means of pure thought....

Similarly, though Einstein described himself, thirty years after the fact, as having been changed "by the problem of gravitation" from "skeptical empiricism" into "a believing rationalist" (quoted in van Dongen, 2010, p. 57), his contemporary writings show that he had already rejected traditional empiricism before starting to work on gravitation (Howard, forthcoming).

Group dynamics also fail to explain why individual scientists can differ in cognitive style within a science. The physicist Dirac (1968) notes that "[w]hether one follows the experimental or the mathematical procedure depends largely on the subject of study, but not entirely so. It also depends on the man" (p. 22). Among his fellow theoretical physicists, he cites Heisenberg as exemplifying the former style, and Schrödinger (and himself) the latter.

Is cognitive style a matter of personality? Diamond & Royce (1980) explicitly argue that personal epistemology does correlate with personality traits, though unfortunately there has been little follow-up (cf. Muis et al., 2006). For example, Pashler, McDaniel, Rohrer, & Bjork (2009) cast serious doubt on the notion of intrinsic learning styles, but putative contrasts like visual versus verbal learning have nothing to do with empiricism versus rationalism.

More relevant are the many studies that reveal individual variation in reasoning. For example, in the Wason card selection task, where people are asked to test for violations of conditional propositions of the form if  $p$  then  $q$ , most fail to test cases of not- $q$ , even though finding not- $q$  given  $p$  would falsify the proposition. Oaksford & Chater (2009) review a series of experiments and mathematical models suggesting that most people approach the Wason task using Bayesian (i.e., essentially inductive) reasoning. This implies that the minority who give the normatively correct answer are using deductive reasoning. Since performing correctly is positively correlated with general intelligence (Stanovich & West, 2000) and working memory capacity (Copeland &

Radvansky, 2004), a facility with deduction seems to be an intrinsic individual trait.

Cognitive style may also be linked to another feature known to show individual variation: tolerance of uncertainty (Neuberg, Judice, & West, 1997). Deduction provides certainty (Euclid cannot be falsified), while induction does not (a black swan may be lurking around the next corner). Given this, it is unsurprising that Wilkinson & Migotsky (1994) found that the belief that knowledge depends on observations and data (which they label empiricism) is associated with the belief that knowledge is relative and context-dependent, whereas the belief that knowledge depends on logical and analytical thinking (which they label rationalism) is not associated with relativist tendencies.

When taken to an extreme, the intolerance of uncertainty is a hallmark of obsessive-compulsive disorder and autism spectrum disorders like Asperger syndrome (Sadock & Sadock, 2007). Indeed, autism is linked to mathematical (i.e., deductive) talent (Baron-Cohen, Wheelwright, Burtenshaw, & Hobson, 2007), and students with familial autism are more likely to choose a mathematics-intensive college major (Campbell & Wang, 2012). Complementarily, Pélissier & O'Connor (2002) found that participants diagnosed with obsessive-compulsive disorder had significantly more difficulty than matched controls in tasks that required induction, whereas both groups performed equally well with deductive tasks. Consistent with the above findings, the rationalists Newton (James, 2003) and Dirac (Farmelo, 2009) have been diagnosed (post hoc) with Asperger, whereas the more empiricism-inclined Darwin earned a very high score from historians for openness to experience (Shermer, 2002).

In short, scientists are unconsciously pushed in one or the other direction along the rationalism/empiricism continuum even before their entry into science. Cognitive styles are thus expected to be relatively immune to persuasion.

### Cognitive Styles and Logical Traps

Whether rationalists or empiricists, scientists all face the problem of induction. Since observations are always consistent with (infinitely) many theories, scientists rely on strategies like Ockham's razor to narrow their options. However, even when Ockham is satisfied, rationalists are free to favor laws and empiricists to favor mechanisms.

The implications of this problem can be investigated in the context of formal learning theory. This approach is most familiar to cognitive scientists in its application to language acquisition, but it also helps inform the philosophy of science (e.g., Kelly, 2000). One lesson is that the challenge faced by scientists is much harder than that faced by infants. Infants may have evolutionarily provided "inside help" guiding them to linguistic knowledge, but scientists are not so lucky. Even if scientific decisions are innately biased, these biases are not guaranteed to lead to scientific truth.

Because of this distinction between children and scientists, formal learning theory leads to opposite conclusions in the two cases. Gold's theorem (Gold, 1967) provides a simple

illustration of this. Any finite set of strings is compatible both with a finite language consisting solely of the attested strings and with a language generated by rules that generate the attested strings plus infinitely many more. However, if the learner is biased to posit only one language type, and the strings are generated by a previous learner with the same bias, successful language learning is guaranteed. Some creatures may achieve this by being innately biased towards finite languages, but presumably humans do so via an innate bias for infinite ones.

But now consider a different scenario. A scientist collects utterances from a human, which we assume has an infinite language, and from an alien with a finite language consisting of symbol strings up to length three. The human is observed to have many more string lengths than the alien, but like the child learner, the scientist can only ever have access to strings of finite length, hence finite sets of strings, even for human utterances. If the scientist is biased towards nomological explanations, an infinite language (e.g., the grammar  $a^*$ ) will be incorrectly posited for the alien as well. If the scientist is biased towards less analytical hypotheses (i.e., is empiricist), the human will be ascribed an alien-like language (i.e., a list of strings).

One may object that the scientist can escape from this dilemma by collecting evidence about what is ungrammatical. Unlike the child learner, the scientist may run an experiment, for example "asking" the alien if some string is "acceptable" (e.g., via some processing task). Suppose the alien accepts  $a$ ,  $aa$ ,  $aaa$ , but rejects  $aaaa$ ,  $aaaaa$ ; surely that demonstrates that it has a finite language. Yet as Johnson (2004) points out, even negative evidence can only come in finite sets. Rejection of  $aaaaa$  does not preclude the acceptance of  $aaaaaa$ .

Kelly (2007) illustrates his proof that Ockham's razor minimizes backtracking with a scenario in which an Ockham-obeying scientist posits all and only the particles that have been emitted by a machine so far, exactly parallel to our string-listing empiricist. Yet the nomological analysis is not only intuitively simple, but also requires no backtracking. If no string longer than three is uttered for a sufficiently long time, we can merely add a constraint to the grammar; we are not compelled to give up the infinite  $a^*$  component. Thus both approaches obey Ockham's razor.

Nothing in the above discussion depends on specific features of Gold's theorem; the problem arises from the general problem of induction. Thus even in more realistic scenarios, the two approaches cannot be distinguished either empirically or rationally.

## Conclusions

This paper has argued that linguists and psychologists talk past each other primarily because they have different epistemic and metaphysical commitments that are beyond conscious control.

Miller (1990, p. 322) predicts that it will be hard for linguists "to make clear to psychologists that simplifying explanations can be satisfying, once you grow accustomed

to them." Despite its tentative nature, the present study has provided ample reason to take Miller's prediction seriously. The predominance of the empiricist/mechanistic approach across the sciences suggests that it may be easier for linguists to appreciate psychological explanations than the other way around. Nevertheless, linguistics will always have a core of nomological rationalists. Given the multifaceted nature of language, this is perhaps just as it should be.

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