Chapter 7

Discussion and Conclusions

7.1 The social contract hypothesis uniquely accounts for empirical results on the Wason selection task

Present in any novel situation are an infinite number of properties and relations. Darwinian algorithms are learning mechanisms keyed to focus attention on those dimensions of a situation that are evolutionarily important, and operate on them with inferential procedures that embody an appropriate evolutionary strategy. Without Darwinian algorithms, nothing could be learned; experience could not be structured to guide action along adaptive paths.

This thesis has proposed the existence of social contract algorithms. These focus attention on the actions of individuals, discern what those actions mean in terms of their desires, and calculate whether the cost/benefit structure of those desires indicates that the situation is one of social exchange; if it is, they operate on the cost/benefit structure of the situation with inference procedures that define cheating and facilitate the detection of cheaters. They operate in novel situations, as well as familiar ones, guiding inference and choices along adaptive pathways. The hypothesis that humans have social contact algorithms was tested using the Wason selection task, a test of how humans reason.

It was already known that how humans reason on the Wason selection task varies with what they are reasoning about; the question was, can the social contract hypothesis explain much of that variation? The null hypothesis from the standpoint of the existing literature is that availability is the sole determinant of performance on Wason selection tasks of varying content. This was tested against the hypothesis that humans have social contract algorithms that are the major determinant of performance on Wason selection tasks whose content involves social exchange.*

Six critical tests -- comparisons for which social contract theory and availability theory make radically different predictions -- were made by comparing performance on unfamiliar social contract problems with performance on both unfamiliar and familiar descriptive problems. Availability predicts a low percentage of logically falsifying, 'P & not-Q', responses for all unfamiliar rules, whether they are social contracts or not, and does not predict the response 'not-P & Q' under any circumstance. Social contract theory predicts a high percentage of 'P & not-Q' responses to "standard" social contracts, and a high percentage of 'not-P & Q' responses to "switched" social contracts -- no matter how unfamiliar the social contracts are. The critical tests were designed to unambiguously choose between the social contract hypothesis and the availability hypothesis. If social contract algorithms exist, they should produce a highly distinctive and unusual pattern of results.

For all six tests, the social contract hypothesis was verified and the null hypothesis that availability is the sole determinant of responses was falsified. Each of these six tests was replicated, using different unfamiliar social contract

* The social contract hypothesis is silent on whether availability exerts an indepedent effect on familiar problems that do not involve social exchange.

problems. The six critical tests, and subsequent experiments, established the following points:

1. Unfamiliar standard social contracts elicit the predicted SC response, 'P & not-Q', in the vast majority of subjects.
2. Unfamiliar switched social contracts elicit the predicted SC response, 'not-P & Q', in the vast majority of subjects.
3. The percentage of SC responses elicited by standard and switched social contracts is equivalent, even though these responses are quite distinct from a logical point of view ('P & not-Q' versus 'not-P & Q'). This is just what one would expect if the same algorithm were producing both responses.
4. Social contract algorithms ignore for a switched social contract the cards they should choose for a standard one, and vice versa, just as social contract theory predicts.
5. Social contract algorithms operate just as well in novel situations as they do in familiar ones: The percentage of SC responses elicited by unfamiliar social contracts is equivalent to that elicited by familiar social contracts.
6. Social contract algorithms are the major determinant of responses to problems whose content involves social exchange. More SC responses are elicited by unfamiliar social contracts than falsifying responses by familiar descriptive problems. The social contract effect is about 50% larger than the effect availability has on familiar descriptive problems.
7. The social contract effect is replicable with a variety of familiar and unfamiliar social contracts.

The hypothesis that humans have social contract algorithms uniquely accounts for the results of these experiments. It predicts them and it explains them; no other hypothesis proposed so far can do either. Moreover, the apparently contradictory literature attempting to stalk the "elusive" content effect on the Wason selection task can be systematically explained only by the social contract hypothesis.* Robust and replicable content effects are found only for rules that are standard social contracts: the only rules for which the predicted SC response is also the logically falsifying response.**

7.2 Are social contract algorithms innate?

Theoretical considerations

Availability theories presume the existence of innate learning mechanisms that are general purpose and content-independent. However, no variant of availability theory can adequately explain the results of the experiments presented in Chapter 6. It is difficult to see how the association 'cassava root-no tattoo' or 'eats duiker meat-has never found ostrich eggshell' could have been "cued" from long-term memory (Manktelow & Evans, 1979; Griggs & Cox, 1982), let alone be the dominant association for over 70% of undergraduates tested (Pollard, 1982). No matter how wildly unfamiliar the rule's terms, social contract problems elicited social contract responses. Furthermore, if associations between specific terms were responsible for the pattern of results on social contract rules,

* Problems with other proposed hypotheses are discussed in depth in Chapter 3.

** See Chapter 2 for a detailed review (especially p. 70-71).

then descriptive rules using the same unfamiliar terms should have elicited the same pattern; they did not. No theory whose predictive and explanatory power rests on associations between specific terms used in a social contract rule can explain the results of my experiments.

Availability theories that emphasize the role of mental modeling (Johnson-Laird, 1982) or frames (Wason, 1983; Rumelhart & Norman, 1981) in recognizing logical contradiction cannot explain the following aspects of the results:

1. Why would subjects find an unfamiliar social contract scenario (U-STD-SC) so much easier to model than an unfamiliar descriptive scenario (U-D), or indeed, a familiar one (F-D)?
2. Why would this situation reverse itself on switched social contracts (U-SWC-SC), for which the scenario to be modeled is identical to that for the U-STD-SC? Unlike the U-STD-SC, the U-SWC-SC does not elicit logically falsifying responses -- although it does elicit the correct social contract response.

The only response an availability theorist of the modeling variety could make would be to claim that people have a generalized social contract "frame" that recognizes and operates on the cost/benefit structure of a social contract as presented in Figure 6.1 (with which I agree -- see Chapter 5), but that it was acquired exclusively through "experience" -- more precisely, through experience structured solely by the content-independent, general purpose information processing systems presumed by associationists (Fodor, 1983). Innateness per se is not the issue here: Every psychological theory -- even Hume's associationism -- assumes the existence of innate algorithms that structure experience. The issue is: Are <u>some</u> of the innate algorithms special purpose, content-dependent, Darwinian algorithms?

There is nothing in availability theory that would lead one to predict the existence of generalized social contract frames. Besides being post-hoc, this view cannot cope with a variety of fundamental issues, for example:

1. There is no reason to believe that SC rules are <u>more common</u> than non-SC prescriptive rules (bureaucratic rules, work orders from employers, safety rules, traffic rules, etc.) or the ubiquitous descriptive relations people use to describe and act on the world. Why, then, would general purpose algorithms have produced generalized SC frames, but not generalized frames for reliably detecting violations of descriptive or prescriptive* rules?

2. Compliance with social contracts is far more common than cheating. Every time a store lets you walk out with the goods you have paid for, you have experienced compliance. General purpose learning mechanisms should therefore create frames that look for compliance, not cheating.** At best, a

* A number of non-SC prescriptive rules have been tested, both in this thesis and in the literature: the AP immigration rule of Experiment 5; the AP of Experiments 1-4, 6; D'Andrade's AP; non-SC post-office rules in Golding, 1981 and Griggs & Cox, 1982; the apparel-color problem of Cox & Griggs, 1982; the deformed SC rules of Griggs & Cox, 1983 (see Chapter 2).

** Contextual exhortations to "look for cheaters" cannot explain this. Each non-SC problem contained several similar requests to see if the facts violate the rule, yet most subjects behaved like verificationists, nevertheless.

subject's ratio of compliance-to-cheating episodes should be the idiosyncratic product of different life experiences, and unfamiliar social contract problems should show at least as much response variability as familiar descriptive ones.

3. Trial and error learning requires some definition of error; hypothesis testing requires some definition of violation. A general purpose, content-independent learning mechanism needs a general purpose, content-independent definition of error. Logical falsification, for example, is a content-independent definition of error or violation. But the definition of violation for social contracts is quite specific: Cheating is defined as absconding with a benefit when you have not paid the required cost. It conforms to no known content-independent definition of error; it certainly does not map onto logical falsification, as a consideration of switched social contracts shows. Without built-in, domain specific knowledge defining what counts as cheating, how could one develop a generalized social contract frame?*

An evolutionarily-based social contract theory handles issues like these with ease. Social contract theory not only provides the most parsimonious explanation of the data, but the assumption that some innate algorithms are special purpose and content-dependent is also more parsimonious from the standpoint of evolutionary theory. Social exchange is a domain for which

* It is not sufficient to say that people learn what counts as cheating because they feel irritated when they have been cheated and therefore attend to the irritating stimuli; that presumes they already know what constitutes cheating. Having been cheated was the stimulus that triggered the irritation in the first place.

the evolutionarily-predicted computational theory is complex, and the fitness costs associated with "errors" are large. Even if it were possible for a domain general information processing strategy to construct social contract algorithms -- and it is by no means clear that it _is_ possible -- it is not reasonable to expect that natural selection would leave learning in such a domain to a general purpose mechanism. Successfully conducted social exchange was such an important and recurrent feature of hominid evolution, that a reliable, efficient cognitive capacity specialized for reasoning about social exchange would quickly be selected for. A general purpose learning mechanism would either be supplanted or used only for learning in other domains.

Ontogeny

Evolutionary considerations can also guide research into the ontogeny of the social contract algorithms (see Cosmides, 1980). The brain is a metabolically expensive organ; expensive cognitive capacities should not mature until the organism needs them, so that metabolic energy can be devoted to other kinds of growth.* Social contract algorithms are not useful to a child until its welfare depends on individuals whose fitness interests are not identical to its own -- individuals to whom it must offer a benefit to get a benefit. Until weaning, the interests of mother and child are identical; benefiting the infant benefits the mother equally. Weaning marks the beginning of the end of this coincidence of interest. It is a period of intense parent-

* Spurts in brain growth appear to be correlated with spurts in cognitive development (Epstein, 1974a,b).

offspring conflict in both humans* and other primates (Trivers, 1976; Shostak, 1981), a period when the child wants more investment than the parent, who is ready to invest in a new offspring, is willing to give. After being weaned from the breast, the child is weaned from its mother's side; its welfare depends increasingly on the behavior of the less related individuals with whom it is left. At this point, the ability to cajole, threaten, exchange, and negotiate become crucial.

Thus, evolutionary considerations suggest that the learning mechanisms that underlie the ability to engage in social exchange should begin to mature slightly before the age usually associated with the onset of weaning during most of human evolution. World-wide, the average age of weaning is age two (Whiting, personal communication**), and this figure agrees well with life history estimates from the San, the hunter-gatherer group whose way of life is currently believed to most resemble that of Pleistocene hunter-gatherers.

A mechanism that guides learning about social exchange should include features that allow the child to a) model other people's values, both by noting their emotional reactions and attempting to manipulate their behavior, b) categorize values according to who has them, c) be aware of its own abilities, as these determine what the child is capable of offering to others,

---

* Most markedly in cultures where the only other food sources are difficult for infants to digest; for example, weaning among the San, who eat a high proportion of fibrous bush food as adults, appears to be particularly stressful (e.g., Shostak, 1981).

** This figure agrees with data for a population believed to approximate natural fertility conditions (Bongaarts & Potter, 1983, pp. 25, 90, 145).

d) understand and apply concepts of obligation and entitlement, e) become interested in notions of fairness and cheating, f) practice intercontingent behavior, g) remember its history of exchange with other individuals (see Chapter 5).

Intriguingly, Kagan (1981) has collected cross-cultural data suggesting the maturation, just prior to age two, of a cognitive capacity that looks suspiciously like it is specialized for learning about and engaging in social exchange. According to Kagan, the mental organ that emerges at this age includes:

* the concept of obligation,
* interest in and concern with other people's values,
* the ability to understand when an emotional reaction is "appropriate" to a person's age and situation,
* an awareness of one's own capacities for action,
* the ability to understand other people's intentions and anticipate their actions,
* an interest in trying to coax others into doing what the child wants (perhaps the most distinguishing characteristic of the "terrible twos").

Moreover, it is at about this age that language, the ultimate negotiative tool, begins to emerge. The computational theory of social exchange presented in Chapter 5 should allow one to generate predictions about other capacities that can be expected to co-occur with those already discovered (see Cosmides, 1980).

The finding that adult subjects are very adept at detecting potential "cheaters" on a social contract, even when it is unfamiliar and culturally alien, stands in marked contrast to the repeated finding that they are not skilled at detecting the potential invalidity of descriptive rules, familiar or unfamiliar. The ontogeny of the algorithms that produce these results remains an open question. It is possible that they are, in some carefully delimited sense, learned. However, the mental processes involved appear to be powerfully structured for social contracts, yet weakly structured for other elements and relations drawn from common experience. This implies that the learning process involved is guided and structured by special purpose innate algorithms, just as learning a natural language is guided and structured by the innate algorithms of the language acquisition device.

7.3 The role of evolutionary theory in psychology

For the past 100 years, domain general psychological mechanisms have been the Holy Grail of experimental psychology. Paradigms rose and fell, mentalism gave way to behaviorism gave way to mentalism, but, undaunted, the quest for an equipotential psyche continued.

And psychology, after a century of research, is not yet an integrated science.

There may be a connection between these two facts. It may be that the processes that govern attention, perception, memory, categorization, reasoning, and learning simply are not equipotential. The Grail of legend could not be found because it did not exist.

The human mind did not evolve to attend "in general", to remember "in general," to learn "in general". It evolved to attend <u>to</u> predators, <u>to</u> the needs of kin, <u>to</u> potential sexual partners, _to_ agents of threat. The cognitive processes required for different evolutionarily important domains are different _in kind_: Attention to predators requires a high level of false positives to cues indicating felids and snakes; attention to the needs of kin requires selective orientation to emotion cues emitted by relatives, and the mobilization of reasoning and investigational processes that allow one to infer what it is that they need.

Attention, perception, categorization, learning, memory, decision making, and reasoning cannot be studied in isolation from motivation, emotion, behavior, and social psychology. To do so is to carve the study of psychology into artificial units that will not hang together. All these aspects of human psychology must be mobilized in different ways to solve different adaptive problems. As Chapter 5 illustrated, cognition, motivation, emotion, and behavior all must play specific and well-defined roles in solving the various adaptive problems associated with social exchange.

The search for domain specific Darwinian algorithms promises to integrate psychology, precisely because it focuses on adaptive problems. Cognitive psychologists can begin addressing issues closer to the heart of human nature. The study of emotion and motivation can be welcomed back into psychological theory, as systems for mobilizing the appropriate Darwinian algorithms when the situation "calls for" them. The exile of behavior from cognitive theory can end, because the presumed purpose of adaptive thought is to produce adaptive behavior.

Psychology and evolutionary biology are sister disciplines.

The goal of evolutionary theory is to define the adaptive problems that organisms must be able to solve. The goal of psychological theory is to discover the information processing mechanisms that have evolved to solve them. Alone, each is incomplete for the understanding of human nature. Together, they are powerful: as I hope the research presented in this thesis demonstrates, understanding what adaptive problems the human mind was designed to solve is a great aid to discovering how it works.

An evolutionary psychology would proceed adaptive problem by adaptive problem, domain by domain. Many adaptive problems have already been defined by evolutionary biologists. The real challenge for psychologists is to develop experimental methods that will allow the outlines of the psychological mechanisms that solve these problems to be traced. Happily, cognitive psychologists are in an excellent position to do this, having already invented an impressive array of concepts and experimental methods for tracking complex information processing systems. The experiments reported in Chapter 6 are a first attempt at such an approach: they used an experimental paradigm that had already been developed by cognitive psychologists.

The hypothesis that the human mind is a equipotential information processing system has been entertained for one hundred years. It is time for a change. The human mind is not a machine that fell out of the sky, of unknown purpose. The human mind was designed by natural selection to accomplish specific, well-defined adaptive functions. An equipotential psyche cannot accomplish these functions. A cognitive science that ignores this reality is a cognitive science that will fail.

Appendix A:

The Frame Problem and So-Called "Constraints" on Learning

Biologists and psychologists have a mysterious tendency to refer to the properties of domain specific (but not domain general) mechanisms as "constraints." For example, the one-trial learning mechanism, discovered by Garcia & Koelling (1966), that permits a blue jay to associate a food taste with vomiting several hours later, is frequently refered to as a "biological constraint on learning". Books reporting the existence of domain specific learning mechanisms frequently have titles like: "Biological Boundaries of Learning" (Seligman & Hager, 1972) or "The Tangled Wing: Biological Constraints on the Human Spirit" (Konner, 1982). This terminology is dangerously misleading, because it incorrectly implies that "unconstrained" learning mechanisms are a theoretical possibility.

All constraints are properties, but not all properties are constraints. Calling a property a "constraint" implies that the organism would have a wider range of abilities if the constraint were to be removed.

Are a bird's wings a "constraint on locomotion"? Birds can locomote by flying or hopping. Wings are a property of birds that enables them to locomote by flying, but wings are not a "constraint on locomotion." Wings expand the bird's capacity to locomote -- with wings, the bird can fly <u>and</u> hop. Removing a bird's wings reduces its capacity to locomote -- without wings, it can hop, but not fly. Wings cannot be a constraint, because removing them does not give the bird a wider range of locomoting abilities. If anything, wings should be called "enablers", because they enable an additional form of locomotion. Having them actually expands the bird's capacity to locomote.*

A thick rubber band placed such that it pins a bird's wings to its body is a constraint on the bird's ability to locomote: With the rubber band the bird can only hop; without it the bird can both hop and fly.

Similarly, there is no evidence that the domain specific mechanisms that permit one trial learning of an association between a taste and vomiting are "constraints on learning." Removing the specific properties that allow the efficient learning of this particular association, would not expand the bird's capacity to learn, it would reduce it. Not only would the blue jay be unable to associate an electric shock with vomiting, it would also be unable to associate a food taste with vomiting.

Having wings to fly is, however, a constraint on (or more precisely, a restricted subset of) the _theoretical_ class of all possible means of locomotion. A robin is capable of only two members of this theoretical set -- it cannot crawl, trot, roll, swim, burrow, or travel through time warps and worm holes in space -- it can only hop and fly. Having wings is not, however, a _constraint on the organism's ability to locomote_. Similarly, internal representations of the movements of solid objects appear to be "constrained" by the same laws of kinematic geometry that

* The ability to fly may turn out to place constraints on an alternative kind of locomotion, that is, efficient bipedal locomotion (flying requires hollow bones, which may not be strong enough to permit prolonged walking or hopping) _but it is not a constraint on the birds capacity to locomote_. Furthermore: Whether the ability to fly places constraints on the efficiency of bipedal locomotion is an _empirical_ claim: One cannot simply assume, a priori, that having the ability to locomote by one means reduces the efficiency of another kind of locomotion.

govern the movement real objects: we only imagine a subset of the theoretically infinite number of possible paths by which an object can travel between two points (Shepard, 1984). This subset is the same subset true of real objects. However, domain specific knowledge like this expands the our capacity to accurately model the world, it does not reduce it.

This mysterious tendency is perhaps the result of the mistaken notion that a tabula rasa is possible, that learning is possible in the absence of a great deal of domain specific innate knowledge. If true, then a property that "prepares" an organism to associate vomiting with a taste may preclude it from associating an electric shock with that taste. However, if an organism had a domain general associative mechanism, there is no reason why that mechanism should not work to pair taste with electric shocks. One would have to hypothesize that the presence of food somehow shut off the domain general mechanism -- and this is an empirical claim that would have to be demonstrated.

Appendix B: Natural Selection in Action

How many generations will it take for indiscriminate altruists to go extinct?

(see Chapter 5, p. 138)

Imagine a population with n "altruists" (individuals who always cooperate, regardless of whether they are playing another altruist or a cheater) and n "cheaters" (individuals who never cooperate), where n is a very large number.* For simplicity's sake, assume each individual reproduces asexually, produces 2 offspring in the absence of any exchange, then dies. Each individual plays one Prisoner's Dilemma game per generation, and this game affects the number of offspring produced according to the payoff matrix in Figure 7.2 (+1 = one more offspring, for a total of 3; -1 = one less than, for a total of 1, and so on). Whether a particular individual plays with an altruist (A) or cheater (C) is random, and therefore proportional to the percentage of the population which each represents. P(A) = probability of playing with an altruist and P(C) = probability of playing with a cheater.

Expected reproductive value
for an individual altruist = [5 x P(A)] + [0 x P(C)]

Expected reproductive value
for an individual cheater = [7 x P(A)] + [2 x P(C)]

	Absolute numbers		Percent of Population	
	A	C	A	C
Parental generation	n	n	50%	50%
F1	2.5 n	4.5 n	36%	64%
F2	4.5 n	17.1 n	21%	79%
F3	4.7 n	52.2 n	8%	92%
F4	1.9 n	125.3 n	1.5%	98.5%
F5	.14 n	260.0 n	.05%	99.95%
F6	.00035 n	520.6 n	.000067%	99.999933%

When n = 10, the altruists are extinct after the fifth generation (F5). When 10 < n < 2857, the altruists would be extinct after the sixth generation (F6).

* This assumption simply smooths out the probabilities. For example, if n=10, then P(A plays with C) = .53, P(A plays with A) = .47, P(C plays with A) = .53, P(C plays with C) = .47. As n reaches infinity, all four probabilities converge on .5. Using the exact probabilities for a small n, simply drives altruists to extinction a bit faster.

You are a homicide detective for the Boston Police. For months, you have been gathering evidence against the infamous Owens Brothers. Jake and Ted Owens are in the drug trade, and are responsible for several particularly bloody underworld murders. They are shrewd and tricky -- they have eluded capture for months. You have amassed a huge amount of evidence against them -- your testimony in court could send them to jail for life. The problem is, they know it -- They have made several attempts on your life. They are ruthless killers and they want you dead.

An anonymous phone caller tells you that Ted will be down at the docks at 10 tonight. You go down there -- the docks are deserted. You turn a corner, and there is Ted. Quickly you pull your gun, shouting "Freeze!". Just as Ted is putting his hands in the air, you feel a gun in your back and hear Jake's cold voice behind you, saying:

"If you make one false move, I'll kill you."

What should you do? Does he mean it? The cards below have information about how this story could end. Each card represents an ending -- not necessarily different endings. One side of a card tells whether you gave up your gun, and the other side of the card tells whether Jake Owens shot you.

Indicate only those card(s) you definitely need to turn over to see if Jake has broken his "promise" in any of these endings.

A. Jake shoots you

B. You give them your gun

C. Jake lets you go

D. You shoot Ted

You are a narcotics detective for the Cambridge Police. For months, you have been gathering evidence against Professor Owens and his student Bill. Professor Owens is a mild mannered fellow who is interested in the consciousness-expanding potential of hallucinatory drugs -- but he has had trouble getting his research funded. He and his students have been using University chemistry labs to manufacture LSD to sell on campus, in order to fund their research. You have enough evidence to arrest them -- the problem is, you have not been able to find them.

An anonymous phone caller tells you that the student, Bill, will be down at the docks at 10 tonight. You go down there -- the docks are deserted. You turn a corner, and there is Bill. Quickly you pull your gun, shouting "Freeze!". Just as Bill is putting his hands in the air, you feel a gun in your back and hear Professor Owens' voice behind you, saying:

"If you make one false move, I'll kill you."

What should you do? Does he mean it? The cards below have information about how this story could end. Each card represents an ending -- not necessarily different endings. One side of a card tells whether you gave up your gun, and the other side of the card tells whether Professor Owens shot you.

Indicate only those card(s) you definitely need to turn over to see if Professor Owens has broken his "promise" in any of these endings.

A. Owens shoots you

B. You give them your gun

C. Owens lets you go

D. You shoot Bill

BIBLIOGRAPHY

Personal communications:

David Pilbeam
Department of Anthropology
Harvard University

John Whiting
Department of Anthropology
Harvard University

Peter Wason
Department of Phonetics & Linguistics
University College London

E.O. Wilson
Department of Biology
Harvard University

Axelrod, R. The evolution of cooperation. New York: Basic Books, 1984.

Axelrod, R. & Hamilton, W.D. The evolution of cooperation. Science, 1981, 211, 1390-1396.

Bahrick, H.P., Bahrick, P.O., & Wittlinger, R.P. Fifty years of memory for names and faces: a cross-sectional approach. Journal of Experimental Psychology: General, 1975, 104, 54-75.

Bartlett, F.C. Remembering: A study in experimental and social psychology. Cambridge, UK: Cambridge University Press, 1932.

Boden, M. Artificial intelligence and natural man. New York: Basic Books, 1977.

Bongaarts, J. & Potter, R.G. Fertility, Biology, and Behavior. New York: Academic Press, 1983.

Bowlby, J. Attachment and loss (Volume 1). New York: Basic Books, 1969.

Bracewell, R.J. & Hidi, S.E. The solution of an inferential problem as a function of the stimulus materials. Quarterly Journal of Experimental Psychology, 1974, 26, 480-488.

Brown, C., Keats, J.A., Keats, D.M., & Seggie, I. Reasoning about implication: A comparison of Malaysian and Australian subjects. Journal of Cross-Cultural Psychology, 1980, 11, 395-410.

Bruner, J.S. Beyond the information given. (J.M. Anglin, ed.) New York: Norton & Co., 1973.

Bruner, J.S. In search of mind: Essays in autobiography. New York: Harper & Row, 1984.

Bruner, J.S., Goodnow, J.J. & Austin, G.A. A study of thinking. New York: Wiley, 1956.

Buss, D. Sex differences in human mate selection criteria: An evolutionary perspective. In Sociobiology and Psychology, in press.

Carey, S. & Diamond, R. Maturational determination of the developmental course of face encoding. In D. Caplan (ed.), *Biological studies of mental processes*. Cambridge, MA: The MIT Press, 1980.

Chomsky, N. *Reflections on language*. New York: Random House, 1975.

Clark, H.H., & Clark, E.V. *Psychology and language: An introduction to psycholinguistics.* New York: Harcourt, 1977.

Cosmides, L. Adaptation and negotiation: A developmental approach. Unpublished manuscript, Harvard University, 1980.

Cosmides, L. Invariances in the acoustic expression of emotion during speech. *Journal of Experimental Psychology: Human Perception and Performance*, 1983, *9*, 864-881.

Cox, J.R., & Griggs, R.A. The effects of experience on performance in Wason's selection task. *Memory and Cognition*, 1982, *10*, 496-502.

Cutting, J.E., Proffitt, D.R., & Kozlowski, L.T. A biomechanical invariant for gait perception. *Journal of Experimental Psychology: Human Perception and Performance*, 1978, *4*, 357-372.

Dawkins, R. *The extended phenotype*. San Francisco: W.H. Freeman, 1982.

de Waal, F. *Chimpanzee politics: Power and sex among apes*. New York: Harper & Row, 1982.

Eibl-Eibesfeldt, I. *Ethology: The biology of behavior* (second edition). New York: Holt, Rinehart and Winston, Inc., 1975.

Ekman, P. *Emotion in the human face* (second edition). Cambridge, UK: Cambridge University Press, 1982.

Epstein, H.T. Phrenoblysis: Special brain and mind growth periods. I: Human brain and skull development. *Developmental Psychobiology 7*, 1974 (a), 207-216.

Epstein, H.T. Phrenoblysis: Special brain and mind growth periods. II: Human mental development. *Developmental Psychobiology 7*, 1974 (b), 217-224.

Evans, J.St.B.T., & Lynch, J.S. Matching bias in the selection task. *British Journal of Psychology*, 1973, *64*, 391-397.

Fillenbaum, S. Inducements: On the phrasing and logic of conditional promises, threats, and warnings. *Psychological Research*, 1976, *38*, 231-250.

Fodor, J.A. *The language of thought.* Cambridge, MA: Harvard University Press, 1975.

Fodor, J.A. Modularity of mind. Cambridge, MA: The MIT Press, 1983.

Garcia, J. & Koelling, R.A. Relations of cue to consequence in avoidance learning. Psychonomic Science, 1966, 4, 123-124.

Gardner, H. The shattered mind. New York: Random House, 1974.

Gilhooly, K.J. & Falconer, W.A. Concrete and abstract terms and relations in testing a rule. Quarterly Journal of Experimental Psychology, 1974, 26, 355-359.

Gleitman, L.R. & Wanner, E. Language acquisition: The state of the state of the art. In E. Wanner & L.R. Gleitman (eds.), Language acquisition: The state of the art. Cambridge, UK: Cambridge University Press, 1982.

Golding, E. The effect of past experience on problem solving. Paper presented at the Annual Conference of the British Psychological Society, Surrey University, April, 1981.

Goodall, J. van Lawick- The behaviour of free-living chimpanzees in the Gombe Stream Reserve. Animal Behaviour Monograph 3, 1968.

Goodall, J. van Lawick- In the shadow of Man. Boston: Houghton-Mifflin, 1971.

Goodwin, R.Q. & Wason, P.C. Degrees of insight. British Journal of Psychology, 1972, 63, 205-212.

Grice, H.P. Meaning. Philosophical Review, 1957, 66, 377-388.

Grice, H.P. Logic and conversation. Unpublished William James Lectures, Harvard University, 1967.

Griggs, R.A. The role of problem content in the selection task and in the THOG problem. In J. St.B.T. Evans, (Ed.), Thinking and reasoning: Psychological Approaches. London: Routledge & Kegan Paul, 1983.

Griggs, R.A., & Cox, J.R. The elusive thematic-materials effect in Wason's selection task. British Journal of Psychology, 1982, 73, 407-420.

Griggs, R.A. & Cox, J.R. The effects of problem content and negation on Wason's selection task. Quarterly Journal of Experimental Psychology, 1983, 35A, 519-533.

Hall, K., & DeVore, I. Baboon social behavior. In I. DeVore (ed.), Primate behavior. New York: Holt, 1965.

Hamilton, W.D. The genetical evolution of social behaviour. Journal of Theoretical Biology, 1964, 7, 1-52.

Hamilton, W.D. Altruism and related phenomena, mainly in social insects. Annual Review of Ecology and Systematics, 1972, 3, 193-232.

Heisenberg, W. *Physics and beyond*. New York: Harper & Row, 1971.

Herrnstein, R.J. The evolution of behaviorism. *American Psychologist*, 1977, *32*, 593-603.

Hughes, M.A.M. The use of negative information in concept attainment. (Doctoral dissertation, University of London, 1966.

Hume, D. *An enquiry concerning human understanding*. (E. Steinberg, ed.) Indianapolis: Hackett, 1977.

Hrdy, S. Blaffer. *The woman that never evolved*. Cambridge, MA: Harvard Univeristy Press, 1981.

Inhelder, B. & Piaget, J. *Growth of logical thinking: From childhood to adolescence*. New York: Basic Books, 1958.

Issac, G.Ll. The food-sharing behavior of protohuman hominids. *Scientific American*, 1978, *238*, 90-108.

Janis, I., & Frick, F. The relationship between attitudes toward conclusions and errors in judging logical validity of syllogisms. *Journal of Experimental Psychology*, 1943, *33*, 73-77.

Johnson-Laird, P.N. Thinking as a skill. *Quarterly Journal of Experimental Psychology*, 1982, *34A*, 1-29.

Johnson-Laird, P.N. *Mental models: Towards a cognitive science of language, inference, and consciousness*. Cambridge, MA: Harvard University Press, 1983.

Johnson-Laird, P.N., Legrenzi, P. & Sonino Legrenzi, M. Reasoning and a sense of reality. *British Journal of Psychology*, 1972, *63*, 395-400.

Johnson-Laird, P.N. & Wason, P. Insight into a logical relation. *Quarterly Journal of Experimental Psychology*, 1970, *22*, 49-61.

Jolly, A. *The evolution of primate behavior*. New York: Macmillan, 1972.

Kagan, J. *The emergence of self-awareness*. Cambridge, MA: Harvard University Press, 1981.

Kant, I. *Critique of pure reason*. New York: Anchor Books, 1966.

Kinzey, W.G. *Primate models for the origin of human behavior*. New York: SUNY Press, 1985.

Konner, M. *The tangled wing: Biological constraints on the human spirit*. New York: Holt, Rinehart, & Winston, 1982.

Kozlowski, L.T., & Cutting, J.E. Recognizing the sex of a walker from a dynamic point-light display. *Perception & Psychodynamics*, 1977, *21*, 575-580.

Landreth, B. Inside the inner circle. Popular Computing, 1985, 4, 62-65, 146-149.

Legrenzi, P. Relations between language and reasoning about deductive rules. In G.B. Flores D'Arcais & W.J.M. Levelt (Eds.), Advances in psycholinguistics. Amsterdam: North Holland, 1970.

Luce, R.D., & Raiffa, H. Games and decisions: Introduction and critical survey. New York: Wiley, 1957.

Manktelow, K.I., & Evans, J. St B.T. Facilitation of reasoning by realism: Effect or non-effect? British Journal of Psychology, 1979, 70, 477-488.

Marr, D. Vision: A computational investigation into the human representation and processing of visual information. San Francisco: Freeman, 1982.

Marr, D. & Nishihara, H.K. Visual information processing: Artificial intelligence and the sensorium of sight. Technology Review, October 1978, 28-49.

McCracken, G.F., & Bradbury, J.W. Social organization and kinship in the polygynous bat Phyllostomus hastatus. Behavioral Ecology & Sociobiology, 1981, 8, 11-34.

Minsky, M. Frame-system theory. R.C. Schank & B.L. Nash-Webber (Eds.), Theoretical issues in natural language processing, (unpublished, MIT), reprinted in P.N. Johnson-Laird & P.C. Wason (Eds.), Thinking: Readings in cognitive science. Cambridge, U.K.: Cambridge University Press, 1977.

Nozick, R. Philosophical explanations. Cambridge, MA: Harvard University Press, 1981.

Owens, J., Bower, G.H., & Black, J.B. The "soap opera" effect in story recall. Memory & Cognition, 1979, 7, 185-191.

Pollard, P. Human reasoning: logical and non-logical explanations. Unpublished PhD thesis, Plymouth Polytechnic, 1979.

Pollard, P. The effect of thematic content on the 'Wason selection task'. Current Psychological Research, 1981, 1, 21-29.

Pollard, P. Human reasoning: Some possible effects of availability. Cognition, 1982, 10, 65-96.

Pollard, P., & Evans, J. St B.T. The influence of logic on conditional reasoning performance. Quarterly Journal of Experimental Psychology, 1980, 32, 605-624.

Pollard, P. & Evans, J.St.B.T. The effects of prior beliefs in reasoning: An associational interpretation. British Journal of Psychology, 1981, 72, 73-81.

Popper, K.R. *The logic of scientific discovery*. London: Hutchinson, 1959.

Popper, K.R. *Objective knowledge: An evolutionary approach*. London: Oxford University Press, 1972.

Quine, W.V.O. *Methods of logic.* (Third Edition) New York: Holt, 1950.

Quine, W.V.O. *Ontological relativity and other essays*. New York: Columbia University Press, 1969.

Reich, S.S. & Ruth, P. Wason's selection task: Verification, falsification and matching. *British Journal of Psychology*, 1982, *73*, 395-405.

Roberge, J.J. Linguistic and psychometric factors in propositional reasoning. *Quarterly Journal of Experimental Psychology*, 1978, *30*, 705-716.

Roberge, J.J. Linguistic factors in conditional reasoning. *Quarterly Journal of Experimental Psychology*, 1982, *34*, 275-284.

Rosenthal, R. & Rosnow, R.L. *Essentials of behavioral research: Methods and data analysis*. New York: McGraw-Hill, 1984.

Rumelhart, D.E., & Norman, D.A. Analogical processes in learning. In J.R. Anderson (Ed.), *Cognitive skills and their acquisition*. Hillsdale, NJ: Erlbaum, 1981.

Schank, R. & Abelson, R.P. *Scripts, plans, goals, and understanding*. Hillsdale, NJ: Erlbaum, 1977.

Searle, J.R. (Ed.) *The philosophy of language.* Oxford: Oxford University Press, 1971.

Seligman, M.E.P. & Hager, J.L. *Biological boundaries of learning*. New York: Meredith, 1972.

Shepard, R.N. Ecological constraints on internal representation: Resonant kinematics of perceiving, imagining, thinking, and dreaming. *Psychological Review*, 1984, *91*, 417-447.

Shepard, R.N. Evolution of a mesh between principles of the mind and regularities of the world. Paper presented at the Conference on Evolution and Information, Stanford University, April, 1985.

Shepher, J. *Incest: A biosocial view*. New York: Academic Press, 1983.

Shostak, M. *Nisa: The life and words of a !Kung woman*. Cambridge, MA: Harvard University Press, 1981.

Smuts, B. Special relationships between adult male and female olive baboons (*Papio anubis*). Doctoral dissertation, Stanford University, 1982.

Sokal, R.R., & Rohlf, F.J. *Biometry*. San Francisco: Freeman, 1969.

Strum, S.C. Baboons may be smarter than people. *Animal Kingdom*, 1985, *88*, 12-25.

Tooby, J. Prospects for an evolutionary psychology. Unpublished manuscript, Harvard University, 1975.

Tooby, J. Pathogens, polymorphism and the evolution of sex. *Journal of Theoretical Biology*, 1982, *97*, 557-576.

Tooby, J. The emergence of evolutionary psychology. In D. Pines (ed.), *Emerging syntheses in science*. New Mexico: Rio Grande Institute, in press.

Tooby, J. & DeVore, I. The reconstruction of hominid behavioral evolution through strategic modeling. In W.G. Kinzey (ed.), *Primate models for the origin of human behavior*. New York: SUNY Press, 1985.

Trivers, R.L. The evolution of reciprocal altruism. *Quarterly Review of Biology*, 1971, *46*, 35-57.

Trivers, R.L. Parent-offspring conflict. *American Zoologist*, 1974, *14*, 249-264.

Tversky, A. & Kahneman, D. Availability: A heuristic for judging frequency and probability. *Cognitive psychology*, 1973, *5*, 207-232.

Van Duyne, P.C. Realism and linguistic complexity in reasoning. *British Journal of Psychology*, 1974, *65*, 59-67.

Van Duyne, P.C. Necessity and contingency in reasoning. *Acta Psychologica*, 1976, *40*, 85-101.

Ward, P., & Zahavi, A. The importance of certain assemblages of birds as 'information-centres' for food finding. *Ibis*, 1973, *115*, 517-534.

Wason, P.C. Reasoning. In B.M. Foss (Ed.), *New Horizons in Psychology*. Harmondsworth: Penguin, 1966.

Wason, P.C. Reasoning about a rule. *Quarterly Journal of Experimental Psychology*, 1968, *20*, 273-281.

Wason, P.C. Structural simplicity and psychological complexity: Some thoughts on a novel problem. *Bulletin of the British Psychological Society*, 1969, *22*, 281-284. (a)

Wason, P.C. Regression in reasoning? *British Journal of Psychology*, 1969, *60*, 471-480. (b)