Cognitive Styles in Two Cognitive Sciences

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In N. Miyake, D. Peebles, & R. P. Cooper (Eds.), *Proceedings of the 34th Annual Conference of the Cognitive Science Society* (pp. 2067-2072). Austin, TX: Cognitive Science Society.

Abstract

Miller (1990) suggests that communication between linguistics and psychology is hampered essentially for cognitive reasons: linguists favor simplifying explanations while psychologists favor causal explanations. This paper reformulates this suggestion as three testable hypotheses. First, sciences vary in cognitive style along a continuum from rationalist/nomological to empiricist/mechanistic, a familiar notion in the philosophy of science. Second, linguistics is a rationalist/nomological science, while psychology is an empiricist/mechanistic one, as exemplified by prominent linguists and psychologists. 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 deductive arguments that they tend to be self-isolating.

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 cognitive styles:

> 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) Sciences vary in cognitive style along a continuum from rationalist and nomological to empiricist and mechanistic.
(2) Linguistics is a rationalist/nomological science, while psychology is 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). Rationalism emphasizes the role of reason in attaining (scientific) knowledge, while empiricism emphasizes the senses. A nomological explanation is expressed in terms of general laws, while a mechanistic explanation is expressed in terms of causal systems. For convenience, this paper will give sciences and scientists specific labels, but what is actually claimed is that they lie at different points along continua. Moreover, though scientists within a discipline may tend to have similar cognitive styles, disciplines are not monolithic, as we shall see.

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) Sciences vary from rationalist to empiricist.
(1b) Sciences vary from nomological to mechanistic.
(1c) Rationalist sciences tend to be nomological, whereas empiricist sciences tend to be mechanistic.

Cognitive scientists are accustomed to think of rationalism as synonymous with nativism, but the focus here is instead what Woleński (2004) calls methodological rationalism (apriorism), which emphasizes the role of reason in scientific inference, as contrasted with methodological empiricism (aposteriorism), which emphasizes the role of observation. Rationalism in this sense is associated with deduction from general axioms, while empiricism is associated with induction from specific tokens.

The only purely rationalist science is mathematics; purely empiricist activities might include butterfly collecting. Science proper requires both inference styles (Scheibe, 2001), but it has often been observed that different sciences emphasize rationalism and empiricism to different degrees.

Regarding (1a), there are good reasons for considering physics the most rationalist of the empirical sciences. Not only has it always been closely allied to axiomatic mathematics (as reemphasized by Galileo and Newton), but philosophers traditionally call other empirical sciences "the special sciences", studying special cases of physical systems. By contrast, while biological facts must be consistent with physical laws, historical contingences make it impossible to deduce them from physics alone. Historical contingencies also make biological systems more complex. This not only reduces the usefulness of pure deduction in biology, but also increases biological variability, which makes induction from multiple observations an appropriate research strategy.

These cross-disciplinary epistemological differences are recognized by scientists themselves. Survey studies reviewed in Muis, Bendixen, & Haerle (2006) have found that mathematicians and theoretical physicists score high on rationalism scales, while biologists and chemists score high on empiricism scales.

Regarding (1b), fundamental physics is also nomological, aiming to discover the axioms underlying nature (exemplified in Newton's *Principia*). By contrast, the special sciences tend to concentrate on uncovering causal mechanisms rather than general laws. As an example of a mechanism in neurobiology, 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 rationalist/empiricist contrast is not identical to the nomological/mechanistic contrast. Descartes notoriously claimed to deduce a mechanistic theory of physics in which atoms cohered via microscopic hooks (Westfall, 1971), and natural selection has lawlike properties (Bock, 2010) even though arguments for it often involve induction from masses of observations (as in Darwin's *Origin of species*).

Yet consistent with (1c), there seems to be an inherent tension when rationalism is combined with mechanisms and empiricism with laws. Newton thoroughly rejected Cartesian hooks (Blake, 1960), and unlike Newton's laws of motion, natural selection also has features of a causal mechanism (Skipper & Millstein, 2005). Moreover, while axiomatic systems appeal to rationalists by maximizing simplicity, mechanisms appeal to empiricists because they are imageable, posit causal interactions of the sort familiar from everyday experience, and accommodate a diversity of observations simply by positing new entities or activities or filling in black boxes.

Mechanisms are so important in the special sciences that non-mechanistic generalizations are often rejected, no matter how elegant. A classic example is the skepticism that greeted Alfred Wegener's theory of continental drift. This was the simplest available explanation for 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, long after Wegener's death (Cohen, 1985).

Although so far we have ascribed cognitive style to disciplines, it is actually a property of individual scientists. In a passage reminiscent of Miller (1990), Shapin (1996, p. 117) highlights the personal nature of cognitive style:

> 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 contrasts Newton with his contemporary Boyle, today known as the father of chemistry (another special science). When Newton first introduced his optical experiments in a communication to the Royal Society, he situated his observations within 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). He also wrote 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, Shapin observes that Boyle avoided speculating on the deeper meaning of his experimental results, refusing to call the gas law that today bears his name a law or even to express it mathematically. His 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.

Individuals within a science can also differ in cognitive style. Making a methodological contrast akin to empiricism versus rationalism, the theoretical 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). He cites Heisenberg as exemplifying the former, and Schrödinger (and himself) the latter. As usual, the contrast is relative: Heisenberg was still less empiricist than Boyle.

Cognitive Styles in Linguistics and Psychology

To avoid stirring up further partisan misunderstanding, we emphasize that (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 in overall disciplinary style.

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 quasi-mathematical grammars, where evidence from one language may be used to support claims about another, given the logical necessity of universal grammar. Psycholinguistic explanations take the form of causal mechanisms (box-and-arrow diagrams and connectionist nets) that are only considered justified if supported by statistical analyses of multiple speakers and items.

Again, cognitive style is primarily a property of individual scientists, and as noted by Shapin (1996), scientists tend to see their personal cognitive style as defining science itself. Thus linguistics has both methodological rationalists like Noam Chomsky and methodological empiricists like Geoffrey Sampson, who both invoke Galileo in support of their favored approach. 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," urging them to "[s]ummarize what you hear and see" in corpora of language use. Causal mechanisms also take center stage in linguistic schools like functionalism (e.g., Nichols, 1984).

A possible reason that both kinds of cognitive style thrive in the study of language is that unlike physics and biology, which inherently lend themselves to relatively distinct cognitive styles, language is both a logical system (modeled mathematically as far back as Aristotle) and a historically contingent process (both culturally and biologically).

Miller (1990, p. 321) admits that the multifaceted nature of language may explain 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." Yet as he emphasizes in the passage that opened this paper, the depth of the rift between linguistics and psychology seems to require a more fundamental explanation.

Indeed, 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 traditionally understood as atemporal, despite the confusion sometimes caused by the term "generative" (see Neeleman & van de Koot, 2010, for a computational argument that grammar must be abstract). Hence grammar cannot be modeled mechanistically, since by definition, mechanisms operate in time (Machamer et al., 2000). This obligates linguists to use nomological explanations. Given hypothesis (1c), linguistics therefore tends to be rationalist as well, while psychology, like all other special sciences, tends to be empiricist.

The difference in cognitive style between linguistics and psychology can be highlighted via two further points. First, even nativist psycholinguists tend to be methodological empiricists. To illustrate this, 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 argument is rationalist: Chomsky ascribes it to Plato, implying the irrelevance of two millennia of evidence. Moreover, Chomsky does not induce universal grammar from grammatical universals (a common misunderstanding that he attempts to clarify in Chomsky & Katz, 1981, among other places).

By contrast, the prominence of these two arguments is exactly reversed in Pinker (1994), the first popular defense of nativism. 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), going on to describe Crain & Nakayama (1986). The remainder of Pinker's book is a long catalog of empirical evidence for nativism from a variety of sources, including cross-linguistic universals.

Jenkins (2000, p. 31) highlights the epistemic contrast between Chomsky's and Pinker's nativism as follows:

> Suppose, contrary to fact, that no converging evidence at all of the kind Pinker detailed in his book [...] had turned up yet. Would one be justified in accepting Chomsky's arguments that the "basic design of language is innate," to use Pinker's words? [...] We think that one would be justified – that the results from the application solely from the argument from poverty of the stimulus are strong enough....

A second important point is that methodological rationalism shaped linguistics long before Chomsky. Chomsky (1966) himself links his approach with Renaissance grammarians who built on the Aristotelian view of language as logic. A more direct ancestor is Saussure, the first linguist to explicitly advocate the primacy of synchronic grammar. As expected if (a)temporality is indeed a key to the linguistics/psychology split, the rise of structuralist linguistics in the wake of Saussure was accompanied by a rejection of psychological approaches to language (exemplified by the contrasting attitudes towards psychology in Bloomfield, 1914, vs. Bloomfield, 1933). Bloomfield (1926) even proposes a *Principia*-like axiomatic system for linguistic theory.

The Relative Intractability of Cognitive Style

Hypothesis (3) is supported by two distinct arguments. Appropriately enough, one is empirical and one is rational. The empirical argument is based on studies in the psychology literature suggesting that cognitive style is associated with intrinsic individual differences. The rational argument is based on results in the mathematical literature suggesting that cognitive styles may be self-isolating.

Individual Differences in Cognitive Style

Do scientists choose cognitive styles, or do cognitive styles choose them? In favor of the former, Einstein described himself as changing from "skeptical empiricism" into "a believing rationalist" (quoted in van Dongen, 2010, p. 57).

Yet cognitive styles also seem to be partly beyond one's conscious control. Jehng, Johnson, & Anderson (1993) found cross-discipline epistemological differences in graduate students but not in undergraduates. Although they interpret this as showing that experience in a field changes one's epistemology, the lack of cross-year differences within the undergraduates seems more consistent with another interpretation: in choosing lifelong careers, graduates are influenced by their preexisting epistemologies. More generally, personal epistemology seems to be associated with personality (e.g., Diamond & Royce, 1980).

Regardless of where cognitive style comes from, it is expected, like all deeply held beliefs, to be reflexively defended out of ego-protection. Indeed, experiments on scientific reasoning, like that of Klaczynski & Narasimham (1998), show that participants tend to diminish the relevance of evidence that threatens their self-image or group commitments.

Nevertheless, group commitments seem to be secondary in the divide between rationalists and empiricists. For example, Chomskyans cite Chomsky when debating non-Chomskyans, but not as an authority figure, which would be self-defeating. Instead, they often cite him as a revealer of necessary truths. In a typical usage, Narita & Fujita (2010, p. 358) write: "Chomsky [...] reminds us of a virtual truism...." In other words, linguists who support Chomsky's methodological rationalism do so because they themselves are rationalists, not the other way around.

Klaczynski & Narasimham (1998) also report cognitive biases in scientific reasoning, fitting with other studies revealing individual variation in reasoning style (e.g., Stanovich & West, 2000). This variation often seems to split roughly between induction and deduction. 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 (2007) review a series of experiments and mathematical models suggesting that most people approach the Wason task using inductive (Bayesian) reasoning. This implies that the minority who give the normatively correct answer are applying deductive reasoning, just as the Wason task expects them to do. Performing (normatively) correctly on such tasks is also highly positively correlated with measures of general intelligence (Stanovich & West, 2000) and working memory capacity (Copeland & Radvansky, 2004).

Another difference between rationalism and empiricism is that deduction provides certainty (Euclid cannot be falsified), while induction does not (a black swan may be lurking around the next corner). Tolerance of uncertainty is also known to show individual variation. In multiple surveys of both students and nonacademics, Neuberg, Judice, & West (1997) found that discomfort with ambiguity was strongly correlated with preference for order, preference for predictability, and closed-mindedness. Such tendencies also seem to correlate with cognitive style, with Wilkinson & Migotsky (1994) finding, in a survey of university students, that the belief that knowledge is relative and context-dependent was associated with the belief that knowledge depends on observations and data (which they label empiricism), while the belief that knowledge depends on logical and analytical thinking (which they label rationalism) was not associated with relativist tendencies.

When taken to an extreme, a preference for predictability is a hallmark of obsessive-compulsive disorder and autism spectrum disorders like Asperger syndrome (Sadock & Sadock, 2007). Indeed, mathematical talent and autism seem to be linked (Baron-Cohen, Wheelwright, Burtenshaw, & Hobson, 2007). Newton (James, 2003) and Dirac (Farmelo, 2009) have even been diagnosed (post hoc) as having had Asperger's, while the "special scientist" Darwin earned a very high score from historians for openness to experience (Shermer, 2002). Disorders associated with intolerance of uncertainty may not only benefit deductive reasoning, but also hamper inductive reasoning. 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.

All this is not to say that either rationalism or empiricism is pathological, or even innate. Rather, the point is to highlight factors that may push scientists in one or the other direction along the rationalism/empiricism continuum, independent of conscious choice. If so, cognitive styles in science are expected to be relatively immune to persuasion, similar to political orientations, which are deeply entrenched neurocognitively (Kanai, Feilden, Firth, & Rees, 2011).

Logical Traps in Cognitive Style

How could rationalist or empiricist scientists ever discover that their epistemology is misleading them? As scientists, both do abandon hypotheses in the face of overwhelming counterevidence or if serious logical flaws are uncovered. The problem is that they differ in when they consider counterevidence to be "overwhelming" and how "serious" they consider a logical flaw. This makes it difficult for rationalists and empiricists to persuade each other.

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 has also been used in the philosophy of science (see Kelly, Schulte, & Juhl, 1997, for a review). Just as linguistic data to the child is consistent with an infinity of possible grammars, the data available to the scientist vastly underdetermines the range of possible hypotheses.

However, the logical challenge faced by scientists is much harder than that faced by infants. Infants may have "inside help" in acquiring the knowledge they require, but scientists do not. Even if scientific decisions are innately biased, these biases are not guaranteed to lead to scientific truth. The poverty of the stimulus argument is thus inapplicable to scientific reasoning.

Because of this distinction between children and scientists, formal learning theory leads to opposite conclusions in the two cases. Paraphrasing what Johnson (2004) calls Gold's theorem (after Gold, 1967), learners that can posit both finite languages (finite sets of strings) and infinite languages (infinite sets of strings) cannot choose between the two types on the basis of evidence alone: 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, success 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.

By contrast, Gold's theorem does not benefit scientists. Consider the following scenario (see Osherson & Weinstein, 1990, for a related argument). A scientist collects utterances from humans, which we assume have infinite languages, and from an alien species with a finite language consisting of symbol strings up to length three. The humans will be observed to have a much larger language than that of the alien (many more string lengths), but as with the human child, 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 simple hypotheses (i.e., is rationalist), an infinite language will be incorrectly posited for the aliens as well (perhaps a^*). If the scientist is biased towards hypotheses that cover the data and no more (i.e., is empiricist), humans will be ascribed an alien-like language (perhaps a^n, $n < m$, m large but finite).

One may object that the scientist can escape from this dilemma by exploiting information that the child does not have: evidence about what is ungrammatical. The scientist need not depend solely on the corpus of utterances, but may also 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*. The biased scientist will still misdescribe either the human or the alien language.

Such considerations suggest the wisdom of being what Einstein called an "opportunist" (quoted in van Dongen, 2010, p. 38), if one's personality makes such flexibility at all possible.

Conclusions

This paper has argued that Miller (1990) is right: Linguists and psychologists seem to talk past each other primarily because they have different epistemic and metaphysical commitments that are partly beyond conscious control.

Important gaps remain in the argument, however. While psychologists have studied cross-discipline differences in epistemology, the social science literature seems to be silent on nomological versus mechanistic metaphysics, let alone the rationalist/nomological and empiricist/mechanistic correlations claimed here. Moreover, too little is known about the causal relationship between cognitive style and scientific field (e.g., whether physicists become rationalists or vice versa). There have also been no surveys specifically comparing linguists and psychologists.

Miller (1990, p. 322) predicts that it will be very hard "to make clear to psychologists that simplifying explanations can be satisfying, once you grow accustomed to them." The results in this paper support his pessimistic conclusion.

Acknowledgments

Research was supported by the grants NSC98-2410-H-194-086-MY3 and NSC100-2410-H-194-109-MY3 from the National Science Council (Taiwan). Insightful comments have come from the self-described rationalist linguists Tsung-Ying Chen and Jon Sprouse, the functionalist linguist James H-Y. Tai, the psycholinguist Jenn-Yeu Chen, and for good measure, the philosopher of science Ruey-Lin Chen. The usual caveats apply.

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