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Psychology in Cognitive Science: 1978–2038

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Abstract

This paper considers the past and future of Psychology within Cognitive Science. In the history section, I focus on three questions: (a) how has the position of Psychology evolved within Cognitive Science, relative to the other disciplines that make up Cognitive Science; (b) how have particular Cognitive Science areas within Psychology waxed or waned; and (c) what have we gained and lost. After discussing what's happened since the late 1970s, when the Society and the journal began, I speculate about where the field is going.

Keywords: History of Cognitive Science; History of Psychology; Future of field

1. Introduction

When the Cognitive Science Society officially began, in the late 1970s, Psychology was by no means the main player. The three disciplines that formed the core group were Artificial Intelligence, Psychology, and Linguistics, with Philosophy, Neuroscience, and Anthropology playing smaller roles. These priorities had grown up during the 1950s and 1960s, as George Miller (2003) reviews in his essay on the cognitive revolution and the origin of Cognitive Science. Miller describes Harvard's Center for Cognitive Studies, where young psychologists met with a brilliant and challenging set of senior scholars—including Jerry Bruner, Peter Wason, Nelson Goodman, and Noam Chomsky—and were inspired by European psychologists, whose tradition had never embraced behaviorism—notably Jean Piaget, Sir Frederick Bartlett, and A. R. Luria. As Miller puts it, ''The bright young graduates grew up to become important psychologists unafraid of words like *mind* and *expectation* and *perception* and *memory*.'' This foment in Psychology met with equally revolutionary work in Computer Science—Norbert Wiener's Cybernetics and Marvin

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Minsky and John McCarthy's Artificial Intelligence (AI). By the mid-1950s, Alan Newell and Herb Simon were engaged in their pioneering work at the intersection of AI and Psychology, simulating human problem solving. These strands became ever more interactive during the 1960s and 1970s, leading to the call for a formal society to solidify the new discipline. Fig. 1 shows some of the key figures in the founding of the Cognitive Science Society, as well as the first three Chairs of the Society.

The journal *Cognitive Science* was founded in 1977 by Roger Schank and Gene Charniak, both in AI, and by Allan Collins, a psychologist who also worked in AI. Two years later (1979), the Cognitive Science Society was incorporated by Allan Collins, Roger Schank, and Don Norman (also a psychologist with work in AI). So of the four founding figures, two were in AI and two were psychologists with AI leanings. This balance of power reflected the feeling among those psychologists who embraced Cognitive Science that Psychology, newly back from its long behaviorist detour, had a lot to learn from AI, as well as from Linguistics and Philosophy.

The balance of disciplines has changed radically over the ensuing decades. One way to look at this evolution is to consider the makeup of authors of papers in the journal *Cognitive*

Fig. 1. Some founding figures of Cognitive Science. The top row shows the founders of the Journal and of the Society: Allan Collins, Roger Schank, Don Norman, and Eugene Charniak. The other two rows show some of the major figures whose work led to the Cognitive Science movement: in the middle row, Jerry Bruner, Marvin Minsky, Allen Newell, and Herb Simon; in the bottom row, Noam Chomsky and George Miller. Also in the bottom row are Eleanor Rosch and Charles Fillmore, the second and third Chairs of the Cognitive Science Society. The first Chair of the Society was Allan Collins.

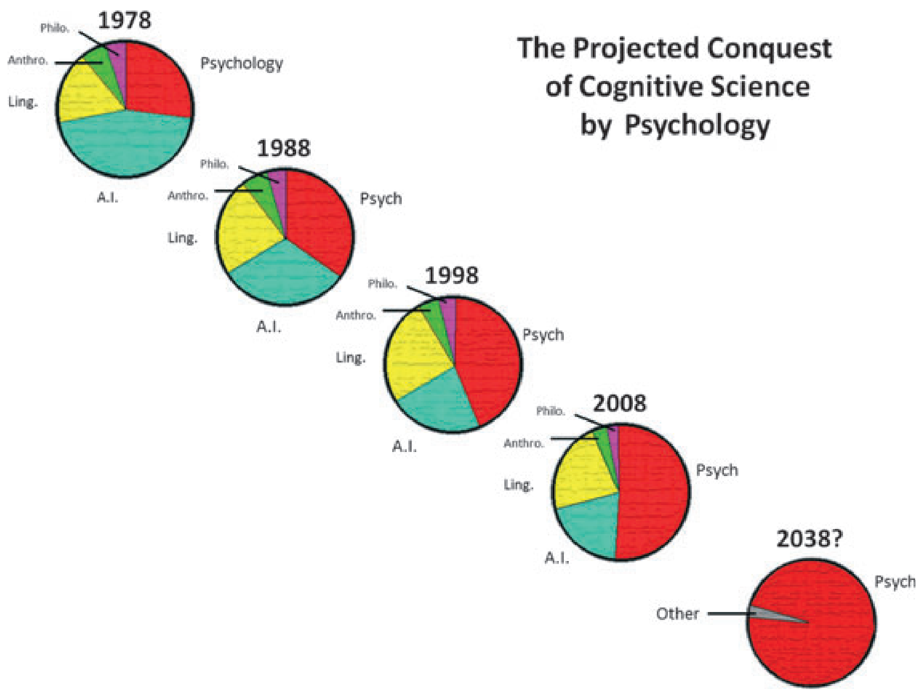

Fig. 2. Proportion of authors by discipline in the first two issues of *Cognitive Science* in each decade, beginning in 1978. If present trends continue, then by 2038, Psychology will have completed its conquest of Cognitive Science.

Science over the decades. Fig. 2 shows the proportions of authors from different disciplines in the first two issues of *Cognitive Science* in each decade, beginning in 1978. The proportion of papers authored by psychologists has increased steadily from 1978, when psychologists constituted about a quarter of the authors, to 2008 when psychologists constituted over half of the contributors. If the proportion doubles again in the next 30 years, by 2038 we will have vanquished the other fields entirely and established total dominion over Cognitive Science.

But such a coup would be a Pyrrhic victory. Cognitive psychology stands to gain a lot from its connection to the rest of the cognitive sciences. At the most obvious level, our neighboring disciplines provide useful methods: For example, psychologists have borrowed syntactic tests from linguists, including tests that provide insights into semantic structure. More deeply, the various disciplines of Cognitive Science differ in their driving questions. Whereas a psychologist is likely to ask ''how is X processed,'' a linguist may ask ''how is X structured'' and a philosopher, ''what are the implicit assumptions required to assert X.'' As this suggests, the constituent disciplines of Cognitive Science tend to focus on different levels of explanation. This can be illustrated using Marr's (1982) levels of explanation: *Computational—w*hat information is computed (and why); *Algorithmic*—how information is represented and computed; and *Implementational*—the physical substrate. Fig. 3 shows the preferred levels for the various disciplines of Cognitive Science.

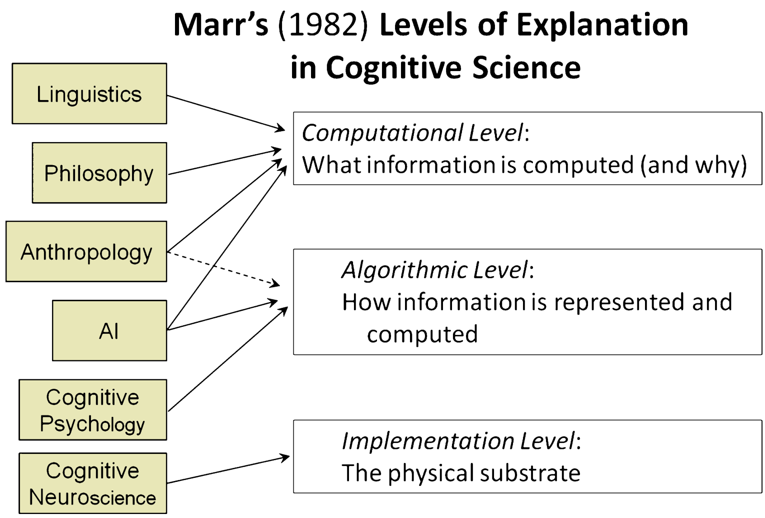

Fig. 3. Marr's (1982) levels of explanation in Cognitive Science, with main disciplinary foci.

Cognitive psychologists[1] like to work at the algorithmic level. We like to find a process model—a computational or mathematical model for preference—and test it with numerous experiments. At its best this leads to precise and elegant work; at its worst it leads to becoming riveted on smaller and smaller subproblems, happily tweaking parameters. Interaction with the other disciplines can remind us of the larger picture. This kind of methodological myopia is not confined to Psychology; each of the disciplines without the others risks falling into narrow grooves. One advantage of the ''converge and conquer'' spirit that characterizes Cognitive Science at its best is that interaction with other cognitive disciplines not only provides useful tools but also suggests different accounts within our own field. For example, Linguistics has offered detailed theories of linguistic structure and phenomena that suggest psychological processes; and especially in recent times, empirical methods that originated in psychology laboratories are used and improved on by linguists themselves. AI has developed explicit representations and processes that have informed psychological models of human cognition (Forbus, this issue). These two disciplines have been extremely influential in suggesting possible representations of semantic and conceptual structure, a crucial need for cognitive researchers. (Psychologists do not have much time for thinking about representation—the reward structure in our field dictates a steady flow of experiments.)

In addition to the tripartite interaction among AI, Linguistics and Psychology, Philosophy, and Anthropology were present at the start. The linkages among these disciplines were described in the Sloan Foundation's 1978 State of the Art Report on Cognitive Science. These interactions were summarized in Fig. 4 (adapted from Gardner's [1987, p. 37] reproduction). The figure depicts strong interactions (solid lines) between Psychology and all six of the constituent disciplines, as well as between AI, Linguistics, and Neuroscience. As Gardner recounts, the report aroused controversy in its time, and one may still disagree

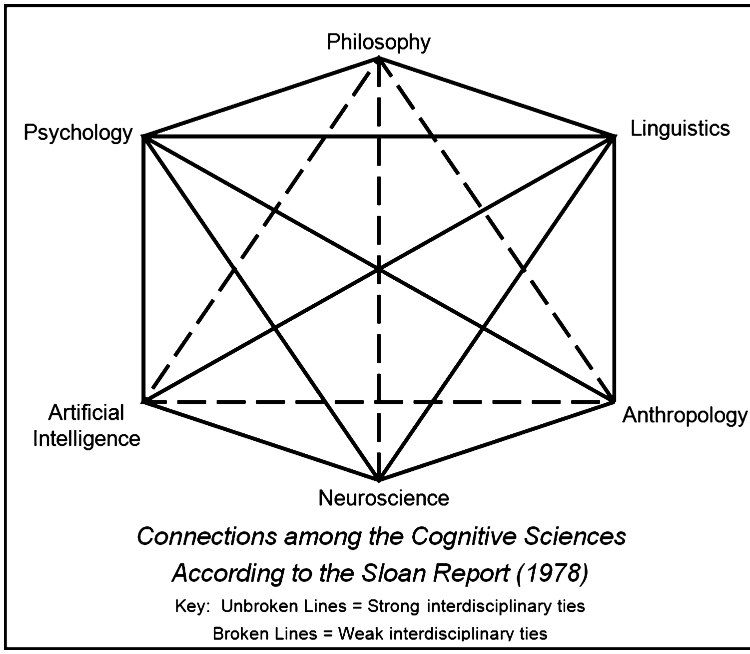

Fig. 4. Cognitive Science linkages as described in the 1978 Sloan Report (adapted from Gardner's [1987] reproduction of the Sloan Foundation's 1978 State of the Art Report on Cognitive Science).

with aspects of the figure. But the point is that in those heady early days, cognitive scientists aimed at a truly multidisciplinary field.

This makes it all the more disappointing that, as Fig. 2 shows, over the last 30 years Psychology has gained at the expense of all the other constituent disciplines. To be fair, this is partly because Psychology has been influenced by Cognitive Science and has broadened its purview. But there is also a degree of imperialism, seen, for example, in the insistence of some psychologists that a theory is not worth publishing unless its predictions have been tested on human subjects.

Not all the news is bad. Although philosophers have never had a large presence at the conference, Philosophy has continued to serve as a source of interesting ideas that have engaged the field—most recently in the area of moral reasoning. Anthropology played a role early on, but then its presence diminished. This was extremely unfortunate, because research in anthropology forces cognitive scientists to consider the varieties of human cognition beyond the scope of our standard subject pool. However, of late, cultural cognition has had a resurgence (see Bender, Hutchins, and Medin, this issue). Several lines of new research have captured wide attention, including work on interdependency versus dependency in cultural cognition (see Nisbett, 2003) and work on folk biology and the loss of folk biological knowledge (see Atran & Medin, 2008). Cultural cognition is again serving as a source of insight into what's universal and what's not in human cognition.

In sum, we in the Cognitive Science movement need to take steps to prevent the ''victory'' of Psychology over Cognitive Science, and instead preserve a fruitful interdisciplinarity. I turn now to how specific topics in Cognitive Psychology/Cognitive Science have fared over the years.

2. The evolution of topics in the cognitive science–psychology intersection

2.1. The beginnings

When the Society began, in the late 1970s, the dominant topics were representation of knowledge and high-level cognitive processes—including thinking, planning, and problem solving. The general belief was that an account of how knowledge is represented was crucial to the general enterprise. Cognitive Science was part of the great countermovement against the behaviorist regime of purely externalist descriptions of human thinking. This movement had started in the 1950s, as described in Miller's (1979, 2003) histories of the cognitive revolution and the birth of Cognitive Science (see also Gardner, 1987). The cognitive revolution had already gained considerable purchase within psychology, but Cognitive Science raised the definitive rallying call for a new approach. Allan Collins's (1977) essay ''Why cognitive science?'' in the first issue of the journal *Cognitive Science* introduced the field as follows:

> Cognitive science is defined principally by the set of problems it addresses and the set of tools it uses. The most immediate problem areas are representation of knowledge, language understanding, image understanding, question answering, inference, learning, problem solving, and planning… The analysis techniques include such things as protocol analysis, discourse analysis, and a variety of experimental techniques developed by cognitive psychologists in recent years. The theoretical formalisms include such notions as means-ends analysis, discrimination nets, semantic nets, goal-oriented languages, production systems, ATN grammars, frames, etc.

He concludes:

> ... the function of the journal is to provide a place to publish new kinds of analyses on theoretical ideas about cognitive representation and processing. I hope the journal will transmit the excitement surrounding the paradigm shift in the study of cognition made possible by the synthesis of artificial intelligence, psychology, and linguistics.

Consonant with this view, the papers in the first issue of *Cognitive Science* (aside from Allan Collins' inaugural editorial) centered on knowledge representation and on explicit descriptions of how cognitive processes operate over these representations (Table 1). They include papers on a knowledge representation language (KRL); on question-asking; on definite descriptions and semantic memory, and one whose title epitomizes the spirit of the enterprise: ''Artificial intelligence, language, and the study of knowledge.'' The same

Table 1
Articles from the first issue of *Cognitive Science* (1977): Volume 1, Number 1

Collins, A., Why cognitive science?
Bobrow, D. G., & Winograd, T., An overview of KRL, a Knowledge Representation Language
Lehnert, W., Human and computational question answering
Ortony, A., & Anderson, R. C., Definite descriptions and semantic memory
Goldstein, I., & Papert, S., Artificial intelligence, language, and the study of knowledge

Table 2
Papers from the First Cognitive Science Conference (1979)

The six Plenary talks
Allan Newell: The knowledge level and the symbolic level
Roger Schank: Language and memory
John Searle: Intention and action
Terry Winograd: What does it mean to understand language?
Don Norman: 12 issues for Cognitive Science
Herb Simon: Cognitive Science—The newest science of artificial phenomena
Sample symposia
Belief systems
Bob Abelson, Ed Hutchins, Jaime Carbonell, Ken Colby, Paul Kay, Naomi Quinn
Cognitive science and education [mental models, naïve physics, folk beliefs]
Allan Collins, Al Stevens, John Seely Brown, John Anderson, Jim Greeno, Ira Goldstein

pattern appears in the major talks given at the first Cognitive Science conference in 1979 (Table 2). Of the six Plenary talks, four (listed first in Table 2) were heavily concentrated on knowledge representation.

This commitment to explicit representation of knowledge was based on the desire to specify clear process models that could operate over complex knowledge. There was general agreement that any process model entails assumptions about the representations over which it operates, and unless those assumptions are made explicit, the theory remains fuzzy (see Palmer, 1978 for a particularly clear treatment of this point). Of course, ''explicit representation'' did not mean ''explicit to the possessor'' but rather ''explicit to the theorist.'' For example, Pat Hayes' (1985) treatise on the naïve physics of liquids contained 80-plus statements (such as ''unsupported water on a flat two-dimensional surface will spread out.''). Hayes did not assume that people could articulate this knowledge; his point was that they nonetheless guide inference and prediction (as when people rush to put a cloth in the path of spilled water). The ability to model complex human behavior such as problem solving with explicit representations and processes offered ammunition against the behaviorist claim that any discussion of internal processes was by its nature unscientific.

The belief in the importance of explicit representation has been fairly durable, though as discussed later it is no longer a universal consensus. Howard Gardner (1987), in his book on Cognitive Science, stated five key features of the field, of which the first was a belief in representation: ''the belief that it is legitimate—in fact, necessary—to posit a separate level of analysis which can be called the ''level of representation.'' When working at this level, a scientist traffics in such representational entities as symbols, rules, images—the stuff of representation which is found between input and output—and in addition, explores the ways in which these representational entities are joined, transformed, or contrasted with one another. This level is necessary in order to explain the variety of human behavior, action and thought.'' A similar idea was expressed in an encyclopedia article on Cognitive Science (Gentner, 2002): ''The assumption that there are mental representations and computational processes that operate over them is close to a universal tenet within cognitive science…the representational paradigm allows a rich vocabulary of processes that operate over these representations: *accessing* mental representations, as in memory retrieval; *transforming* a representation, as in problem-solving; *aligning* representations, as in analogy and similarity; *concatenating* representations, as in conceptual combination, and so on…'' The article went on to note that the dominant computational model for most of Cognitive Science's history was symbolic processing.

Although some version of this view is still accepted by most cognitive scientists, there have been challenges to this view, especially to the claims concerning symbolic processing. There have also been fusions and specializations that have taken on a life of their own as subfields. Fig. 5 shows a histomap of the changing focus on different topics within Psychology/Cognitive Science, based partly on counts of Cognitive Science conference papers by topic each decade (1978, 1988, 1998, 2008) and partly on my subjective estimates of mindshare.[2] The diagram also shows the various new subfields that have sprung up—including some that have waxed and waned and others that have become part of the mainstream.

The left side of the diagram shows how the once-mighty strain of knowledge representation has fared over the decades. The first major challenge was the PDP movement

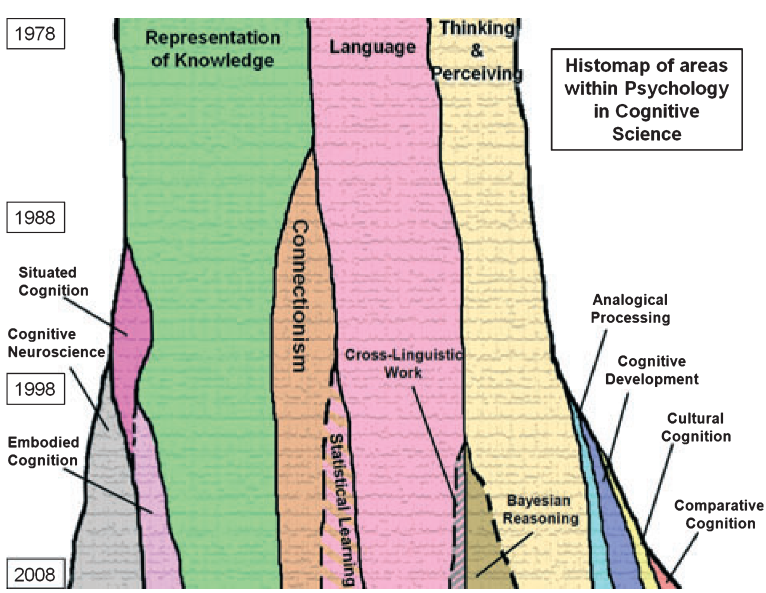

Fig. 5. Histomap of the rise and fall of Cognitive Science areas that intersect with Psychology.

(e.g., Hinton, 1989; McClelland, Rumelhart, and the PDP Research Group, 1986; Rumelhart, McClelland, and the PDP Research Group, 1986). Of course, related ideas had surfaced before (Minsky & Papert, 1969; Rosenblatt, 1958), but the more powerful multilayered models of the PDP group, and the confluence of brilliant, intense researchers, created great excitement and led to rapid spread of the ideas during the late 1980s and early 1990s. Interest in connectionism was fueled by dissatisfaction with the brittleness of the extant symbolic representations and especially by the desire to capture learning processes (which, despite the good intentions of the founders, had been largely neglected in symbolic accounts). Of course, connectionism did not reject the idea of representations and processes; but it rejected the commitment to explicit symbolic models. For many proponents, it seemed obvious that distributed connectionist systems would arrive at structured representations (or at least at the same capabilities as structured models) on their own, via experiential learning. But some of the signature phenomena of human thinking have failed to emerge from purely distributed models (see Gentner & Markman, 1993, 1995; Holyoak & Hummel, 2000; Markman, 1999). In analogy, for example, structured symbolic models, such as SME (Falkenhainer, Forbus, & Gentner, 1989), and structured symbolic-connectionist models, such as LISA (Hummel & Holyoak, 1997), have had the greatest success in accounting for the range of phenomena in analogical thinking and learning. However, the connectionist revolution can be counted a success in that connectionism has become one standard style of modeling, useful for many purposes. Equally importantly, connectionist models showed that rule-like behavior need not stem from codified rules. Connectionism also paved the way for statistical learning, which seems likely to remain a permanent part of the arsenal of cognitive science techniques.

Another set of challenges to knowledge representation is shown at the far left of the diagram. These challenges—situated cognition and embodied cognition—could be seen as rebel movements, or perhaps as the Loyal Opposition. While generally not breaking from Cognitive Science, these movements, and their predecessor, Gibsonianism, have in common a skeptical view of the centrality of representation and/or symbolic processing in human cognition. Although these three movements are related, each has a distinct profile. At the risk of oversimplifying, each of them can be seen as calling for attention to some neglected side of human mental life. Of course, it is in the nature of rebel movements that some adherents consider all other approaches worthless. I will not attempt to argue against the most extreme versions of these positions, but will instead try to characterize their main thrust and the effects on Cognitive Science as a whole.

Fig. 6 presents a schematic zoom-in on these three movements. Gibsonianism (or Ecological Psychology), though never a dominant movement, had a presence in Cognitive Psychology for some decades prior to the inception of Cognitive Science. It stressed the need to consider the structure of the environment (Gibson, 1970), sometimes phrased as ''It's not what is inside the head that is important, it's what the head is inside of.'' Gibsonianism rejected information processing and the idea of internal representations in favor of direct perception of the affordances of the environment. This movement left an important legacy of studies demonstrating the exquisite sensitivity of human (and animal) perception to the structure of the perceptual environment. Unfortunately, this work had less influence than it should have

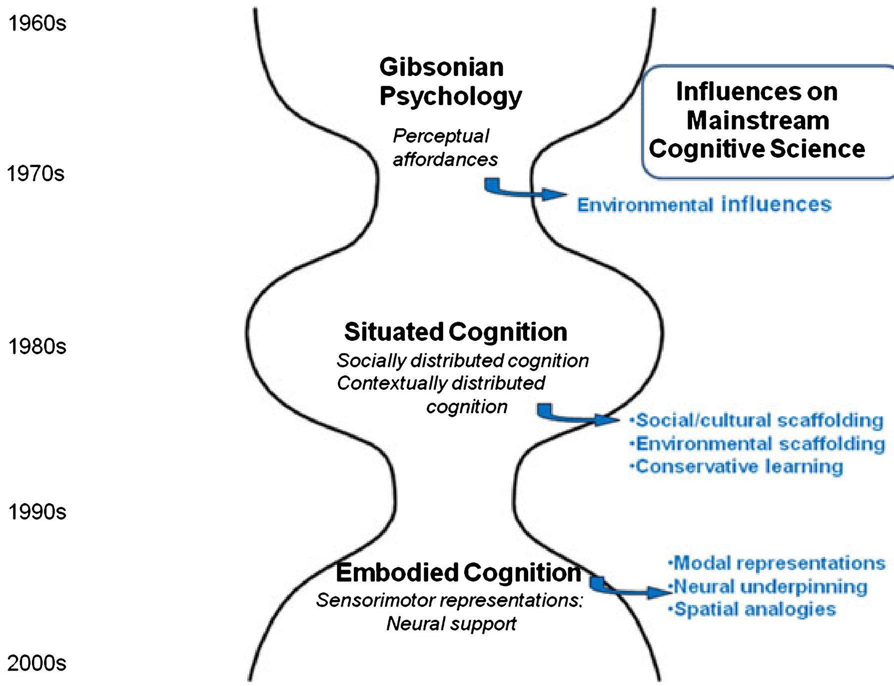

Fig. 6. Detail of histomap, showing countertrends to the mainstream Cognitive Science view of representation and processing and their influences on the main field.

had, in part because the Gibsonian prohibition against the idea of mental representation made it difficult to incorporate into mainstream Cognitive Science.

Situated cognition had a different agenda. It had two salient assumptions: (a) that human intelligence is fundamentally interactive; that is, that humans rely on external systems—other people, situations, and devices—to make ourselves smart (Hutchins, 1996, this issue); and (b) that far from being abstract and symbolic, human cognition is fundamentally inseparable from context (Lave, 1988). The first point has been extremely influential and may have helped bring about the increased prominence of sociocultural explanations in Cognitive Science. The second point is more contentious. Not surprisingly, the extreme positions associated with this movement—that ''cognition is not in the mind but in the room/fingers/environment'' and that ''transfer is impossible''—have not been particularly persuasive to the field at large. However, the idea that human learning is often concrete and contextually embedded, especially early in learning, and that this limits the degree of transfer, has resonated with work in learning. This theme of initial conservative learning has been taken up in both Psychology (e.g., Gentner & Medina, 1998; Goldstone & Son, 2005; Medin & Ross, 1989; Reeves & Weisberg, 1994) and Education, where it connects to the ''inert knowledge'' problem of failure to transfer knowledge from one domain to another (Bransford, 1979; Brown, Collins, & Duguid, 1989). Methods like self-explanation (Chi, Bassok, Lewis, Reimann, & Glaser, 1989) and analogical comparison (Gick & Holyoak, 1983; Loewenstein, Thompson, & Gentner, 2003) are researched as ways of forming more abstract, portable representations.

Embodied cognition, like Gibsonianism, stresses the importance of perceptual and motoric information. But in contrast to Gibsonianism, the information is allowed to come inside, as modality-specific sensorimotor representations (Barsalou, 1999). This allows for the inviting possibility that these sensorimotor representations might then participate in further mental processes such as reasoning, simulation, and analogical abstraction. Another distinctive feature of embodied cognition is its pursuit of neural signatures of sensorimotor underpinnings for conceptual processing (Barsalou, this issue). As with the other movements, there is an extreme version of embodied cognition, which holds that *all* representations are modality specific and discounts the possibility of enduring symbolic abstractions. There are also more moderate positions that allow for the possibility of (more) abstract symbolic representations as well as modal representations, and for the possibility that some abstract representations may derive from modal representations and retain some connection to them. Embodied cognition has been highly generative of new research in conceptual processing (see Fischer & Zwaan, 2008) and cognitive neuroscience (see Chatterjee, 2010). In sum, although some aspects of the embodied cognition movement would seem to argue for a radical break with the idea of abstract symbolic representations, it is quite possible that more pluralistic views, such as the graded abstraction view, will win out.

The final entry on the left is cognitive neuroscience. Although it was always conceived of as part of the interdisciplinary mix, only recently has cognitive neuroscience taken on a large role in Cognitive Science. Early work was limited by techniques that invite asking about localization—''where is it,'' rather than ''what does it connect to'' and ''how does it work.'' But as new methods of probing the brain are developed, and as more is known about linkages across areas, cognitive neuroscience is providing new knowledge about the mind—much more than can be reviewed here. A case in point is Chatterjee's (2010) review of neuroscience work on embodied cognition, which uses patterns of activation and deficits across different areas of the brain to argue for a graded abstraction view.

Another important current trend is Bayesian learning and reasoning. Because Bayesian learning is couched in terms of gathering evidence for hypotheses, it can be seen as a continuation of the explicit representation tradition in Cognitive Science. However, Bayesian processes are typically considered to apply at Marr's computational level, rather than at the algorithmic level, where psychological representations and processes reside.

On the right side of Fig. 5, branching off from the Thinking and Perceiving strand, are contributions from cultural cognition, cognitive development, and comparative cognition. While none of these is currently a strong presence within Cognitive Science, I believe they are gaining ground. Cultural cognition has a unique profile in the field. It had a considerable influence in Cognitive Science and Psychology in the 1970s and 1980s, with the work of Berlin, Romney, and D'Andrade (e.g., Berlin, Breedlove, & Raven, 1973; D'Andrade, 1984; Romney & D'Andrade, 1964). Then, for reasons beyond the scope of this paper, its role in Cognitive Science waned; but recently there has been a welcome resurgence (see Bender et al., this issue), fueled in part by cross-linguistic research, as discussed later. Cognitive development, cultural cognition, and comparative cognition all share the important property of offering very different perspectives from the standard focus on adult humans from western European-American cultures and speaking (mostly) Indo-European languages.

The right side of the figure also shows a modest expansion of research on analogical processing. Analogy research has had a long-standing role in the cognitive science of problem-solving and reasoning, but it is now also making contributions to accounts of learning in both children and adults. Work on analogy mostly continues the representational tradition of Cognitive Science; most accounts of analogical processing posit processes that operate over structured symbolic representations, although some processing may be assumed to be parallel (Forbus, Gentner & Law, 1995) or distributed (Hummel & Holyoak, 1997).

2.2. Gains and losses

2.2.1. Gains

One big gain in the field is work on learning. Looking again at Fig. 4, we notice that learning is essentially absent from the starting set of topics, despite the intentions of the founders. Given the centrality of learning in Cognitive Science today, it is hard to believe that it was largely neglected in the early days of the field. I believe there were at least three reasons for this. First, in part it reflected a reaction against the behaviorist agenda, in which learning was the major focus. Second, in arenas like language and cognitive development, there was a belief in innate structures that rendered the learning problems rather uninteresting. And third, there was a general sentiment in Cognitive Science that one had to understand *what* is learned, at a representational level, before studying how it is learned.

Learning came into special prominence with the connectionist movement, and it gained further ground with the advent of statistical learning techniques and evidence. Within cognitive development, learning processes were largely ignored in the early post-Piagetian phase, which focused on characterizing what children know and when they know it. But in recent times learning processes have become a strong current in cognitive development. Learning has always been central in the arena of analogical processing, and this has had some influence on research in the development of language and cognition. Finally, statistical learning techniques have led to a vastly increased emphasis on learning in the language arena. In sum, an important gain in our field over the years has been to make learning a major arena within Cognitive Science.

Another gain is that cognitive development, though still underrepresented in Cognitive Science, has become more integrated and more influential. This is partly because of the advent of methodologies for penetrating early cognition, such as habituation and familiarization. But, more importantly, the study of how cognition unfolds developmentally is a source of insight into its nature. The increased attention to cognitive development is shown in the selection of Susan Carey as the 2009 Rumelhart Prize winner for her work on cognitive development and conceptual change (e.g., Carey, 2009).

Another gain is the lifting of some former taboos. It was once absolutely off the table to study whether language influences thought. Indeed, in the 1990s I used to advise my lab that although we discussed the possibility of Whorfian effects in the lab, they should never do so in public, on pain of being written off as either a lunatic or a moron. There is still controversy about whether and how language influences cognition (e.g., Levinson, 1996; Li & Gleitman, 2002). But the important point is that the issue of whether and how language influences nonlinguistic cognition has taken its rightful place as an empirical question (e.g., Gentner & Goldin-Meadow, 2003).

Relatedly, the role of cultural cognition is increasing, with work ranging through folk biology, moral reasoning and perception of fairness, risk perception, and dependency-interdependency. There is increasing consensus that understanding the nature of human cognition requires examining the commonalities and differences among the peoples of the earth.

Another taboo that has been lifted is the ban on talk about the unconscious. We are now free to discuss it, although it is best to do so under the rubric of ''implicit/nonaware/nondeliberate'' processing.

Another gain is the lifting of taboos on discussion of animal cognition. In the past, nonhuman animals were granted instincts and perhaps associative learning. Comparative researchers bent over backwards to avoid ''anthropomorphizing'' by speculating about cognitive models and processes. Thankfully, recent work on the other great apes, (Tomasello & Call, 1997), on crows and their ilk (Emery & Clayton, 2004), and on the incomparable African gray parrot, Alex (Pepperberg, 1999), has clearly demonstrated a range of complex abilities to represent and process information. Clever techniques have been developed (some of them borrowed from developmental research) that allow researchers to ask about relational cognition and theory of mind in chimpanzees, planning for the future among Clark's nutcrackers, or tool use in the great apes and corvids. As with cross-cultural and cross-linguistic studies, findings in this arena are intrinsically fascinating—but beyond that, they offer the possibility of aligning our cognitive processes with those of others—in this case with those of other species—to discover the bits that pattern together to permit specific kinds of learning and reasoning (Seed & Tomasello, this issue). With luck, this research will help us tease apart the elements of cognition.

2.2.2. Losses

The big loss in our field is work on representation of knowledge. As Fig. 5 shows, the once-mighty stream of knowledge representation has dwindled sharply. A related diminution in work on semantic structure and conceptual semantics has occurred within language research, as shown in a recent paper by Hall, Jurafsky, and Manning (2008). They used statistical methods to analyze historical trends in topic coverage in the publications of the Association of Computational Linguistics (ACL). Their results show great increase in strength since 1980 for some topics, such as classification, probabilistic models, and statistical parsing, and great declines for others. The declining areas are conceptual semantics, plan-based dialogue and discourse, and computational semantics—areas critically reliant on analysis of meaning. This decline in linguistic and cognitive work on meaning and knowledge is a serious problem. The founders were right in their belief that human cognitive abilities rely critically on richly structured systems of knowledge and on symbolic reasoning abilities, without which our ability to draw inferences, detect contradictions, and process sentences like this one would be seriously impaired.

All is not lost, however. There is work on knowledge representation from Doug Lenat's CYC group, from George Miller's WordNet project, and from Fillmore's Framenet project, for example (see Baker, Fillmore, & Lowe, 1998; Lenat, 1995; Miller, 1995). And Dan Jurafsky in a recent talk[3] demonstrated that it is possible to apply statistical methods to issues in conceptual semantics (such as discovering category-subcategory pairs), and he speculated that as such methods become more available, they may create the conditions for rapid gains in understanding semantic structure.

3. The future: 30 years hence

Where is it all going? Here are some predictions:

- Cognitive Neuroscience will continue to be important. Its contribution to the study of higher-order cognition will grow as we learn more about the connectivity of processes across areas and as methods evolve to permit more precise inference about the mental processes that underlie neural activity.
- Bayesian modeling will peak and then settle into a standard useful technique, but it will not (some have either predicted or feared) be the answer to everything.
- Embodied cognition will leave its mark on the field, but accounts that allow for varying degrees of abstract representation will win out. Once some version of the embodied view becomes accepted into the mainstream, a new countermovement will spring up.
- Knowledge representation will regain some of its former ground, fueled in part by new statistical and neural techniques and in part by the demand for more powerful web-searching methods.
- Social cognition will become more important and more integrated with cognitive processing, as is already happening within cognitive development.
- Comparative cognition will continue to thrive (providing our species does not first eradicate all other intelligent life on the planet) and will lead to deeper understanding of the components of cognition.
- Statistical modeling will be a major methodology. Its scope of application will increase to include semantic and conceptual issues, at least up to a point. Further, some brands of statistical learning will incorporate structural matching algorithms borrowed from analogical modeling.
- General learning processes, including analogical processes, will gain ground in explaining linguistic and developmental phenomena.
- Finally, will Psychology complete its conquest of Cognitive Science? I cautiously predict that this will not happen, based on the efforts of the Journal and the Society to prevent such an outcome. But I'm not willing to lay long odds on this.

Notes

1. I focus here chiefly on cognitive psychology, which has been the main area of intersection of Psychology with Cognitive Science. For a discussion of interactions with Education, see Chipman, this issue.
2. Reducing this complex history required some oversimplifications and rather arbitrary decisions. For example, Bayesian methods could plausibly be a neighbor of statistical learning; but statistical learning emerged largely as an approach to language, whereas Bayesian reasoning is more concerned with general reasoning than with language. So they are shown as separate strands.
3. Personal communication, October 27, 2009.

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