Dual-Processing Accounts of Reasoning, Judgment, and Social Cognition

Jonathan St. B. T. Evans

Center for Thinking and Language, School of Psychology, University of Plymouth, Plymouth PL4 8AA, United Kingdom; email: jevans@plymouth.ac.uk

Annu. Rev. Psychol. 2008. 59:255–78

First published online as a Review in Advance on May 31, 2007

The *Annual Review of Psychology* is online at http://psych.annualreviews.org

This article's doi: 10.1146/annurev.psych.59.103006.093629

0066-4308/08/0203-0255$20.00

Key Words

thinking, reasoning, decision-making, social cognition, dual-process theory

Abstract

This article reviews a diverse set of proposals for dual processing in higher cognition within largely disconnected literatures in cognitive and social psychology. All these theories have in common the distinction between cognitive processes that are fast, automatic, and unconscious and those that are slow, deliberative, and conscious. A number of authors have recently suggested that there may be two architecturally (and evolutionarily) distinct cognitive systems underlying these dual-process accounts. However, it emerges that (*a*) there are multiple kinds of implicit processes described by different theorists and (*b*) not all of the proposed attributes of the two kinds of processing can be sensibly mapped on to two systems as currently conceived. It is suggested that while some dual-process theories are concerned with parallel competing processes involving explicit and implicit knowledge systems, others are concerned with the influence of preconscious processes that contextualize and shape deliberative reasoning and decision-making.

Contents

INTRODUCTION

Dual-processing accounts of human behavior abound in cognitive and social psychology. So many authors have appealed to dual processes in so many different ways that it has proved a complex and challenging task to draw together any coherent overview of this topic. The review is restricted to "higher" cognitive processes typically described as thinking, reasoning, decision-making, and social judgment, although selected work from outside of these domains is also included where directly relevant. For example, there is some reference to work in the psychology of learning and memory, the philosophy of mind, and evolutionary psychology.

What dual-process theories have in common is the idea that there are two different modes of processing, for which I use the most neutral terms available in the literature, System 1 and System 2 processes (Kahneman & Frederick 2002, Stanovich 1999). Almost all authors agree on a distinction between processes that are unconscious, rapid, automatic, and high capacity, and those that are conscious, slow, and deliberative. Different authors have proposed a number of names for the two kinds of thinking they contrast, some of which are shown in **Table 1**. The labels are aligned in a manner consistent with generic dual-system theory (see below) under the headings System 1 and System 2. Despite the tidy way in which all these labels line up, readers should beware of inferring that there are necessarily just two systems or just two kinds of dual-processing theory for reasons that will become clear later. Some authors propose only dual-process distinctions without assumptions about underlying cognitive systems; some propose parallel and some sequential relationships between the two processes, and so on.

Attempts have been made to map various dual-process accounts into a generic dual-system theory (Evans 2003; Evans & Over 1996; Stanovich 1999, 2004). A major issue for this review is to consider whether such a grand theory is sustainable, or whether, in spite of first appearances, we need to classify dual-process theories as being of different and distinct kinds. I approach this question in part by considering the clusters of attributes supposedly belonging to System 1 and 2, which have been extracted from the numerous dual-process theories to be found in the literature. Of course, not all authors have made explicit statements about all of these attributes, but when they do so, they tend to make comments that are remarkably consistent from theory to theory. These putative features of Systems 1 and 2 are somewhat arbitrarily grouped here into four categories (see **Table 2**) and each is discussed in turn prior to the review of specific dual-process theories of higher cognition.

It should be noted that the attributes listed in **Table 2** do not include emotion, the discussion of which is generally beyond the scope of this review. Although many authors ignore emotion altogether in the fields reviewed here, it is clear that emotional processing would be placed in the System 1 rather than

Table 1 Labels attached to dual-processes in the literature, aligned on the assumption of a generic dual-system theory

References	System 1	System 2
Fodor (1983, 2001)	Input modules	Higher cognition
Schneider & Schiffrin (1977)	Automatic	Controlled
Epstein (1994), Epstein & Pacini (1999)	Experiential	Rational
Chaiken (1980), Chen & Chaiken (1999)	Heuristic	Systematic
Reber (1993), Evans & Over (1996)	Implicit/tacit	Explicit
Evans (1989, 2006)	Heuristic	Analytic
Sloman (1996), Smith & DeCoster (2000)	Associative	Rule based
Hammond (1996)	Intuitive	Analytic
Stanovich (1999, 2004)	System 1 (TASS)	System 2 (Analytic)
Nisbett et al. (2001)	Holistic	Analytic
Wilson (2002)	Adaptive unconscious	Conscious
Lieberman (2003)	Reflexive	Reflective
Toates (2006)	Stimulus bound	Higher order
Strack & Deustch (2004)	Impulsive	Reflective

Table 2 Clusters of attributes associated with dual systems of thinking

System 1	System 2
Cluster 1 (Consciousness)	
Unconscious (preconscious)	Conscious
Implicit	Explicit
Automatic	Controlled
Low effort	High effort
Rapid	Slow
High capacity	Low capacity
Default process	Inhibitory
Holistic, perceptual	Analytic, reflective
Cluster 2 (Evolution)	
Evolutionarily old	Evolutionarily recent
Evolutionary rationality	Individual rationality
Shared with animals	Uniquely human
Nonverbal	Linked to language
Modular cognition	Fluid intelligence
Cluster 3 (Functional characteristics)	
Associative	Rule based
Domain specific	Domain general
Contextualized	Abstract
Pragmatic	Logical
Parallel	Sequential
Stereotypical	Egalitarian
Cluster 4 (Individual differences)	
Universal	Heritable
Independent of general intelligence	Linked to general intelligence
Independent of working memory	Limited by working memory capacity

System 2 list. Emotion is explicitly linked to the first system in some dual-process accounts (Epstein 1994), implied by the neurological regions identified in others (Lieberman 2003), and specifically attributed to automatic processes in some recent accounts of social cognition (Hassin et al. 2005). Moreover, the idea that emotions play a key role in decision making is being developed in some contemporary work that contrasts a fast emotional basis for decision making with a slower and more deliberative cognitive basis (Haidt 2001, Hanoch & Vitouch 2004, Wang 2006).

FEATURES ATTRIBUTED TO DUAL PROCESSES AND SYSTEMS

Consciousness

A central concern for philosophers of mind, the problem of consciousness is one that has engendered a resurgence of interest in recent years in psychology and neuroscience (Velmans 2000). However, the concept of consciousness has had a somewhat checkered history in psychology. Mentalism and introspectionism dominated philosophy of mind and early laboratory studies of the nineteenth century when psychology first emerged as a distinct discipline. Thereafter, a series of movements led instead to an emphasis on what is automatic and unconscious in the control of human behavior. These are sometimes described as the psychoanalytic, behavioral, and cognitive unconscious (Uleman 2005). Each refers to a movement that undermined the concept of consciousness and the explanation (in scientific psychology) of behavior in terms of conscious beliefs and desires. Freud and other psychoanalysts introduced the world to the notion of an unconscious mind motivating our behavior with a combination of innate drives and repressed emotions as well as a conscious mind prone to rationalization and self-deception. Behaviorists such as Watson, Hull, and Skinner demonstrated associative and instrumental learning processes in both humans and animals in theories that apparently allowed no place for consciousness and mentalistic accounts of behavior. However, the emergence of cognitive science and the widespread acceptance of a computational theory of mind led in the later part of the twentieth century to the idea of a cognitive unconscious (Kihlstrom 1987, Reber 1993) in the form of complex information processing in the brain that is conducted without conscious awareness. Some authors are now advocating a "new unconscious" that also incorporates motivation and emotion (Hassin et al. 2005).

While the problem of what consciousness *is* may seem intractable, the study of its function and evolution seems more promising. Dual-process theories of cognition effectively address the important question of the cognitive correlates of consciousness. The attributes listed for Systems 1 and 2 under Cluster 1 (**Table 2**) all reflect the proposed differences between the cognitive unconscious and the cognitive conscious. Authors talk of processes that are explicit and controlled (rather than implicit and automatic) reflecting two key concepts of consciousness: awareness and volition. Consciousness is also inherently slow, sequential, and capacity limited. This might be taken to mean that folk psychological accounts of mind are adequate at the System 2 level provided the System 1 level of mind is also recognized (Frankish 2004). In other words, System 2 is a form of thinking under intentional level control, supported by unconscious processes in System 1 that deliver percepts, memories, and so on. However, this happy state of affairs, which leaves "us" in control of our behavior, is contradicted by much psychological research. Many researchers have emphasized the fact that unconscious processes may control our behavior without us being aware of them doing so, and that conscious reasoning in System 2 is often used for the confabulation of explanations for these behaviors (Evans & Over 1996, Nisbett & Wilson 1977, Stanovich 2004, Wason & Evans 1975, Wilson 2002, Wilson &

Dunn 2004). It appears that we use the concepts of belief-desire psychology to theorize about our behavior as well as that of others. To muddy the waters further, some social psychologists are claiming evidence of intentionality in unconscious processing (Bargh et al. 2001, Bargh & Ferguson 2000).

The distinction between automatic and controlled cognition has been extensively researched in the study of lower-order cognition such as that involved in perception, attention, and the acquisition of motor skills, in a tradition dating from Schneider & Shiffrin (1977) and more recently linked with neuroscience (Monsell & Driver 2000). In this tradition, automatic processes are typically viewed as having been "automated" from those that were once controlled and conscious, an approach that seems to have had a strong influence on the development of dual-process accounts of social cognition (Chaiken & Trope 1999). However, as Sloman (2002) points out, this conception is too limited for the purposes of dual-process accounts of higher cognition, in which we may feel an experience of conflict between an intuition acquired from experience and a conscious piece of reasoning. Moreover, there is a contrasting literature on implicit learning (Berry & Dienes 1993, Reber 1993, Sun et al. 2005) that provides much evidence that people can acquire implicit knowledge, for example to predict or control a complex system, without ever knowing an explicit rule that they could state. Hence, the term "automatic" is used here simply as a contrastive with "controlled," implying no assumption about how such processes were acquired.

An operational definition of consciousness that seems to have appeared (often implicitly) in dual-process theories is that System 2 thinking requires access to a central working memory system of limited capacity, whereas System 1 does not. What we are aware of at a given time is represented in this working memory, through which conscious thinking flows in a sequential manner. This would seem to be a working memory of the kind originally described by Baddeley & Hitch (1974), which has not only short-term memory capacity but also executive and inhibitory functions, a theory that has engendered a huge research literature in its own right (see Gathercole 2003). (Consciousness is also closely associated with working memory in global workspace theory—see Baars & Franklin 2003.) The association of conscious thought with such a working memory explains the slow, sequential, and low-capacity nature of System 2 as well as its relation to individual differences in cognitive ability (see below). However, skeptics may see this as the only firm foundation on which the various dual-process theories stand: There is one conscious working memory system and everything else.

Age of Evolution

The idea that System 1 cognition evolved earlier than System 2 is a recurring theme in dual-process theories (Evans & Over 1996, Epstein & Pacini 1999, Reber 1993, Stanovich 1999). System 2 is thought to be associated with language, reflective consciousness, and higher-order control and with the capacity to think hypothetically about future and counterfactual possibilities. Authors have often asserted that such characteristics of thought are distinctively or uniquely human, while at the same time arguing that System 1 cognition, shared with other animals, continues to control much of our behavior. However, there is considerable evidence of a distinction between stimulus-bound and higher-order control process in many higher animals (Toates 2006), including rodents, which could be seen as the biological foundations for the System 1 and 2 cognition in humans. There is also evidence that primates, especially chimpanzees, have the capacity for higher-order mental representations, manifest as rudimentary theory of mind (Mithen 1996, Whiten 2000), albeit very limited in comparison with the ability of the human mind for meta-representation and higher-order intentionality.

The proposal that System 1 cognition is evolutionarily old and shared with other

animals is also problematic because it is almost certainly not one system with a single evolutionary history. There are a number of distinct possible types of implicit cognitive processes, including forms of learning, automaticity, modular cognition, and the pragmatic processes that have been particularly studied in dual-process theories of deductive reasoning (see below). The concept of cognitive modules was introduced by Fodor (1983) in a dual-process theory that distinguished between input modules (such as those involved in vision and language) and general purpose, central cognition. Fodor proposed a number of strict criteria for modules including the requirements that they are innate, domain-specific, have specialized and isolated databases (knowledge encapsulation), are neurologically localized, and are associated with specific disorders. Some schools of evolutionary psychology later argued that the mind should consist mostly or entirely of domain-specific cognitive modules, even when engaged in higher order reasoning (Cosmides & Tooby 1992, 1996; Pinker 1997; Samuels 1998; Sperber 1994; Tooby & Cosmides 1992). This view included strong claims that domain-general processes would have little part to play in human cognition, such as that of Tooby & Cosmides (1992, p.112): "... there is a host of... reasons why content-free, general-purpose systems could not evolve, could not manage their own reproduction, and would be grossly inefficient and easily outcompeted if they did." Not surprisingly, this "massive modularity hypothesis" has been strongly attacked by dual-process theorists (Fodor 2001, Over 2003, Stanovich 2004, Stanovich & West 2003). More recent writings of evolutionary psychologists appear to have more compatibility with dual-processing frameworks, however, as they acknowledge the extraordinary and distinctive features of human higher cognition (Cosmides & Tooby 2000, Sperber 2000). There has also been a recent trend to weaken the criteria for modules to make massive modularity a more credible hypothesis (Barrett & Kurzban 2006, Carruthers 2006).

It seems unsustainable to argue that there is just one form of implicit processing, in System 1, all of which is evolutionarily old and shared with other animals. For example, we may have forms of modular cognition that are relatively old (e.g., vision, attention) and others that are much more recent and distinctively human (e.g., language, theory of mind). Conditioning and other forms of associative learning appear to be ancient and shared with other animals, but forms of explicit memory, and in particular the human belief system, seem to be much more recent. However, although the notion that there are distinct implicit and explicit memory systems is central to a number of the dual-process theories that are considered in this review, it could well be an error to think of the latter as uniquely human in origin. There are powerful evolutionary arguments (as well as neurological evidence) for multiple systems of learning and memory in both humans and other animals (Carruthers 2006, Sherry & Schacter 1987). For example, Sherry & Schacter (1987), who interestingly referred to System 1 and 2 memory, noted that "... a strong case can be made for a distinction between a memory system that supports gradual or incremental learning and is involved in the acquisition of habits and skills and a system that supports rapid one-trial learning and is necessary for forming memories that represent specific situations and episodes" (p. 446). Taken in conjunction with the evidence of higher-order control systems in animals (Toates 2006), these arguments suggest that dual-system theorists would be better off claiming that System 2 cognition is uniquely developed, rather than uniquely present, in modern humans. Such an argument also has much greater evolutionary plausibility.

If Systems 1 and 2 incorporate different memory as well as reasoning systems, then it may be a mistake to assume that any influence of prior knowledge on reasoning necessarily arises in System 1. For example, Goel

(2005) has questioned the idea that the "belief bias" in reasoning that theorists have associated with System 1 processing (Evans & Over 1996, Stanovich 1999) could be ancient in origin or shared with animals that lack an explicit belief system. In support of this, he has evidence from neural imaging studies that belief bias arises in the prefrontal cortex, an area most strongly developed in the modern human brain (Goel et al. 2000, Goel & Dolan 2003). However, a dual-system theorist can reply that although System 1 has much in common with animal cognition, it looks very different in a brain that has System 2. Thus Stanovich (2004, Chapter 2), for example, suggests that goals that are acquired reflectively through System 2 can, through repeated activation, be installed into rigid implicit processing mechanisms—a kind of automation of thought. This may be why Stanovich (2004) now prefers to talk about TASS—the set of autonomous subsystems—rather than System 1. Certainly, there seems to be little foundation in arguments based on age of evolution for the claim that all implicit processes belong—in any useful sense—to a single system.

Functional Characteristics

Along with already discussed attributes of System 1 as rapid and automatic and System 2 as slow and controlled go a number of functional differences attributed to the two kinds of cognition, as shown in **Table 2** under Cluster 3. It appears that conscious thought is inherently sequential, whereas many theorists suppose the rapid processing and high capacity of System 1 reflects use of parallel processes. System 1 has been characterized as associative by Sloman (1996, 2002; see also Smith & DeCoster 2000), as contrasted with rule-based cognition in System 2. Those authors who are not focused on the idea of innate modules certainly emphasize the experiential nature of System 1 (for example, Epstein & Pacini 1999, Evans & Over 1996, Reber 1993), which could reflect implicit learning stored in functionally parallel neural networks (Dijksterhuis & Smith 2005; Smith & DeCoster 1999, 2000). However, although the notion that System 2 is in some sense rule-based is compatible with the proposals of most dual-process theorists, the characterization of System 1 as associative is not. The problem, as already identified, is that there are multiple systems of implicit processes and it is far from clear that the different theories can be mapped on to each at the System 1 end. In particular, theories that contrast heuristic with analytic or systematic processing (Chen & Chaiken 1999, Evans 2006) seem to be talking about something different from associative processing.

Other recurring themes in the writing of dual-process theorists are that System 1 processes are concrete, contextualized, or domain-specific, whereas System 2 processes are abstract, decontextualized, or domain-general. The notion that System 1 processes rapidly contextualize problems with prior knowledge and belief has been particularly emphasized in dual-process accounts of human reasoning (Evans 2006, Klaczynski & Lavallee 2005, Stanovich 1999). Such authors assume that belief-based reasoning is the default to which conscious effortful analytic reasoning in System 2 may be applied to overcome. However, it may be unwise to define System 2 as being abstract and decontextualized if we also want to retain its description as slow, sequential, explicit, and rule-based because none of these characteristics may be limited to abstract forms of reasoning (Sloman 2002, Verschueren et al. 2005). It would probably be more accurate to say that although abstract reasoning requires the use of System 2, concrete contexts do not preclude its application.

The consideration that System 2 thinking is not necessarily abstract and decontextualized is also one reason why it should not be equated with a mental logic. The idea that higher forms of thinking require a logic in the mind was popularized by Piaget (see Inhelder & Piaget 1958) and is particularly associated with the idea that people have natural

logics composed of inference rules in their minds (Braine & O'Brien 1998a, Rips 1994). However, the popular mental models theory of deductive reasoning (Johnson-Laird 1983, Johnson-Laird & Byrne 1991) can also be regarded as a form of mental logic, accounting for deductive competence by semantic rather than syntactic principles (Evans & Over 1996, Oaksford & Chater 1995). Whichever account of deduction is preferred, it is clear that the System 2 concept is much broader than that of logical reasoning, including such ideas as an inhibitory role (suppressing pragmatic influences of System 1) and the ability to engage in hypothetical thought via supposition and mental simulations. This is probably why most dual-process theorists prefer broader terms such as "analytic" or "systematic" to describe the second system.

Individual Differences

Some dual-process theorists (Reber 1993, Stanovich 1999) have claimed a link between System 2 processing and general intelligence, with the corollary that System 1 processes are independent of general intelligence. This proposal has led to an increasing use of individual differences methodology in dual-process research, as revealed in the sections below. In addition to linking the effectiveness of analytic reasoning and decision making with general intelligence measures, researchers have also investigated two close correlates: working memory and age of development. It is now well established that individual differences in working memory capacity and general intelligence measures are very highly correlated (Colom et al. 2004). Working memory capacity is known to predict performance levels in a very wide range of cognitive tasks and has been directly linked with dual-process accounts of cognitive functions, albeit primarily at a lower level than those that form the focus of the current review (Barrett et al. 2004). Developmental studies are also relevant, as the analytic thinking skills that contribute to performance on general intelligence tests develop with age. However, it has recently been claimed that it is ability and not age that is the important predictor of analytic reasoning, which may explain some inconsistencies in developmental research (Kokis et al. 2002). A further complication is that, as some researchers claim, System 1 may develop in parallel with System 2 (Klaczynski 2000, 2001).

Evolutionary psychologists such as Tooby & Cosmides (1992) have emphasized that their main interest lies in explaining intelligence that is universal and optimized across the human species. However, they have been strongly criticized (Stanovich 1999, Stanovich & West 2003) for downplaying the importance of heritable characteristics, particularly that of general intelligence, in their discussion of higher-order cognitive processes such as reasoning and decision making. In general, one of the stronger bases for dual-systems theory is the evidence that "controlled" cognitive processing correlates with individual differences in general intelligence and working memory capacity, whereas "automatic" processing does not. It seems at least to indicate that behavior may be controlled both with and without the use of executive working memory resources.

An important distinction in the individual differences approach is that between measures of cognitive capacity and dispositional thinking styles. The difference is between what people are able to do and what they are inclined to do. Stanovich (1999), for example, shows that residual variance in solution rates of reasoning and judgment task, when the effects of cognitive ability have been taken out, can be accounted for in terms of dispositions for critical thinking. Evidence for cross-cultural differences in thinking styles (Nisbett et al. 2001) are also dispositional as they can alter when people move to another culture. In the social cognition literature, there has been much attention to individual differences in thinking style as measured by such scales as "need for cognition" (Cacioppo & Petty 1982) or the rational-experiential inventory (Epstein et al. 1996). It is important to note

that the observation of two thinking styles in itself does not constitute evidence for dual processes arising from two distinct cognitive systems.

APPLICATIONS OF DUAL-PROCESS THEORIES IN DIFFERENT DOMAINS

As the preceding discussion illustrates, System 2 appears to be a more coherent and consistent concept in the generic dual-system theory than does System 1 because multiple systems of implicit cognitive processes exist (Wilson 2002, Stanovich 2004). It is also likely that different dual-process theorists have different implicit systems in mind and that these systems do not have a single evolutionary history. I return to the issue of whether generic dual-system theory is sustainable at the end of the review. At this point, I look more closely at how dual-process theories are applied to the explanation of particular phenomena in higher cognition.

Dual-Process Theories of Reasoning

The psychology of deductive reasoning was largely established by the work of Peter Wason in the 1960s and 1970s (see Wason & Johnson-Laird 1972). Wason invented several famous tasks—including the four-card selection task—that are still used in current research. The field has expanded rapidly over the past 40 years and changed its character as authors have become progressively less attached to the normative standard of formal logic and more interested in the influence of contextual factors invoking prior belief and knowledge (Evans 2002). Dual-process ideas developed quite early on, with the first use of the term appearing in the title of a paper published by Wason & Evans (1975). This paper focused on the finding that card choices on the selection task were strongly influenced by a seemingly primitive matching bias (selecting cards explicitly mentioned in the conditional statement). Participants showed no awareness of this in their verbal reports, instead justifying their choices with regard to the experimental instructions to prove the rule true or false. Wason & Evans concluded that participants were rationalizing with their conscious reasoning causes of behavior that were in fact unconscious. Their arguments were very much in accord with the famous critique of introspective reports presented by Nisbett & Wilson (1977).

The heuristic-analytic theory of reasoning (Evans 1989) shifted the emphasis of the heuristic processes responsible for biases to a pragmatic and preconscious level that preceded any attempt at analytic processing. This theory is narrower in scope than typical dual-process theories and is strongly focused on the explanation of biases in reasoning and judgment tasks. The idea was that heuristic processes selectively focused attention on task features that appeared relevant, introducing relevant prior knowledge in the process. Since analytic processing could only be applied to these selective representations, biases would be observed when either (*a*) logically relevant information was excluded or (*b*) logically irrelevant information was included by heuristic processing.

The sequential nature of the heuristic-analytic theory contrasts with parallel and interactive forms of dual-process theory, although many of the proposed features of the two processes correspond to those of the generic System 1 and 2: Heuristic processes are fast, automatic, and belief based, whereas analytic reasoning is slow, sequential, and can make an effort at deduction. In a recent reformulation of the theory, Evans (2006) has sought to reconcile it with conflict models by the proposal that heuristic responses can control behavior directly unless analytic reasoning intervenes. In other words, heuristics provide default responses that may or may not be inhibited and altered by analytic reasoning. Analytic system intervention may be cued by strong deductive reasoning instructions and may be more likely to occur when individuals have high cognitive ability or a disposition

to think reflectively or critically (Stanovich 1999).

For much of its recent history, the psychology of deductive reasoning has been dominated by a debate between proponents of mental logic theorists, who attribute deductive competence to sets of abstract inference rules (Braine & O'Brien 1998a, Rips 1994), and mental model theorists (Johnson-Laird 1983, Johnson-Laird & Byrne 1991), who explain it in terms of a fundamental semantic principle: An argument is valid if there are no counterexamples to it. Although the writings of mental logic and mental model theorists include little explicit discussion of dual-process theory, the distinction is implicitly present in the theories. Mental logic theorists (for example, Braine & O'Brien 1998b) make great play of the distinction between direct rules of inference, which are applied effortlessly and accurately, and indirect rules, which require conscious effort and are much more error prone. They also explain errors in reasoning by reference to pragmatic implicatures and other contextual effects. Similarly, the mental model theory describes the formation of initial mental models as a relatively automatic and effortless process. The process of searching for counterexamples (Johnson-Laird & Bara 1984) or the fleshing-out of initially implicit mental models (Johnson-Laird & Byrne 2002) is, however, effortful and error prone and constrained by working memory capacity. Both theories include proposals that could account for pragmatic influences on reasoning and for the relation of reasoning accuracy to individual differences in cognitive capacity.

The paradigm case for dual processes in reasoning is belief bias. In the standard paradigm, people are given syllogisms and asked to evaluate their logical validity. Syllogisms vary in both their validity (whether the conclusion follows from premises) and their believability (whether the conclusion conforms or conflicts with prior belief). Thus, some syllogisms are belief-logic compatible, but some provide conflict—valid arguments with unbelievable conclusions and invalid arguments with believable conclusions. The basic phenomena of this paradigm were established by Evans et al. (1983), whose findings have been replicated many times since (see Klauer et al. 2000 for a recent extensive study). There is (*a*) a main effect of logic, in that valid conclusions are more often accepted than invalid conclusions, (*b*) a main effect of belief (belief bias) in that believable conclusions are much more often accepted, and (*c*) a belief by logic interaction, in that belief bias is much more marked on invalid syllogisms.

In the original study, Evans et al. (1983) argued, on the basis of protocol analyses and the examination of individual response patterns, that there was a within-person conflict between a logical and belief-based reasoning process. They offered two explanations of the belief by logic interaction, which were later augmented by one derived from mental model theory (Oakhill et al. 1989). More recently, accounts of the phenomena have been developed that are strongly compatible with dual-process theory (e.g., Klauer et al. 2000). These accounts are supported by evidence of a shift from logical to belief-based reasoning under severe time pressure (Evans & Curtis-Holmes 2005) and under concurrent working memory load (De Neys 2006).

There has been considerable interest in how people reason on belief-logic conflict problems; that is, the valid-unbelievable and invalid-believable syllogisms. Logical performance on such cases is known to decline with age (Gilinsky & Judd 1994) and to be related to individual differences in cognitive ability (Kokis et al. 2002, Newstead et al. 2004, Stanovich & West 1997). Stanovich (1999) argued on this basis that participants of higher cognitive ability are more able to inhibit belief-based reasoning. However, available data are more consistent with the view that although high-ability people reason more logically with belief-laden (as well as abstract) syllogisms, the belief bias effect is no less marked for them than for lower-ability people (Klaczynski 2000, Newstead et al. 2004,

Torrens et al. 1999). Thus, it may be that higher-ability people do not engage in more System 2 reasoning but rather are simply more successful when they do so.

A large literature exists on how people reason with the Wason four-card selection task (see Evans & Over 2004, Chapter 5, for a review). The task requires people to decide which of four cards to turn over to decide the truth of a conditional statement. For example, if the statement says, "If a card has an A on one side then it has a 3 on the other," and the visible sides display A, D, 3, and 7, then the logically correct choice is the A and the 7. This is because only a card that has an A and *not* a 3 could disprove the statement. Few people give this answer; most are more likely to choose A and 3, or just A. Although this abstract, indicative form of the task is very difficult, concrete and deontic forms (concerning rules and regulations) are much easier. For example, given the statement, "If a person is drinking beer in a bar, that person must be over 19 years of age," most participants readily see that they must check beer (rather than soda) drinkers and those who are under 19 years of age.

The heuristic-analytic theory explains the difficulty of the abstract task on the grounds of heuristics that focus attention on selected cards, a claim supported by the time that people spend observing individual cards (Evans 1996, but see Ball et al. 2003, Roberts 1998) and the accentuation of matching bias by a requirement to respond rapidly (Roberts & Newton 2001). Stanovich & West (1998) have produced strong evidence that analytic reasoning is involved in solving the abstract selection task, since solvers have much higher SAT scores than do nonsolvers. The relation to cognitive ability is, however, much weaker for concrete and deontic forms of the task, suggesting that it can be solved by pragmatic belief-based reasoning in System 1 (see also Newstead et al. 2004).

Recently, various authors have applied dual-process theory to the inferences people draw from conditional statements. Considerable evidence shows that reasoning with realistic conditionals is strongly influenced by pragmatic factors, including the availability of counterexamples to inferences from semantic memory (Cummins et al. 1991; Thompson 1994, 2000) and the strength of association of counterexamples as measured across both materials and individual participants (De Neys et al. 2005, Markovits et al. 1998, Markovits & Quinn 2002). Participants are also more likely to draw inferences from conditionals that they believe rather than disbelieve (George 1997; Liu et al. 1996; Newstead et al. 1997; Stevenson & Over 1995, 2001). However, evidence suggests that analytic System 2 reasoning processes, as well as heuristic System 1 processes, may be influenced by prior belief about the problem context (Verschueren et al. 2005).

In conclusion, dual-process theory has been widely applied to the study of syllogistic reasoning, the Wason selection task, and conditional inference. (For a critical review of the theory in the psychology of reasoning, see Osman 2005.) Experimental evidence has consistently shown that responses are partially consistent with logic but are also influenced by systematic biases such as matching bias and belief bias. Cognitive models have generally depicted these as competing influences in a within-participant conflict. Several different forms of evidence support dual-processing accounts, including (*a*) the observation of more logical and less belief-based reasoning under strong deductive reasoning instructions, (*b*) the association (in general) of better logical accuracy with higher-ability participants when problems cannot also be solved by a pragmatic route, and (*c*) the finding that working memory load or instructions to respond rapidly increase levels of typical biases as well as reduce logical accuracy.

Dual-Process Theories of Judgment and Decision Making

Three main research paradigms have dominated the psychology of judgment and decision making: (*a*) the "heuristics and biases"

research program that is focused particularly on judgments of probability (Gilovich et al. 2002, Kahneman et al. 1982), (*b*) the study of decision making under risk (Wu et al. 2005), and (*c*) social judgment theory and the lens model (Doherty 1996). The last of these paradigms, which may be less familiar to readers, is focused on judgments made where multiple cues are available in the environment. An example might be medical diagnosis in light of a number of demographic factors, patient history, symptoms, diagnostic tests, and so on. It is possible to capture the implicit policy of judges by using multiple regression analysis to show which of the various cues predict their overall judgment.

Until recently, dual-process theory played a much smaller part in these fields than in the study of reasoning and social cognition. An exception is the cognitive continuum theory of Hammond (e.g., 1996), working in social judgment theory, which contrasts intuitive and analytic thinking. However, as the name suggests, this theory proposes two ends of a continuum rather than discrete processes or systems and hence is not the main type of theory with which this review is concerned.

Kahneman & Frederick (2002, 2005) recently developed a dual-process theory of probability judgment that they link to the generic dual-system theory. Heuristic judgments, which lead to biases, are associated with System 1, and analytic reasoning, which may intervene with these judgments and improve them, are linked to System 2. This helps explain general findings that although biases in probability judgment can be linked to heuristics such as representativeness (Kahneman & Tversky 1972, Teigen 2004) and availability (Reber 2004, Tversky & Kahneman 1973), these biases are not universally observed but do appear to compete with a tendency to give normatively correct answers. Such conflicts stand in parallel with the findings in the deductive reasoning literature, reviewed above, in which matching and beliefs biases compete with logically correct answers. In general, normatively correct solutions to problems from both literatures tend to be found more often by those of higher cognitive capacity (Stanovich 1999), who may be assumed to make more effective interventions with analytic or System 2 reasoning processes.

The processing assumptions of Kahneman & Frederick's theory are similar to those of the heuristic-analytic theory of reasoning (Evans 2006). It is assumed that fast System 1 (heuristic) processes cue default intuitive judgments that must nevertheless be endorsed by the (analytic) System 2, which often does so casually. This may involve attribute substitution, in which people actually answer a different (and easier) question than the one asked. However, high-effort deliberative reasoning may be applied, which can inhibit the biased response and replace it with one based on reflective reasoning. I call this kind of dual-process theory "default-interventionist" as compared with theories (e.g., that of Sloman, 1996) that are "parallel-competitive" in nature. Kahneman & Frederick suggest that even heuristics that are apparently conscious in application, such as the recognition heuristic (Gigerenzer et al. 1999), have an automatic component. In this case, feelings of familiarity are automatically recruited and then consciously interpreted as a basis for making a judgment, such as the relative size of foreign cities.

A major recent debate in the probability judgment literature has concerned the claim that probability problems are much easier if framed in terms of frequencies rather than in probabilities (Barbey & Sloman 2007, Cosmides & Tooby 1996, Gigerenzer & Hoffrage 1995), thus reducing biases such as base rate neglect in Bayesian reasoning (Kahneman & Tversky 1973, Koehler 1996). It was argued from an evolutionary perspective that we would have evolved a cognitive module for processing frequency information in the environment (Cosmides & Tooby 1996) that could not be applied to one-case probabilities. However, from a dual-process viewpoint, it appears that such a module would affect learning behavior in System 1 rather

than in explicit System 2 reasoning about the quantitative word problems that are actually presented (Evans et al. 2000). Consistent with this, there is now much evidence that what facilitates Bayesian reasoning is a problem structure that cues explicit mental models of nested-set relationships (Evans et al. 2000, Girotto & Gonzalez 2001, Sloman et al. 2003) as originally proposed by Tversky & Kahnemant (1983). However, Hoffrage et al. (2002) have responded by arguing that such nested sets are intrinsic to natural sampling, a process that leads to the observation of natural frequencies that encode base rate information implicitly. Hence, they claim that Bayesian posterior probabilities can be derived from direct comparison of such frequencies with no difficult calculation involved. However, Barbey & Sloman (2007) have recently argued that this kind of evolutionary account, when examined in detail, is a good deal less parsimonious than an explanation in terms of dual processing.

Discussion of work on reasoning and judgment to this point may have suggested that System 2 processing is in some sense superior to that of System 1, in that the former is often associated with normatively correct responding and the latter with cognitive biases. However, those authors who have looked at expert judgment and decision-making provide a somewhat different perspective. For example, in Klein's (1999) naturalistic studies of decision making in groups such as fire officers and paramedics, the author argues that very little rational decision-making goes on, in the sense of deliberation between alternatives. What typically happens is that an expert recognizes a situation as of a kind encountered previously and rapidly retrieves a schema that provides a solution, a process Klein terms "recognition-primed" decision-making. The application will involve some explicit reasoning (sometimes mental simulations to check feasibility of solutions), but the key to intelligent action is the automatic retrieval process.

The value of System 1 processing has also been emphasized by other dual-process theorists in applications to decision-making. For example, Reyna (2004) argues that experts acquire gist knowledge that allows them to make intuitive responses that are automatic, rapid, and effective, whereas novices need to rely on explicit analytic reasoning. However, Reyna notes also that the former kind of process can lead to bias and error when novel problems are presented, as is typically the case in laboratory studies of probability judgment. Perhaps more controversial is the recent claim of Dijksterhuis et al. (2006) that there are processes of conscious and unconscious reasoning, both of a deliberative nature, and that the unconscious reasoning leads to superior decision making. This is a very different kind of claim from those of the theories we have been considering that envisage fast heuristic processes delivering contextualized content for evaluation by a conscious, analytic process.

The evidence for superiority of unconscious decision-making is that people may make better decisions as measured by normative analysis or by correspondence with expert judgments (Wilson & Schooler 1991) when conscious deliberation is prevented by shortage of time or by competing tasks. This applies to fairly complex, multiattributed decision problems. However, it is unclear why any unconscious process of deliberative reasoning need be postulated. The evidence is consistent with the claim that where participants have a history of relevant experiential learning, fast recognition processes may provide accurate intuitive responses. What is interesting, however, is that conscious deliberative reasoning may then interfere with good decision-making. It may be that this reflects its sequential and low-capacity nature. An analogous finding in the learning literature is that complex rule learning may sometimes be inhibited by an instructional set for explicit learning (Reber 1993).

Dual processes would seem to be implicated when we contrast intuitive judgment with reflective decision-making. Many everyday decisions seem to involve rapid intuitive

judgments in which courses of action spring to mind with little or no effort of conscious thinking. Much expert decision-making seems to have this character (Klein 1999). On the other hand, we can and do make some decisions in a manner much more akin to that prescribed by decision theory, exploring alternative actions and their consequences with extended mental simulations (Kahneman & Tversky 1982). Intuitive judgments seem to have the System 1 characteristics, whereas reflective decision-making seems much more like a System 2 process (see also Kahneman & Frederick 2002). Other examples familiar to us all concern phobias and compulsive behaviors like gambling, overeating, or smoking, where we may become aware of a System 1 and 2 conflict. We may judge our own behavior or that of others to be irrational because we compulsively behave in ways that are at odds with our explicitly stated (System 2) goals. Some authors have described these kinds of phenomena as implying two minds in one brain (Evans 2003) or a brain at war with itself (Stanovich 2004).

Dual-Process Theories of Social Cognition

Dual-process theories of social cognition emerged in the 1980s (Chaiken 1980, Petty & Cacioppo 1981) and developed in popularity to form the dominant paradigm for the past 20 years or more. Contemporary work particularly concerns the automatic and unconscious processing of social information in such domains as person perception, stereotyping, and attitude change (Bargh 2006, Chaiken & Trope 1999, Forgas et al. 2003, Hassin et al. 2005, Smith & DeCoster 2000, Wilson 2002) and its apparent dissociation from explicit beliefs and conscious processing. The proposal of new accounts or at least new labels for dual processes in social cognition has reached near epidemic proportions, causing some reaction in terms of a unimodel that instead emphasizes multiple parameters known to influence social judgments (Kruglanski et al. 2003). Another interesting recent development is the quad model of Conrey et al. (2005), which proposes four kinds of process that should be distinguished in order to interpret research on automatic and controlled cognition.

Dual-processing accounts of social cognition have their roots in cognitive psychology, especially the study of automaticity and implicit memory, but have made curiously little connection with the dual-process theories of reasoning and decision-making discussed above. Although there is currently very little cross-referencing between these literatures, dual-process accounts in social psychology nevertheless share many common features with those in the cognitive psychology of reasoning and judgment. However, there are differences of emphasis. In general, the social cognition literature is less concerned with issues about cognitive architecture and evolution but more focused on issues concerning consciousness, free will, and the implications for moral and legal responsibilities of individuals.

A long-established dual-process theory is the heuristic-systematic model of Chaiken. According to Chen & Chaiken (1999, p. 74; Petty & Cacioppo 1981) "*Systematic processing* entails a relatively analytic and comprehensive treatment of judgment relevant information.... Given its nature, systematic processing requires both cognitive ability and capacity" whereas "*Heuristic processing* entails the activation and application of judgmental rules and 'heuristics' that are presumed to be learned and stored in memory.... Relative to systematic processing, heuristic processing make minimal cognitive demands on the perceiver." Systematic processing seems a similar concept here to that of analytic or System 2 reasoning in theories described above. However, heuristic processing in this theory sounds more like the recognition-primed decision making of Klein (1999) than the contextualization process postulated by reasoning theorists (Evans 2006, Stanovich 1999). In fact, heuristic processing so defined could be taken to be a form

of System 2 or rule-based reasoning, albeit one less effortful than that which is called systematic processing (see Strack & Deutsch 2004).

The cognitive experimental self theory, or CEST (Epstein 1994, Epstein & Pacini 1999), proposes two cognitive systems—experiential and rational—that share many common features with the generic two-system theory of reasoning. Like System 1, the experiential system is described as having a long evolutionary history with clear links to animal cognition, whereas the rational system, like System 2, is recent and distinctively human. Many other features of the generic theory shown in **Table 1** are included: fast-slow, unconscious-conscious, associative-rule based, and so on, whereas emotion is explicitly linked to the experiential system. However, the theory has a parallel-competitive, rather than default-interventionist, structure, and it includes the proposal that each system has access to distinct forms of knowledge. Epstein's approach is distinctive in the linkage of the two systems to two competitive processing styles. In contrast with reasoning theorists like Stanovich, who keep a clear separation between cognitive systems and dispositional thinking styles, Epstein has developed a psychometric tool, the rational experiential inventory, or REI (Epstein et al. 1996), for measurement of the two styles based on self-report. Epstein & Pacini (1999) review a number of experimental studies that appear to support the existence of these two processing styles. However, neither people classified as rational thinkers nor those scoring highly on the related need-for-cognition scale appear to have any advantage on abstract tests of logical reasoning (Bors et al. 2006, Newstead et al. 2004).

Social psychologists have been particularly interested in links between unconscious processing and implicit forms of knowledge representation. For example, it has been proposed that people may have both implicit and explicit attitudes (Wilson et al. 2000), something that may help to explain the traditional dissociation between verbal and behavioral measure of attitude changes. It may be possible to change our explicit attitude while an implicit attitude continues to control our social behavior. Similarly, it has been argued that we may have both implicit and explicit stereotypes that are dissociated from one another (Bargh 1999, Bargh & Williams 2006, Devine 1989). Many studies have used the methodology of semantic priming, borrowed from the literature on implicit memory (Lucas 2000). For example, Macrae et al. (1997) showed that when people are asked to view photographs of males or females and required to process them in a semantic manner, their subsequent threshold for word recognition is primed for stereotype-consistent words. Although some authors have proposed an optimistic view that conscious processing can inhibit implicit stereotypes, the evidence suggests the contrary. Even people who have nonstereotypical explicitly stated beliefs and who are aware of the problem of stereotypical behavior can be shown experimentally to have much of their social behavior unconsciously controlled (Bargh 1999).

A recent attempt to link dual-process accounts in social cognition with those in cognitive psychology was made by Smith & DeCoster (2000), who build on the distinction of two kinds of memory, one based on slow acquisition through associative learning and one linked to explicit memory (McClelland et al. 1995). These led them to a parallel system account in which associative and rule-based processing (cf. Sloman 1996) are linked to the two forms of knowledge. This proposal is essentially similar to dual-process accounts that have been developed to distinguish implicit and explicit forms of learning (Berry & Dienes 1993, French & Cleeremans 2002, Reber 1993, Sun et al. 2005). Smith & DeCoster argue that the major dual-process theories in social psychology can be accommodated within this general framework. However, as noted earlier, this is doubtful in the case of the heuristic-systematic theory, which looks more like two forms of rule-based processing (Strack & Deutsch 2004).

An important development for dual-process and dual-system theory generally is the emergence of social cognitive neuroscience. Particularly interesting is the identification of reflexive (System 1) and reflective (System 2) cognitive processing, with two neurological systems described as the X-system and C-system, respectively (Lieberman 2003, Lieberman et al. 2004). The X-system is composed of the amygdala, basal ganglia, and lateral temporal cortex, brain areas known to be involved in conditioning and associative learning and now being linked by Lieberman and colleagues with social cognitive processes traditionally described as automatic or implicit. The C-system involves the anterior cingulate cortex, prefrontal cortex, and the medial-temporal lobe (including hippocampus), brain areas known to be involved with (among other things) explicit learning and inhibitory, executive control. This account is supported by recent findings concerning the neurological systems that underlie response to immediate and deferred rewards in decision-making (McClure et al. 2004), which correspond to X- and C-system regions of the brain. Although in its early stages, this research program provides perhaps the strongest basis in the literature for maintaining some form of dual-system distinction.

A final issue to note in this section is that of self-knowledge. Although the notion that System 2 reasoning may engage in rationalization or confabulation is mentioned in the cognitive literature (Evans & Over 1996, Stanovich 2004), this idea has been more thoroughly investigated in the social psychology literature, especially by Wilson and his colleagues (Nisbett & Wilson 1977, Wilson 2002, Wilson & Dunn 2004). The basic idea here is that although much of our behavior is unconsciously controlled, "we" (conscious beings) are not aware of this fact and may live with an illusion that we are much more in control of our behavior than we actually are. On this view, we observe and theorize about our own social behavior in much the same way as we attempt to perceive and understand the behavior of others.

CONCLUSIONS

Although dual-process theories have been around in cognitive and social psychology for 30 years and more, it is only within the past 10 years or so that the terms System 1 and System 2 have come into common use. So popular are these terms now that it may be somewhat difficult to discourage their use and the implication of two underlying generic systems that they convey. However, close inspection of the evidence suggests that generic dual-system theory is currently oversimplified and misleading. In particular, (*a*) it is not possible coherently to link together all the attributes associated with Systems 1 and 2, respectively, in **Table 2**, certainly when moving between clusters, and (*b*) there are at least two quite distinct forms of dual-process theory to be found in these various literatures that cannot readily be mapped on to each other.

We might be better off talking about type 1 and type 2 processes since all theories seem to contrast fast, automatic, or unconscious processes with those that are slow, effortful, and conscious (Samuels 2006). Such terminology does not commit use to a two-system view. However, it would then be helpful to have some clear basis for this distinction. If we cannot associate all the System 1 (or type 1) features shown in **Table 2** together, for example, then which are the key ones that should distinguish them from System 2 (or type 2) processes? My suggestion is that type 2 processes are those that require access to a single, capacity-limited central working memory resource, while type 1 processes do not require such access. This implies that the core features of type 2 processes are that they are slow, sequential, and capacity limited. The last feature implies also that their functioning will correlate with individual differences in cognitive capacity and be disrupted by concurrent working memory load. Depending upon what else is assumed about working memory, there

may be a rationale for describing such type 2 processes as registering in consciousness and having properties associated with executive processes and intentional, higher-order control. However, other proposed features of System 2 in the generic theory do not immediately follow from this definition of type 2 processes, for example, the proposal that such processes are uniquely human or associated with decontextualized thought or rule-based reasoning.

The problem with this distinction is that type 1 processes then simply refer to any processes in the mind that can operate automatically without occupying working memory space. As already indicated, there are a number of different kinds of such implicit processes. We may have innate cognitive modules with encapsulated processes for perception, attention, language processing, and so on. We appear to have an associative learning system that implicitly acquires knowledge of the world in a form similar to weights in neural networks; the knowledge cannot be called to mind as explicit knowledge, but it can directly affect our behavior. We have habitual and automated behavior patterns that once required conscious type 2 effort but seem to have become type 1 with practice and experience. We also have powerful pragmatic processes that rapidly identify and retrieve explicit knowledge for conscious processing. Type 2 processing requires supporting type 1 processes to supply a continuous stream of relevant content into working memory.

If there are indeed multiple kinds of type 1 processes, then it is to be expected that psychologists will have developed different kinds of dual-process theories, which seems to be the case. Parallel-competitive forms of dual-process theory seem to be rooted in the idea of two forms of learning, leading to two forms of knowledge (implicit and explicit) that can then lead to competing attempts to control behavior. Theories of this type include those of Sloman (1996), Reber (1993), and Smith & DeCoster (2000). As mentioned above, there is promising evidence that these theories can be mapped onto neurologically distinct X- and C-systems (Lieberman 2003). However, the category of theories that I call "default-interventionist" assume, in contrast, that rapid preconscious processes supply content for conscious processing, cueing default behaviors that the analytic reasoning may approve or intervene upon with more effortful reasoning. This approach is reflected in dual-process theories of reasoning (Evans 2006, Stanovich 1999) as well as the theory of intuitive and reflective judgment proposed by Kahneman & Frederick (2002). If there are indeed two parallel cognitive and neurological systems, it is possible either that (*a*) the latter class of theories are mistaken in their architectural assumptions or (*b*) they are dealing with interactions between preconscious and conscious elements of the second system.

In short, my conclusion is that although dual-process theories enjoy good empirical support in a number of fields of psychology, the superficially attractive notion that they are all related to the same underlying two systems of cognition is probably mistaken, at least in the way that Systems 1 and 2 are being defined in the current literatures. For example, it is almost certainly wrong to think of System 1 as one system, all of which is old and shared with other animals. Equally, it is probably a mistake to think of System 2 as the conscious mind, all of whose processes are slow and sequential. If there is a second system, distinctively human, involving working memory and neurologically distinct structures, it does not follow that all of its workings are conscious and controlled. It is perfectly possible that one system operates entirely with type 1 processes and that the other includes a mixture of type 1 and type 2 processes, the latter being linked to the use of working memory, which this system uses—among other resources. Such a proposal could resolve the conflict between evidence for dual systems on the one hand with the proposals of different dual-process theorists on the other.

ACKNOWLEDGMENTS

The writing of this review was supported by a Research Fellowship award to the author by the Economic and Social Research Council of the United Kingdom (RES 000–27-0184). The author is grateful to Keith Stanovich, Tim Wilson, Phil Core, Eliot Smith, Shira Elqayam, and Yaniv Hanoch for their comments on an earlier draft of this review.

LITERATURE CITED

Baars BJ, Franklin S. 2003. How conscious experience and working memory interact. *Trends Cogn. Sci.* 7(4):166–72

Baddeley AD, Hitch GJ. 1974. Working memory. In *The Psychology of Learning and Motivation, Vol. 8*, ed. GA Bower, pp. 47–90. New York: Academic

Ball LJ, Lucas EJ, Gale AG, Miles JNV. 2003. Inspection times and the selection task: What do eye-movements reveal about relevance effects? *Q. J. Exp. Psychol.* 56A(6):1053–77

Barbey AK, Sloman SA. 2007. Base-rate respect: from ecological validity to dual processes. *Behav. Brain Sci.* In press

Bargh JA. 1999. The cognitive monster: the case against the controllability of automatic stereotype effects. See Chaiken & Trope 1999, pp. 361–82

Bargh JA, ed. 2006. *Social Psychology and the Unconscious*. New York: Psychol. Press

Bargh JA, Ferguson MJ. 2000. Beyond behaviorism: on the automaticity of higher mental processes. *Psychol. Bull.* 126(6):925–45

Bargh JA, Gollwitzer PM, Lee-Chai A, Barndollar K, Trötschel R. 2001. The automated will: nonconscious activation and pursuit of behavioral goals. *J. Personal. Soc. Psychol.* 81(6):1014–27

Bargh JA, Williams EL. 2006. The automaticity of social life. *Curr. Dir. Psychol. Sci.* 15(1):1–4

Barrett HC, Kurzban R. 2006. Modularity in cognition: framing the debate. *Psychol. Rev.* 113:628–47

Barrett LF, Tugade MM, Engle RW. 2004. Individual differences in working memory capacity and dual-process theories of the mind. *Psychol. Bull.* 130:553–73

Berry DC, Dienes Z. 1993. *Implicit Learning*. Hove, UK: Erlbaum

Bors DA, Vigneau F, Lalande F. 2006. Measuring the need for cognition: item polarity, dimensionality, and the relation with ability. *Personal. Individ. Differ.* 40(4):819–28

Braine MDS, O'Brien DP, eds. 1998a. *Mental Logic*. Mahwah, NJ: Erlbaum

Braine MDS, O'Brien DP. 1998b. The theory of mental-propositional logic: description and illustration. See Braine & O'Brien 1998a, pp. 79–89

Cacioppo JT, Petty RE. 1982. The need for cognition. *J. Personal. Soc. Psychol.* 42(1):116–31

Carruthers P. 2006. *The Architecture of the Mind*. Oxford, UK: Oxford Univ. Press

Chaiken S. 1980. Heuristic versus systematic information processing and the use of source versus message cues in persuasion. *J. Personal. Soc. Psychol.* 39:752–66

Chaiken S, Trope Y, eds. 1999. *Dual-Process Theories in Social Psychology*. New York: Guilford

Chen S, Chaiken S. 1999. The heuristic-systematic model in its broader context. See Chaiken & Trope 1999, pp. 73–96

Colom R, Rebollo I, Palacios A, Juan-Espinosa M, Kyllonen PC. 2004. Working memory is (almost) perfectly predicted by g. *Intelligence* 32(3):277–96

Conrey FR, Gawronski B, Sherman JW, Hugenberg K, Groom CJ. 2005. Separating multiple processes in implicit social cognition: the quad model of implicit task performance. *J. Personal. Soc. Psychol.* 89(4):469–87

Cosmides L, Tooby J. 1992. Cognitive adapations for social exchange. In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, ed. JH Barkow, L Cosmides, J Tooby, pp. 163–228. Oxford, UK: Oxford Univ. Press
Cosmides L, Tooby J. 1996. Are humans good intuitive statisticians after all? Rethinking some conclusions from the literature on judgment under uncertainty. *Cognition* 58:1–73
Cosmides L, Tooby J. 2000. Consider the source: the evolution of adaptations for decoupling and metarepresentation. In *Metarepresentations*, ed. D Sperber, pp. 53–115. Oxford, UK: Oxford Univ. Press
Cummins DD, Lubart T, Alksnis O, Rist R. 1991. Conditional reasoning and causation. *Mem. Cogn.* 19:274–82
De Neys W. 2006. Dual processing in reasoning—two systems but one reasoner. *Psychol. Sci.* 17(5):428–33
De Neys W, Schaeken W, d'Ydewalle G. 2005. Working memory and everyday conditional reasoning: retrieval and inhibition of stored counterexamples. *Think. Reasoning* 11(4):349–81
Devine PG. 1989. Stereotypes and prejudice: their automatic and controlled components. *J. Personal. Soc. Psychol.* 56:680–90
Dijksterhuis A, Bos MW, Nordgren LF, von Baaren RB. 2006. On making the right choice: the deliberation-without-attention effect. *Science* 311:1005–7
Dijksterhuis A, Smith PK. 2005. What do we do unconsciously? And how? *J. Consum. Psychol.* 15(3):225–29
Doherty ME, ed. 1996. Social judgement theory. *Think. Reasoning* 2:2, 3
Epstein S. 1994. Integration of the cognitive and psychodynamic unconscious. *Am. Psychol.* 49:709–24
Epstein S, Pacini R. 1999. Some basic issues regarding dual-process theories from the perspective of cognitive-experiential theory. See Chaiken & Trope 1999, pp. 462–82
Epstein S, Pacini R, Denes-Raj V, Heier H. 1996. Individual differences in intuitive-experiential and analytic-rational thinking styles. *J. Personal. Soc. Psychol.* 71:390–405
Evans JStBT. 1989. *Bias in Human Reasoning: Causes and Consequences*. Brighton, UK: Erlbaum
Evans JStBT. 1996. Deciding before you think: relevance and reasoning in the selection task. *Br. J. Psychol.* 87:223–40
Evans JStBT. 2002. Logic and human reasoning: an assessment of the deduction paradigm. *Psychol. Bull.* 128:978–96
Evans JStBT. 2003. In two minds: dual process accounts of reasoning. *Trends Cogn. Sci.* 7:454–59
Evans JStBT. 2006. The heuristic-analytic theory of reasoning: extension and evaluation. *Psychon. Bull. Rev.* 13(3):378–95
Evans JStBT, Barston JL, Pollard P. 1983. On the conflict between logic and belief in syllogistic reasoning. *Mem. Cogn.* 11:295–306
Evans JStBT, Curtis-Holmes J. 2005. Rapid responding increases belief bias: evidence for the dual-process theory of reasoning. *Think. Reasoning* 11(4):382–89
Evans JStBT, Handley SJ, Perham N, Over DE, Thompson VA. 2000. Frequency versus probability formats in statistical word problems. *Cognition* 77:197–213
Evans JStBT, Over DE. 1996. *Rationality and Reasoning*. Hove, UK: Psychol. Press
Evans JStBT, Over DE. 2004. *If*. Oxford, UK: Oxford Univ. Press
Fodor J. 1983. *The Modularity of Mind*. Scranton, PA: Crowell
Fodor J. 2001. *The Mind Doesn't Work That Way*. Cambridge, MA: MIT Press
Forgas JP, Williams KR, von Hippel W, eds. 2003. *Social Judgments: Implicit and Explicit Processes*. New York: Cambridge Univ. Press

Frankish K. 2004. *Mind and Supermind*. Cambridge, UK: Cambridge Univ. Press
French RM, Cleeremans A, eds. 2002. *Implicit Learning and Consciousness.* Hove, UK: Psychol. Press
Gathercole S. 2003. *Short-Term and Working Memory*. London: Taylor & Francis
George C. 1997. Reasoning from uncertain premises. *Think. Reasoning* 3:161–90
Gigerenzer G, Hoffrage U. 1995. How to improve Bayesian reasoning without instruction: frequency formats. *Psychol. Rev.* 102:684–704
Gigerenzer G, Todd PM, ABC Research Group. 1999. *Simple Heuristics That Make Us Smart*. New York/Oxford: Oxford Univ. Press
Gilinsky AS, Judd BB. 1994. Working memory and bias in reasoning across the life-span. *Psychol. Aging* 9:356–71
Gilovich T, Griffin D, Kahneman D. 2002. *Heuristics and Biases: The Psychology of Intuitive Judgement*. Cambridge, UK: Cambridge Univ. Press
Girotto V, Gonzalez M. 2001. Solving probabilistic and statistical problems: a matter of information structure and question form. *Cognition* 78:247–76
Goel V. 2005. Cognitive neuroscience of deductive reasoning. In *The Cambridge Handbook of Thinking and Reasoning*, ed. K Holyoak, RG Morrison, pp. 475–92. Cambridge, UK: Cambridge Univ. Press
Goel V, Buchel C, Rith C, Olan J. 2000. Dissociation of mechanisms underlying syllogistic reasoning. *NeuroImage* 12:504–14
Goel V, Dolan RJ. 2003. Explaining modulation of reasoning by belief. *Cognition* 87:B11–22
Haidt J. 2001. The emotional dog and its rational tail: a social intuitionist approach to moral judgement. *Psychol. Rev.* 108(4):814–34
Hammond KR. 1996. *Human Judgment and Social Policy*. New York: Oxford Univ. Press
Hanoch Y, Vitouch O. 2004. Information, emotional arousal and the ecological reframing of the Yerkes-Dobson law. *Theor. Psychol.* 14:427–52
Hassin RR, Uleman JS, Bargh JA, eds. 2005. *The New Unconscious*. Oxford, UK: Oxford Univ. Press
Hoffrage U, Gigerenzer G, Krauss S, Martigon L. 2002. Representation facilitates reasoning: what natural frequencies are and what they are not. *Cognition* 84:343–52
Inhelder B, Piaget J. 1958. *The Growth of Logical Thinking*. New York: Basic Books
Johnson-Laird PN. 1983. *Mental Models*. Cambridge, UK: Cambridge Univ. Press
Johnson-Laird PN, Bara BG. 1984. Syllogistic inference. *Cognition* 16:1–61
Johnson-Laird PN, Byrne RMJ. 1991. *Deduction*. Hove & London: Erlbaum
Johnson-Laird PN, Byrne RMJ. 2002. Conditionals: a theory of meaning, pragmatics and inference. *Psychol. Rev.* 109:646–78
Kahneman D, Frederick S. 2002. Representativeness revisited: attribute substitution in intuitive judgement. In *Heuristics and Biases: The Psychology of Intuitive Judgment*, ed. T Gilovich, D Griffin, D Kahneman, pp. 49–81. Cambridge, UK: Cambridge Univ. Press
Kahneman D, Frederick S. 2005. A model of heuristic judgment. In *The Cambridge Handbook of Thinking and Reasoning*, ed. K Holyoak, RG Morrison, pp. 267–94. Cambridge, UK: Cambridge Univ. Press
Kahneman D, Slovic P, Tversky A. 1982. *Judgment Under Uncertainty: Heuristics and Biases*. Cambridge, UK: Cambridge Univ. Press
Kahneman D, Tversky A. 1972. Subjective probability: a judgment of representativeness. *Cogn. Psychol.* 3:430–54
Kahneman D, Tversky A. 1973. On the psychology of prediction. *Psychol. Rev.* 80:237–51
Kahneman D, Tversky A. 1982. The simulation heuristic. See Kahneman et al. 1982, pp. 201–10

Kihlstrom JF. 1987. The cognitive unconscious. *Science* 237:1445–52
Klaczynski PA. 2000. Motivated scientific reasoning biases, epistemological beliefs, and theory polarization: a two-process approach to adolescent cognition. *Child Dev.* 71(5):1347–66
Klaczynski PA. 2001. Framing effects on adolescent task representations, analytic and heuristic processing, and decision making: implications for the normative/descriptive gap. *Appl. Dev. Psychol.* 22:289–309
Klaczynski PA, Lavallee KL. 2005. Domain-specific identity, epistemic regulation, and intellectual ability as predictors of belief-biased reasoning: a dual-process perspective. *J. Exp. Child Psychol.* 92(1):1–24
Klauer KC, Musch J, Naumer B. 2000. On belief bias in syllogistic reasoning. *Psychol. Rev.* 107:852–84
Klein G. 1999. *Sources of Power*. Cambridge, MA: MIT Press
Koehler JJ. 1996. The base rate fallacy reconsidered: descriptive, normative and methodological challenges. *Behav. Brain Sci.* 19:1–53
Kokis JV, MacPherson R, Toplak ME, West RF, Stanovich KE. 2002. Heuristic and analytic processing: age trends and associations with cognitive ability and cognitive styles. *J. Exp. Child Psychol.* 83(1):26–52
Kruglanski AW, Chun WY, Erb HP, Pierro A, Mannett L, Spiegel S. 2003. A parametric unimodel of human judgment: integrating dual-process frameworks in social cognition from a single-mode perspective. See Forgas et al. 2003, pp. 137–61
Lieberman MD. 2003. Reflective and reflexive judgment processes: a social cognitive neuroscience approach. See Forgas et al. 2003, pp. 44–67
Lieberman MD, Jarcho JM, Satpute AB. 2004. Evidence-based and intution-based self-knowledge: an fMRI study. *J. Personal. Soc. Psychol.* 87:421–35
Liu I-M, Lo K-C, Wu J-T. 1996. A probabilistic interpretation of "If-Then." *Q. J. Exp. Psychol.* 49A:828–44
Lucas M. 2000. Semantic priming without association: a meta-analytic review. *Psychon. Bull. Rev.* 7(4):618–30
Macrae CN, Bodenhausen GV, Milne AB, Thorn TMJ, Castelli L. 1997. Out of mind but back in sight: stereotypes on the rebound. *J. Exp. Soc. Psychol.* 33:471–89
Markovits H, Fleury M-L, Quinn S, Venet M. 1998. The development of conditional reasoning and the structure of semantic memory. *Child Dev.* 69:742–55
Markovits H, Quinn S. 2002. Efficiency of retrieval correlates with "logical" reasoning from causal conditional premises. *Mem. Cogn.* 30(5):696–706
McClelland JL, McNaughton BL, O'Reilly RC. 1995. Why there are complementary learning systems in the hippocampus and neocortex: insights from the successes and failures of connectionist models of learning and memory. *Psychol. Rev.* 102(3):419–57
McClure SM, Laibson DI, Loewenstein G, Cohen JD. 2004. Separate neural systems value immediate and delayed monetary rewards. *Science* 306(5695):503–7
Mithen S. 1996. *The Prehistory of the Mind*. London: Thames & Hudson
Monsell S, Driver J. 2000. *Control of Cognitive Processes*. Cambridge, MA: MIT Press
Newstead SE, Ellis C, Evans JStBT, Dennis I. 1997. Conditional reasoning with realistic material. *Think. Reasoning* 3:49–76
Newstead SE, Handley SJ, Harley C, Wright H, Farelly D. 2004. Individual differences in deductive reasoning. *Q. J. Exp. Psychol.* 57A:33–60
Nisbett R, Peng K, Choi I, Norenzayan A. 2001. Culture and systems of thought: holistic vs. analytic cognition. *Psychol. Rev.* 108:291–310
Nisbett RE, Wilson TD. 1977. Telling more than we can know: verbal reports on mental processes. *Psychol. Rev.* 84:231–95

Oakhill J, Johnson-Laird PN, Garnham A. 1989. Believability and syllogistic reasoning. *Cognition* 31:117–40

Oaksford M, Chater N. 1995. Theories of reasoning and the computational explanation of everyday inference. *Think. Reasoning* 1:121–52

Osman M. 2005. An evaluation of dual-process theories of reasoning. *Psychon. Bull. Rev.* 11:988–1010

Over DE. 2003. From massive modularity to metarepresentation: the evolution of higher cogntion. In *Evolution and the Psychology of Thinking: The Debate*, ed. DE Over, pp. 121–44. Hove, UK: Psychol. Press

Petty RE, Cacioppo JT. 1981. *Attitudes and Persuasions: Classical and Contemporary Approaches*. Dubuque, IA: Brown

Pinker S. 1997. *How the Mind Works*. New York: Norton

Reber AS. 1993. *Implicit Learning and Tacit Knowledge*. Oxford, UK: Oxford Univ. Press

Reber R. 2004. Availability. In *Cognitive Illusions*, ed. R Pohl, pp. 147–64. Hove, UK: Psychol. Press

Reyna VF. 2004. How people make decisions that involve risk: a dual-processes approach. *Curr. Dir. Psychol. Sci.* 13(2):60–66

Rips LJ. 1994. *The Psychology of Proof*. Cambridge, MA: MIT Press

Roberts MJ. 1998. Inspection times and the selection task: Are they relevant? *Q. J. Exp. Psychol.* 51A:781–810

Roberts MJ, Newton EJ. 2001. Inspection times, the change task, and the rapid-response selection task. *Q. J. Exp. Psychol.* 54(4):1031–48

Samuels R. 1998. Evolutionary psychology and the mass modularity hypothesis. *Br. J. Philos. Sci.* 49:575–602

Samuels R. 2006. The magical number two, plus or minus: some comments on dual-processing theories of cognition. *In Two Minds: Dual Process Theories of Reasoning and Rationality. 2006. Intl. Conf., Cambridge, UK*, July 5–7

Schneider W, Shiffrin RM. 1977. Controlled and automatic human information processing I: detection, search and attention. *Psychol. Rev.* 84:1–66

Sherry DF, Schacter DL. 1987. The evolution of multiple memory systems. *Psychol. Rev.* 94:439–54

Sloman SA. 1996. The empirical case for two systems of reasoning. *Psychol. Bull.* 119:3–22

Sloman SA. 2002. Two systems of reasoning. In *Heuristics and Biases: The Psychology of Intuitive Judgment*, ed. T Gilovich, D Griffin, D Kahneman, pp. 379–98. Cambridge, UK: Cambridge Univ. Press

Sloman SA, Over DE, Slovack L. 2003. Frequency illusions and other fallacies. *Organ. Behav. Hum. Decis. Process.* 91:296–309

Smith ER, DeCoster J. 1999. Associative and rule-based processing: a connectionist interpretation of dual-process models. See Chaiken & Trope 1999, pp. 323–60

Smith ER, DeCoster J. 2000. Dual-process models in social and cognitive psychology: conceptual integration and links to underlying memory systems. *Personal. Soc. Psychol. Rev.* 4(2):108–31

Sperber D. 1994. The modularity of thought and the epidemiology of representations. In *Mapping the Mind: Domain Specificity in Cognition and Culture*, ed. LA Hirschfield, SA Gelman, pp. 39–67. Cambridge, UK: Cambridge Univ. Press

Sperber D. 2000. Metarepresentations in an evolutionary perspective. In *Metarepresentations*, ed. D Sperber, pp. 117–38. Oxford, UK: Oxford Univ. Press

Stanovich KE. 1999. *Who is Rational? Studies of Individual Differences in Reasoning*. Mahwah, NJ: Elrbaum

Stanovich KE. 2004. *The Robot's Rebellion: Finding Meaning in the Age of Darwin*. Chicago: Chicago Univ. Press
Stanovich KE, West RF. 1997. Reasoning independently of prior belief and individual differences in actively open-minded thinking. *J. Educ. Psychol.* 89(2):342–57
Stanovich KE, West RF. 1998. Cognitive ability and variation in selection task performance. *Think. Reasoning* 4:193–230
Stanovich KE, West RF. 2003. Evolutionary versus instrumental goals: how evolutionary psychology misconceives human rationality. In *Evolution and the Psychology of Thinking*, ed. DE Over, pp. 171–230. Hove, UK: Psychol. Press
Stevenson RJ, Over DE. 1995. Deduction from uncertain premises. *Q. J. Exp. Psychol.* 48A:613–43
Stevenson RJ, Over DE. 2001. Reasoning from uncertain premises: effects of expertise and conversational context. *Think. Reasoning* 7(4):367–90
Strack F, Deutsch R. 2004. Reflective and impulsive determinants of social behavior. *Personal. Soc. Psychol. Rev.* 8(3):220–47
Sun R, Slusarz P, Terry C. 2005. The interaction of the explicit and the implicit in skill learning: a dual-process approach. *Psychol. Rev.* 112(1):159–92
Teigen KH. 2004. Judgments by representativeness. In *Cognitive Illusions*, ed. R Pohl, pp. 165–82. Hove, UK: Psychol. Press
Thompson VA. 1994. Interpretational factors in conditional reasoning. *Mem. Cogn.* 22:742–58
Thompson VA. 2000. The task-specific nature of domain-general reasoning. *Cognition* 76:209–68
Toates F. 2006. A model of the hierarchy of behaviour, cognition and consciousness. *Conscious. Cogn.* 15:75–118
Tooby J, Cosmides L. 1992. The psychological foundations of culture. In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, ed. JH Barkow, L Cosmides, J Tooby, pp. 19–136. New York: Oxford Univ. Press
Torrens D, Thompson VA, Cramer KM. 1999. Individual differences and the belief bias effect: mental models, logical necessity, and abstract reasoning. *Think. Reasoning* 5:1–28
Tversky A, Kahneman D. 1973. Availability: a heuristic for judging frequency and probability. *Cogn. Psychol.* 5:207–32
Tversky A, Kahneman D. 1983. Extensional vs intuitive reasoning: the conjunction fallacy in probability judgment. *Psychol. Rev.* 90:293–315
Uleman JS. 2005. Introduction: becoming aware of the new unconscious. In *The New Unconscious*, ed. RR Hassin, JS Uleman, JA Bargh, pp. 9–15. Oxford, UK: Oxford Univ. Press
Velmans M. 2000. *Understanding Consciousness*. London: Routledge
Verschueren N, Schaeken W, d'Ydewalle G. 2005. A dual-process specification of causal conditional reasoning. *Think. Reasoning* 11(3):239–78
Wang XT. 2006. Emotions within reason: resolving conflicts in risk preference. *Cogn. Emot.* 20(8):1132–52
Wason PC, Evans JStBT. 1975. Dual processes in reasoning? *Cognition* 3:141–54
Wason PC, Johnson-Laird PN. 1972. *Psychology of Reasoning: Structure and Content*. London: Batsford
Whiten A. 2000. Chimpanzee cognition and the question of mental re-representation. In *Metarepresentations*, ed. D Sperber, pp. 139–67. Oxford, UK: Oxford Univ. Press
Wilson TD. 2002. *Strangers to Ourselves*. Cambridge, MA: Belknap
Wilson TD, Dunn EW. 2004. Self-knowledge: its limits, value, and potential for improvement. *Annu. Rev. Psychol.* 55:493–518

Wilson TD, Lindsey S, Schooler TY. 2000. A model of dual attitudes. *Psychol. Rev.* 107(1):101–26

Wilson TD, Schooler JW. 1991. Thinking too much: introspection can reduce the quality of preferences and decisions. *J. Personal. Soc. Psychol.* 60(2):181–92

Wu G, Zhang J, Gonzales R. 2005. Decision under risk. In *Blackwell Handbook of Judgment and Decision Making*, ed. DJ Koehler, N Harvey, pp. 299–423. Oxford, UK: Blackwell

Annual Review of Psychology
Volume 59, 2008

Contents