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Two Is Not Always Better Than One

A Critical Evaluation of Two-System Theories

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ABSTRACT—*Over the past two decades, there has been an upsurge in theoretical frameworks alluding to the existence of two different processing systems that supposedly operate according to different rules. This article critically examines the scientific advance offered by these theories (in particular advances in the domains of reasoning, decision making, and social cognition) and questions their theoretical coherence as well as the evidence for their existence. We scrutinize the conceptual underpinnings of two-system models and explicate the assumptions underlying these models to see whether they are reasonable. We also evaluate the empirical paradigms used to validate two-system models and ponder about their explanatory strength and predictive power. Given the popularity of these models, we discuss the appeal of two-system theories and suggest potential reasons for their prevalence. We comment on the potential costs associated with these models and allude to the desired nature of potential alternatives. We conclude that two-system models currently provide little scientific advance, and we encourage researchers to adopt more rigorous conceptual definitions and employ more stringent criteria for testing the empirical evidence in support for two-system theories.*

Like many biological systems, the development of science is characterized by two opposite forces: an explosion in the amount of knowledge accompanied by attempts to decrease the diversity and complexity. To this end, scientific formulations in psychology attempt to weed out theoretical redundancies and construct higher order theoretical structures that aim to find regularities in the multitude of lower order characteristics of mental phenomena. Whether or not the higher order structures are scientifically useful depends on the cogency of assumptions they make and their success in providing generalizations above and beyond those achieved by considering only the lower order components. The goal of this article is to examine the success of a particular kind of higher order theoretical structures: the two-system models of the human mind.

The idea that there are different tracks of thought can be traced through the history of philosophy as far back as Aristotle. In particular, intuition and reasoning have been contrasted and assumed to constitute two distinct mental modes. In its broadest definition, *intuition* is thought of as "immediate apprehension" (Edwards, 1967, p. 4). This definition implicitly assumes that because such comprehension occurs instantaneously (in current terminology, automatically), contrary to deliberate analytical reasoning that consumes nontrivial amounts of cognitive resources and time, it is devoid of chains of inference and lacks adequate justification.

Over the past two decades, there has been an upsurge in theoretical frameworks under the general label of dual- or two-system theories (e.g., Epstein, Lipson, Holstein, & Huh, 1992; Evans, 2003, 2006; Kahneman & Fredrick, 2002; Lieberman, Gaunt, Gilbert, & Trope, 2002; Loewenstein & O'Donoghue, 2005; Sloman, 1996; Slovic, Finucane, Peters, & MacGregor, 2002a, 2002b; Smith & DeCoster, 2000; Stanovich & West, 2000; Strack & Deutsch, 2004). Recently, economists have also developed two-system models (e.g., Fudenberg & Levine, 2006) that are said to offer a unified explanation for several empirical regularities such as time inconsistency and inconsistencies associate with loss aversion. Common to all of these is an all-encompassing assumption about the existence of two qualitatively different mental systems. Different authors, however, have used different terminologies to characterize the two systems: rational versus

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experiential (Epstein et al., 1992), rule-based versus associative (Sloman, 1996), noetic versus experiential (Strack & Deutsch, 2004), deliberative versus affective (Loewenstein & O'Donoghue, 2005), and System 1 versus System 2 (Evans, 2003; Kahneman & Fredrick, 2002). Whether these different authors, who frequently cite each other, really mean the same thing by these classifications is highly questionable (Gigerenzer & Regier, 1996; Newstead, 2000). Indeed, in a recent article (Evans, 2008) reviewing dual-system theories in the areas of reasoning, judgment, and social cognition in detail, the author cautions readers to "beware of inferring that there are necessarily just two systems" (p. 256). We agree with Evans's warning but believe that he failed to go far enough. In particular, neither Evans nor other researchers have explicitly discussed the norms that should be used in testing any hypothesis about one, two, or more systems. The major goal of this article is to establish such norms. A few preliminary clarifications are in order before laying out our line of reasoning.

Not only do two-system researchers use different names for each of their two systems, but they also tend to use diverse terminologies to label their models. The most prevalent terms are *two-system*, *dual-mode*, and *dual-process*. Several researchers (e.g., Evans, 2006, 2008; Kahneman & Frederick, 2002; Slovic, Finucane, Peters, & MacGregor, 2002b; Strack & Deutsch, 2004) have used the different terms interchangeably in their exposition. For instance, most recently, Evans (2008) suggested that "what dual process theories have in common is the idea that there are two different modes of processing, for which I will use the most neutral terms available in the literature, system 1 and system 2 processes" (p. 256). We consider this confusion of terms as an indication of the conceptual vagueness and lack of precision associated with these two-system models. In an attempt to alleviate the confusion, some researchers define the theoretical terms, specifically the term *system*, in their own unique way. To illustrate, consider the following assertion by Kahneman and Frederick (2002). They suggest denoting intuitive and deliberate reasoning by borrowing the terms *System 1* and *System 2* from Stanovich and West (2000) and then assert that "These terms may suggest the image of autonomous homunculi, but such a meaning is not intended. We use the term *systems* as a label for collections of processes that are distinguished by their speed, their controllability, and the contents on which they operate" (p. 51). We propose that the proliferation of models, each using its own definition of the theoretical constructs or, even worse, using theoretical constructs that are not well defined, offers researchers and their readers a false sense of understanding. This also poses a problem for those who desire to consider the models critically because the entity under examination is not well defined.

In this article, we analyze the implications of the term *system* for dual-system models. Therefore, our analysis focuses exclusively on two-system models rather than dual-process models (e.g., Chaiken & Trope, 1999). Although *system* and *process* are often confused (and at times are used interchangeably), they are not synonymous. In our view, a process is conceptually a different unit of analysis than a system. Schachter and Tulving (1994) discussed the system–process distinction and noted that systems are characterized by the kind of information they handle, their rules of operation—or, in our terminology, the transformations undergone by the information within them—and their corresponding substrates. In the computer analogy, processes might be seen as the software, and systems might be seen as the computer involving both software and hardware. This analogy highlights the fact that the same process (software) can operate under different systems (hardware) and that processes can be viewed as observers' description of the transformations linking an input state to an output state. In this sense, processes are more specific than systems, and yet, abstractly, the same process can run on different informational contents in different systems. Thus, processes and systems are not the same and must be distinguished theoretically.

We fully acknowledge that the above-mentioned theoretical frameworks differ in their scope and assumptions. For instance, some two-system models restrict themselves to the purely cognitive domain (e.g., Evans, 2003; Sloman, 1996), whereas others are more concerned with the traditional distinction between reason and will (e.g., Loewenstein & O'Donoghue 2005; Slovic et al., 2002a, 2002b; Strack & Deutsch, 2004) and thus bear on affect and emotions. Two-system theories have also been proposed to explain phenomena in other areas, such as perception (e.g., Goodale & Humphrey, 1998), memory (e.g., Schacter & Tulving, 1994), self-control (Metcalfe & Mischel, 1999), and intertemporal choice (Fudenberg & Levine, 2006). It is not our intent to compare and contrast the existing models (see Evans, 2008; Osman, 2004, for reviews), nor to analyze any particular model in detail. Rather, we seek to investigate the implications of the "system" construct for the phenomena discussed by dual-system researchers. To this end, we use a generic model that captures the central tendencies of the diverse sets of dual-system models. To anticipate our conclusions, we propose that the different two-system theories lack conceptual clarity, that they are based on methodological methods that are questionable, and that they rely on insufficient (and often inadequate) empirical evidence. A main reason for this state of affairs is the failure to consider what a mental system is, which leads to the absence of stringent and transparent criteria to examine whether the mind consist of one, two, or perhaps multiple systems. We do not strive to answer the "number of systems" query, and we wonder whether the question is meaningful. Rather, our main goal is to propose some criteria that may assist in formulating the appropriate questions (and possible answers) in a more rigorous manner than has been the case up to now.

Gigerenzer and Regier (1996) were probably the first to address the difficulties associated with two-system models of this sort. Commenting on Sloman's (1996) article, they correctly noted that the two-system dichotomy is slippery and conceptually unclear. These authors observed that many of the two-system models stem from apparently conflicting responses to the same stimulus. They rightly noted that the presence of two conflicting responses should not necessarily imply the existence of two systems, a point that we elaborate on below.

Gigerenzer and Regier (1996) also noted that different researchers use different dimensions to describe their two systems. At times, these differences are theoretically significant (e.g., whether or not affect is used as an attribute that distinguishes the two systems). At other times, people use different terms for what are supposedly very similar concepts. For example, Epstein characterizes System 2 as "encoding reality in abstract symbols, words and numbers," whereas Sloman (1996) describes it as "using concrete, generic and abstract concepts" and Evans defines it as "logical and abstract" (see examples in Osman, 2004). Such conceptual richness makes it exceedingly difficult to obtain objective and unequivocal empirical support for a valid and meaningful two-system partitioning.

Moreover, Gigerenzer and Regier (1996) claimed that even if some attributes on which the alleged two systems are distinguished may provide testable characterizations, much of the afforded clarity is lost when the different characteristics (usually presented in a table) are superimposed one on top of the other in what are supposedly two all-embracing systems. Indeed, Newstead (2000) questioned whether the tacit assumption made by two-system researchers, that the similarities in the distinctions made by different models are so striking and transparent that they need no further evidence, is warranted. The commentaries on Stanovich and West (2000) highlight several additional conceptual ambiguities that are associated with two-system models. Likewise, Osman (2004) pointed out methodological difficulties and inferential leaps in several two-system models of reasoning.

In this article, we go further and critically examine a variety of two-system theories. For ease of exposition, the rest of the article adopts the generic terminology used by Evans (2003) and Kahneman and Fredrick (2002). We use *System 1* to refer to the system that is presumably experiential and characterized as being intuitive, associative, experiential, and affectively hot, and we use *System 2* to refer to the system based on formal reasoning that is characterized as rational, rule-based, reflective, and cold.[1] To illustrate the difference between the two systems, consider the following two forms of trusting. You may trust John because of your previous experience with him, because you believe you know him well, or perhaps even because he looks similar to you (DeBruine, 2002)—in short, you trust him because your "gut feelings" tell you he is trustworthy. Alternatively, you may trust John because your analysis of John's incentives structure, together with an assumption that he is rational, lead to the (unavoidable) logical conclusion that he can be trusted (e.g., Hardin, 2001).[2] Following the two-system approach, trust in the former case is the product of System 1, whereas in the latter case it is based on a game-theoretical analysis computed by System 2. As we argue later, however, these two kinds of trust are also perfectly compatible with a single system employing two different classes of criteria for establishing each kind of trust.

The present examination of two-system models is explicitly aimed at the generic level without going into the details associated with any particular framework. Undoubtedly, such details are critical to assess each dual-system theory within its particular context. However, we are interested in the common themes—namely, in the general question of the scientific viability of dual-system models as applied to higher order psychological phenomena involving judgments, reasoning, and decisions.

The remainder of the article is set as follows. We first discuss briefly three different levels at which mental systems can be examined—namely, the brain level, the structural level, and the functional level. We then discuss the assumptions underlying current two-system models and question whether they are reasonable in light of three criteria: (a) the nature of the characteristics employed to distinguish the two systems (dichotomies vs. continuous), (b) whether the characteristics are alienable, and (c) whether they satisfy the isolability requirement. We conclude that none of the current formulations of dual-system models satisfy all the three criteria. This leads to the examination of one of the major motivations for the development of two-system models: the existence of conflicts or inconsistencies between concurrent mental states. We ask whether such conflicts constitute a necessary reason for postulating two systems. Subsequently, we evaluate the empirical paradigm used to validate the models and ponder on their explanatory strength and predictive power. The above analyses point to the potential weakness of dual systems as scientific tools. Yet, given the growing popularity of two-system models, we discuss the appeal of two-system theories and suggest possible reasons for their prevalence. Finally, we comment on costs that may be associated with these models and briefly allude to potential alternatives.

LEVELS OF ANALYSIS

The proposition postulating the existence of two systems can be made at least at three levels. First, mental systems might be described by their *brain-level* correspondence—that is, through brain structures that implement them. Roughly speaking, different brain systems utilize different parts of the brain for their operations, so that one system can function without the other. There is unequivocal evidence that our senses constitute different systems. For instance, there is ample knowledge in-

[1]Most of the papers reviewed here characterize their two systems in terms of dichotomist features. We elaborate on these dichotomies below.

[2]This latter analysis would be mainly couched in terms of game theory.

dicating that the visual and the auditory systems are anatomically and physiologically different, although their outputs may converge on the same internal representation. So clear is the difference that the medical system has different specialized physicians for vision and audition. Two-system researchers vary in their emphasis on brain-level correspondence. Lieberman, Jarcho, and Satpute (2004) and Kahneman and Fredrick (2007), for example, emphasize the brain-level analysis, whereas Sloman (1996) deemphasizes it. It is important to note that the empirical support for claims about brain localization is still weak and sporadic (cf. Nee, Berman, Moore, & Jonides, 2008), and even those who suggest correspondence (in our opinion, too early) admit that much additional research is needed. This issue is further elaborated on when we discuss the evidence in support of the two systems.

Second, mental systems might be described at a *structural level* through classification of their mental elements, be they representations or processes, into different sets, with a focus on commonalities within sets and differences between sets (Titchener, 1899). According to a structural perspective, mental systems might be considered different "mental organs" or "mental machines," which may or may not be corresponding to different parts of the brain. From the structural perspective, one seeks to show how the different contents (representations) in the two systems undergo transformations in different ways or, in other words, are dealt with by different processes. To illustrate, consider the distinction between short-term and long-term memory. The two types of memory are supposedly structurally different in the properties of their representations as well as how the representations are created, change, and interact (but see Wickelgren, 1975). Whether this distinction is also instantiated at the brain level is a matter of considerable debate and thus remains to be seen (Bedford, 1997; Davelaar, Goshen-Gottstein, Ashkenazi, Haarmann, & Usher, 2005; Nee et al., 2008; Ranganath & Blumenfeld, 2005).

Third, mental systems can be examined at the *functional level*. Looking back at a classic debate in psychology, it has been argued that psychological phenomena cannot be described without reference to their function or to the relationship between one's mind and the environment (Calkins, 1906). Others have claimed (Chomsky, 1975; Tooby & Cosmides, 2005) that our mental faculties, like our physical constituents, have been selected by evolution based on functional criteria. Functionalism, unlike structuralism, focuses on the acts and functions of the mind rather than its internal content (Block, 1980; Danziger, 1990; see also Eagly & Chaiken, 1993, for discussion of functionalism vs. structuralism in models of attitudes). Its impact is reflected, for instance, in the work of Brunswik who focused on the adaptive interrelation of the organism with the environment (e.g., Hammond, 1966) and more recently in the computational work of Marr (1982). From this perspective, therefore, it is critical for a mental system to include mechanisms that are concerned with the fulfillment of desired functions and attainment of goals and are capable of testing goal satisfaction (e.g., Kunda & Spencer, 2003).

Perhaps because of discourse conventions or due to the researchers' deliberate choice, most of the two-system frameworks are specified, explicitly or implicitly, by their structural properties, such as the kind of processing they do (e.g., controlled vs. automatic, conscious vs. unconscious, rule-based vs. associative) and the type of representation they use (e.g., concrete vs. abstract; affect-infused or "hot" vs. affect-absent or "cold"). In all the articles reviewed here, the systems' functions and goals serve as the background, but they are not incorporated into or highlighted in the characterization of the system. An example of a functional approach that does not necessitate two separate systems is Bruner's (1984) analysis of two modes[3] of thought, or, using his terminology, "two modes of cognitive functioning," which he termed *paradigmatic* and *narrative*. The former relies on a set of operating principles based on logic, mathematics, and scientific rules "leading to good theory, tight analysis and logical proof." The latter is based on experience that "leads to good stories, gripping drama, and believable historical accounts." The two modes are reminiscent of statistical and clinical predictions or judgments (Dawes, Faust, & Meehl, 1989). Though statistical and clinical judgments are based on different processes or rules of inference, they, like Bruner's two modes, do not necessitate separate systems. Bruner's approach is further explicated later in this article, when we discuss alternatives to two-system models.

The discussion so far suggests that we generally view the emphasis on structural-level characteristics as a theoretical weakness of two-system models. Notwithstanding, the next section suggests that even structural-level considerations point to the untenability of classifying higher order functioning into two systems. To this end, the following examination of system models starts with considerations of the structural properties of a system. Based on this examination, we propose that sufficiently complex higher order mental phenomena, such as reasoning, cannot be modeled by two nonoverlapping systems, because such dual subsystems are unlikely to be either isolable or complete. We elaborate on these requirements below and return to the functional-level analysis at the end.

CHARACTERISTICS OF THE TWO SYSTEMS

With very few exceptions, two-system researchers refrain from defining or explaining what is meant by a mental system and, as mentioned earlier, often alternate between using the term *system* and using other terms such as *process*, *module*, or *mode*. They are not unique in this regard. Although these concepts are theo-

[3]Bruner presented his theoretical framework of two modes in several publications (e.g., Bruner, 1986), yet his 1984 presentation and his explication of modes of reasoning is the clearest one in which it is apparent that modes and systems are not interchangeable.

retically significant to almost any theory in psychology, they are rarely defined theoretically, compared, or contrasted. Among the few who address such issues, Schacter and Tulving (1994) noted that the term *system*, in the domain of memory research, is complex and has only been vaguely defined. They proposed that a very broad definition of a system, such as "a set of correlated processes," is too general. Parenthetically, it is this kind of general and loose approach that underlies many of the two-system theories examined in this article. The disadvantage of such an approach, as noted by Schachter and Tulving, is that it does not direct, guide, or constrain research, and consequently does not yield any testable questions. Accordingly, Schachter and Tulving also proposed a narrower formulation that, as we noted earlier, defines a system by three general properties: kind of information, rules of operation, and neural substrates.

Nevertheless, Schachter and Tulving (1994) noted that their own conceptualization of a system will undoubtedly undergo alterations and modifications (p. 14), and, indeed, recent discussions of the architecture of mind (e.g., Bechtel, 2008; Lyons, 2001; Sperber, 2005; Tooby & Cosmides, 2005) provide alternative conceptions of what a system might be. Yet, the question of what constitutes a mental system remains thorny and controversial. Therefore, rather than provide our own complete definition of a system, we discuss several criteria that a dual-system model must satisfy so that each of the two "systems" could be considered a system.

The dual-system models examined here characterize the alleged two systems by using a set of pairs of dichotomous characteristics and continuous features that are dichotomized. Stanovich and West (2000, Table 3)—for example, include the following features in characterizing System 1: associative, holistic, automatic, relatively undemanding of cognitive capacity, and relatively fast. System 2 is characterized by the opposite features: rule-based, analytic, controlled, demanding of cognitive capacity, and relatively slow (see also Evans, 2008). Other researchers use similar, although by no means identical, sets of features. Because the models differ in their scope and terminology, our critique does not address any specific two-system model. Rather, the examples we use should be viewed as illustrations to the problems specific to the different models. In the following sections, we discuss three potential concerns. First, supposedly, because researchers seek to contrast the two systems, they employ dichotomies as qualitative markers to characterize the systems. It is, however, highly questionable whether such a characterization is justified, or useful, from a scientific viewpoint. Second, we wonder whether the dichotomous characteristics used to define the two-system models are uniquely and perfectly correlated. Put differently, the question is raised whether a hybrid system that combines characteristics from both systems could not be theoretically and empirically viable. Finally, we discuss the interactions between the two systems and question whether the systems are sufficiently independent to satisfy the criterion of being isolable.

The Use of Binary Features

Every two-system model describes the two systems by a set of binary characteristics or *dichotomies*. The use of dichotomies to characterize the systems seems an important feature of the models, as it allows the researchers to propose that the systems are qualitatively different. The use of the dichotomies carries an implicit promise to assist in cognitive organization, yet this pledge may be illusory (Barbe, 2001) and sometimes may even hamper theoretical progress (Newell, 1973). We propose that employing a dichotomy in the present context may be inappropriate for several reasons.

First, in some cases the researchers construct dichotomies by contrasting a particular attribute with everything that is not that attribute. Bedford (1997) termed this method as the "not-the-liver" fallacy. To illustrate the logical trap, Bedford describes a physician from the mid-18th century who claimed a new discovery: isolating the organ system that removes toxins from the blood, which this physician labeled the "liver." Further, this physician claimed that he had ". . . discovered a second organ, [which] circulates the blood, absorbs nutrients, expels waste products from the body, and attacks foreign invaders. For when the liver is removed, the body is still able to do all these things and more, until such time as the toxin buildup is fatal" (p. 231). The physician, so the story goes, suggested calling this second organ "not-the-liver." Obviously, the physician had not discovered a second organ at all. He has merely shown that the liver is not the only organ present in the body. The "not-the-liver" fallacy refers to the "erroneous conclusion that what remains after damage must be a coherent category, process, module, or natural kind" (Bedford, 2003, p. 170). Because "not-the-attribute" may not be a unitary concept, such a practice makes the attribute under discussion vague and, as noted by Bedford, may lead to self-perpetuating false claims and misguided research (see also the discussion of "objects" in Lewontin, 2000). In a later paper, Bedford (2003) illustrated how the fallacy occurs in different domains of psychology (e.g., the explicit vs. implicit memory distinction) and in neuropsychological research.

A second reason to be concerned about the use of dichotomies is that the attributes under consideration are in fact inherently continuous in many cases (e.g., Newstead, 2000). Dichotomizing an intrinsically continuous dimension could be theoretically unsatisfying because the splitting point is not well defined and often arbitrary and because dichotomization of a continuous variable leads to loss of information (MacCallum, Zhang, Preacher, & Rucker, 2002). Two examples are examined below to illustrate these points (see MacDonald & Geary, 2000; Osman, 2004, for more examples).

One central dichotomy employed by many researchers involves the hot–cold dimension: Although System 1 is infused with hot affect, System 2 is characterized by cold logical reasoning. This dichotomization implies a well-defined demarcation between hot and cold processing, mirroring the everyday intuition about processing differences between passion and reason, which has been documented extensively (e.g., Zajonc, 1980). Janis and Mann (1977), for example, explicitly distinguished between hot and cold cognitions in decision making, and they discussed in detail the effect of making two types of decisions. Decisions involving hot cognitions (i.e., affectively loaded) may be associated with less elaboration, shallower processing of information, or failure to consider all possible options than decisions involving cold cognitions. It is important to note, however, that Janis and Mann clearly considered the hot–cold distinction to lie on a continuum and, in fact, discussed variables that lead to more or less hot decisions.

A hot–cold dichotomy can occur in one of two architectures. In one, some degree of affect is present continuously (e.g., Zajonc, 1980) and cold states are defined as those in which the level of affect is sufficiently low. A hot–cold dichotomization could occur in such architecture if System 2 is consistently associated with a low state of affect. In the other architecture, affect is not present continuously—rather, generation of affect can be turned on or off. The hot–cold dichotomization is observed because whenever System 2 is working, the affect-triggering mechanism is off. For reasons outlined below, we maintain that both alternatives are theoretically and empirically unlikely and that the system-level hot–cold dichotomy is therefore not theoretically viable.

According to the first interpretation, one has to define what is meant by weak affect and how it is related to arousal. None of the two-system models contend with this issue persuasively. Emotional states vary in arousal from very high to very low (e.g., Russell, 2003). The status of affect-absent states (i.e., cold states) is ambiguous in this theoretical scheme. Are affect-absent states similar to extreme low-arousal states or to mid-level (default) arousal states? Is it theoretically meaningful to compress the arousal dimension into two states (affect present vs. affect absent)? The second interpretation implies that affect is generated during the operation of System 1 but not during the operation of System 2. It is unclear whether the affect-generating mechanism is part of System 1 or whether it is triggered by it—yet, in both cases a two-system model has to contend with affects that result from cognitively complex processes. The joy of coming up with a good story that explains complex patterns of data, the agony of failure to understand your findings, the excitement of designing a complex experiment to test a theoretical model, and the sorrow that comes with the realization that a plan is not likely to work are clearly triggered by System 2 processes.

Consider a different example: the automatic–controlled distinction, which is one of the central characteristics used to describe most, if not all, two-system models (Evans, 2008). Schneider and Shiffrin (1977; Shiffrin & Schneider, 1977) were among the first to present a systematic research program on the automatic–controlled distinction. According to these researchers, controlled processes require attention and draw on resources of limited capacity, whereas automatic processes require little, if any, attention and are not restricted by capacity limitations. One of the major points emerging from their research program is that performance can change with practice and gradually become more automatic in the sense of requiring fewer cognitive resources. The distinction between automatic and controlled behavior, in this framework, is unequivocally on a continuum. To illustrate, consider driving behavior that can be described initially as pure controlled behavior, which, with practice (over months and years), gradually requires fewer and fewer resources and thus turns into an automatic activity.

Notwithstanding the above, one may argue that behavior is defined as automatic only when its need for mental resources is extremely small. Although conceptually reasonable, such a suggestion leads to theoretical complications when one attempts to explain how a two-system theory shifts from controlled to automatic processing, as in the proceduralization of skill. Assume that one of the systems (say System 2) handles performance in the early stages of learning. With practice, the various mental components become more and more closely associated with each other, so that, after a while, performance becomes automatic in the sense described by Schneider and Shiffrin (1977). At that point, it must be carried out by the other system (System 1), as this system is supposedly imbued with the ability to carry out automatic activity. How does the switch between systems occur? The Schneider and Shiffrin model assumes that the representations become increasingly interassociated with practice. Yet, if the two systems are assumed to use different representations, how does System 1 acquire the integrated representation? One may suggest that System 2 employs the same associative network that underlies System 1. However, this suggestion is inconsistent with the requirement of isolability, on which we elaborate later in this article.

Alignment of Characteristics

Assume for the moment that each of the processing dichotomies specified by two-system models, such as automatic–controlled, affective–cognitive, or within–outside consciousness can be demonstrated empirically in a convincing way. To establish the existence of two systems, one would have to put forth a strong argument regarding just how the different dichotomies are aligned, allowing one system to be characterized by one attribute from each dichotomy (e.g., as being "automatic, affective, and outside consciousness") and the other by its complement (e.g., "controlled, cognitive, and within consciousness"). It is important to note here that we are not concerned with the specific attributes used to define the system, but rather with the very strong claim that a limited set of binary attributes can be combined in only one, single, unique way, permitting the existence of exactly two systems (and no more!). We argue that not only is there no evidence for this claim (Newstead, 2000), but that even if some were found, it would not be conclusive.

What kind of evidence can be marshaled in support of the two-system thesis? Assume that there is a set of three dichotomous features—a1/a2, b1/b2, and c1/c2—used to characterize the two systems, so that System 1 is characterized by a1, b1, and c1, and System 2 is characterized by a2, b2, and c2. To establish the existence of a two-system model, it is necessary to demonstrate not only that the two feature sets exist (i.e., that a1, b1, and c1 tend to appear together and so do a2, b2, and c2), but also to establish that all hybrid combinations (e.g., a1, b1, and c2) do not! With three dichotomous features, five (out of six) combinations must be ruled out. As the number of features increases (most systems under consideration here are characterized by six or more dichotomies), so does the number of comparisons.

Moreover, even if the relevant empirical evidence could be obtained, it would be problematic. To demonstrate that a hybrid combination (e.g., a1, b1, and c2) is not viable, one has to show that this combination could be rejected. For example, one may wish to demonstrate that when processing is affective (a1) and automatic (b1), it is necessarily unconscious (c1) rather than conscious (c2). But, how could such an inference be made? Even if one were willing to accept the claim that processing in a particular experiment is below consciousness, can one make the inferential leap that it is necessarily so in every possible task characterized by a1 and b1?

To illustrate the problem of hybrid combinations, consider performance flexibility. System 1 is often characterized as being automatic and nonconscious, implying that its activity is controlled by the stimuli rather than the performer's goals. System 2, in contrast, is described as conscious, rule-based, and controlled. This fits well with the characterization of System 1 as impulsive and System 2 as reflective. Does this mean that performance flexibility is necessarily a characteristic of System 2 (and not of System 1)? Hassin (2005) has recently argued, convincingly, for the existence of automatic goal pursuit that is both flexible and unconscious (see Eitam, Hassin, & Schul, 2008, for empirical demonstration). Most two-system researchers would find such a phenomenon hard to implement because it combines features from the two opposite systems: automaticity (System 1) and flexibility (System 2).

As another example, consider the alignment between affective processing and automaticity. We already noted the assignment of emotions to System 1, a system that is also characterized as automatic. This fits well with the common sense view that emotions come to play whenever individuals encounter emotion-triggering situations with little involvement of the controlled processes (or possibly despite such involvement). However, a recent theoretical analysis and review of the empirical findings (Feldman Barrett, Ochsner, & Gross, 2007) suggests that there is little support for the view that specific emotions (e.g., anger, sadness) are automatically generated. Rather, these authors propose that control processes can and often do shape the experience of emotions. The combination of affective processes (System 1) and controlled processes (System 2) is another example of a hybrid model.

Concerns about alignment come up even when one deals with a supposedly single attribute. Bargh (1994) noted, almost 15 years ago, that automaticity may not be a single concept in the sense that manifestations of automaticity (such as nonawareness, nonintentionality, efficiency, and noncontrollability) are not aligned, meaning that there are examples of processes that are automatic in one sense but not in the others (see Bargh, 1994, for examples). As such, the general concept is not well defined, and its scientific usefulness becomes questionable. To quote Bargh, "It was time to get rid of the all-or-none idea of automaticity. It certainly was causing confusion and misunderstanding" (p. 3).

Another facet of the alignment issue can be illustrated in the context of an experimental design that includes three factors, such as consciousness, automaticity, and abstractness. Although, in principle, this $2 \times 2 \times 2$ design has 8 cells, dual-systems approaches presuppose that we need to consider only two cells in the design (i.e., the conscious, nonautomatic, abstract cell and the unconscious, automatic, nonabstract cell) and that we take for granted that the other cells are not interesting from a psychological point of view. The research cited earlier suggests that such a presupposition is unwarranted. There is an increasing body of evidence demonstrating that conscious behavior can be automatic, that abstract, propositional performance can be triggered by unconscious associative processes, or that so-called automatic behaviors can be altered through conscious strategic processes.[4]

Are the Two Systems Isolable?

At the most general level, a system can be conceived of as an entity that transforms one state (an input) into another state (an output). The input–output transformations reflect the way the task for which the system is specialized is carried out. To be complete, a system must contain all the components needed to perform its tasks. Put differently, a system should not depend on another system in carrying out its operations. This property is termed *isolability*. Briefly, we maintain that since System 1 and System 2 carry out higher order mental tasks (e.g., among other functions, System 1 is involved in making intuitive judgments, creativity, imagining, whereas System 2 is involved in deliberating, explaining, and controlling), the two systems cannot be independent of each other and thus cannot be considered two separate systems.

The required interdependence within a system implies that a system cannot be defined by an arbitrary set of components (be they physical or mental) and processes. Assume A and B are two (sub)systems performing Tasks a and b, respectively. Lyons (2001) proposed that the union of A and B is a system (for Tasks a and b) if the components within A and those within B interact with each other. That is, interaction between the system's com-

[4]We thank an anonymous reviewer for indicating this perspective to us.

ponents is a central characteristic of a system. Interdependence also comes into play when one tries to determine whether two entities are discrete mental systems. To be considered discrete, Systems *A* and *B* should be isolable: The operation of *A* should not be influenced by the operation of *B*, and in principle, *A* could perform *a* even if *B* is completely inhibited or absent[5] (Caruthers, 2005; Lyons, 2001).

The independence (or lack of it) between systems has been described by other terms besides isolability. Perhaps the most well known is Fodor's (1983) notion of *information encapsulation*, which assumes limited access to information in one system by other systems. Unlike informational encapsulation, isolability does not impose restrictions on access, but rather is defined by the system's ability to function even if other systems are not functioning. Even though isolability is a weaker criterion than encapsulation, we propose that two-system models do not satisfy this weaker demand. Simon (1998) discusses nearly decomposable systems, whose short-term behaviors are approximately independent of each other, although their long-term behavior depends, in an aggregate way, on the other systems. Nearly decomposable systems, like isolable systems, are tested by the effectiveness of the system—namely, whether or not it depends on other systems in its operations. It is highly doubtful whether the two systems under discussion satisfy the decomposable criterion.

Indeed, the trade-off between interdependence and independence of mental systems and between integration and segregation is one of the most fundamental and least understood problems (O'Reilly, 2006; Sporns, Chialvo, Kaiser, & Hilgetag, 2004; Tononi & Edelman, 1998). Some peripheral systems may be isolable in the sense that their operation is independent of other parallel systems. For example, vision and audition are accomplished by separate systems at the initial sensory level. The visual system is designed to register, encode, and interpret visual stimuli. Similarly, the auditory system is designed to register, encode, and interpret auditory stimuli. As simple empirical tests can show, these two systems are dissociable. This is not to say that visual information processing cannot be influenced by auditory information (and vice versa). Of course it can, perhaps through feedback from higher centers, as both systems contribute to higher order internal representations (see Lami, Mudrik, & Deouell, 2008). Notwithstanding, the question of the isolability of two systems refers to the possibility of one system functioning without necessarily requiring information from the other system. Evidence for the isolability of the visual and auditory systems can be found in the fact that one system can be damaged with little effect on the other. It is not incidental that vision and audition are treated by different experts in the medical world.

The question of interest here is whether System 1 and System 2, as specified by two-system models, are similarly isolable. Can a complex reasoning task, which was selected because it is presumably carried out by System 2, be performed without the involvement of System 1? We submit that reasoning performance would fail because System 2 cannot function without participation of associative networks that are the core of System 1 (Friedrich, 2000). In other words, any scientific hypothesis or theory that is presumed to be examined and analyzed by System 2 must obtain its original (raw) idea from System 1. Hence, once System 1 is neutralized, a breakdown in the performance of System 2 must follow. We shall return to this issue in the discussion of the empirical evidence for two systems.

[5]Assuming, of course, that *B* is not responsible for the input for *A*.

SIGNIFICANCE OF THE THREE ASSUMPTIONS

So far, we have argued that "system" models make implicitly three assumptions that are unreasonable in the domains of mental phenomena to which the two-system models pertain. However, we have also pointed out that two-system researchers use the term *system* imprecisely. This begs the following question: Are models that omit one or more of these assumptions more acceptable? To be sure, the term *two-system* might be inappropriate, yet, the models themselves might be more theoretically defendable.

Evans (2008) contrasts two classes of dual-system theories that he terms *parallel-competitive* and *default-interventionist*. The former refers to the classical two-system models that assume the existence of two isolable systems operating in parallel to generate potentially conflicting responses. Our discussion so far pertained to this class of models. Like Evans, we believe that parallel isolable systems are unlikely in the domains of decision making and reasoning.

Evans (2008) considers a second type of model, termed default-interventionist, that replaces the isolability assumption with one about a hierarchy between the systems, so that System 1 (the rapid associative system) supplies the content for the operations of System 2 (the conscious and controlled system). Without analyzing this class of models in much detail, we note that the assumption of a strict hierarchy between the so-called automatic processes (System 1) and controlled processes (System 2) conflicts with recent findings about the role of goals and intentions on various automatic processes (e.g., Eitam, Hassin, & Schul, 2008; Moskowitz, 2002) and/or with the influence on controlled processes on the experience of emotion (Feldman Barrett et al., 2007).

The second assumption system models make has to do with alignment of their characteristics. It is assumed that certain processing characteristics always go together or combine in a single way because they reflect one of the systems. Consequently, hybrid cases, processes that have characteristics from both systems, constitute a theoretical impossibility. Relaxing this assumption means that sets of characteristics are task dependent. One mental phenomenon can be automatic and hot, whereas another phenomenon may be automatic and cold. In a sense, this implies a single multicomponent, dynamic mental system in which the processes are tailored to the task, context, and the history of the processor. We discuss this alternative in more detail in the last section. Note, that there are dual- or multiprocess models that fit this characterization quite well (see Sherman, 2006).

HOW STRONG IS THE EVIDENCE IN FAVOR OF TWO-SYSTEMS?

In this section, we discuss the nature of empirical evidence that would be needed to support a two-system framework and briefly examine the extent to which such evidence is indeed available. We point to potential flaws in reasoning often used by advocates of the two-system model. We first evaluate critically the extent to which the existence of two incompatible mental states necessarily implies the existence of two systems. We then comment on double-dissociation studies that are often used as major evidence in support of the two systems. Finally, we note the recent appeal to neural investigations and question whether the current neural evidence is sufficiently strong to support two-system models.

Inconsistencies, Mental Conflicts, and Criterion S

Two-system models have been developed, in part, to explain the existence of conflicts and inconsistencies among mental states. How could a unitary system derive both *X* and *not X* simultaneously? Inconsistencies such as those between reason and intuition, reason and behavior, ego and id, or cognition and emotion have been highlighted by most researchers. Indeed, several researchers explicitly mention the existence of conflicts (e.g., Denes-Raj & Epstein, 1994; Evans, 2006; Sloman, 1996; Strack & Deutsch, 2004) . Conflict should be understood here as the existence of incompatible mental states. As with pure ambiguous perceptual examples such as the Necker cube (Rock, 1975), the conflict arises from two or more potential interpretations or responses to the same stimulus. Two-system models are seen as a useful mechanism for explaining conflicts because each of the two systems can give rise to a different potential interpretation or response. Indeed, if two systems exist, they can produce response conflict. We are concerned, however, with the other direction, namely, whether the existence of conflicts can be used as evidence in support of a two-system model.

Sloman (1996) suggested that the demonstration of a particular type of conflict constitutes necessary and sufficient evidence for the existence of two systems. This issue is addressed in depth in the discussion of Criterion S: "A reasoning problem satisfies Criterion S if it causes people to simultaneously believe two contradictory responses" (Sloman, 1996, p. 11). Sloman and others present many examples of conflicting internal responses and view their two-system model as a theoretical vehicle that accounts for the existence and resolution of these conflicts.

To illustrate the meaning of Criterion S, we analyze two examples employed by Sloman (1996). Consider, first, the Muller–Lyer illusion. It demonstrates that knowledge about the length of two lines does little to affect the perceptual experience that one line seems to be longer than the other. The illusion thus illustrates the dissociation between knowledge and perception.[6] It is important to note that mental dissociations of this sort can also be shown among conceptual responses, as in the conjunction fallacy, which is best exemplified by Tversky and Kahneman's (1983) "Linda the bank teller" problem. What is critical from the perspective of Criterion S is that even individuals who know that a conjunction of two conditions (e.g., feminist and bank teller in Linda's description) is less probable than each condition separately find that the conjunction fits or resembles the portrayal of Linda better than just one of the conditions. This is essential because the very existence of two concurrent contradictory beliefs is taken by Sloman as evidence for the existence of two mental systems, each supporting one of the conflicting internal responses or beliefs.

We seriously doubt whether the experience of two concurrent contradictory beliefs can be taken as evidence for a two-system model for two reasons.[7] First, the experience of simultaneity does not guarantee the actual simultaneity of the mental events. As noted by Osman (2004), although the idea is compelling, it is yet to be demonstrated empirically that individuals do indeed consider two contradictory beliefs concurrently rather than sequentially. Might it not be the case that when people reason about the combined option in the Linda problem they momentarily forget the single option and vice versa (cf. Pashler, 1994)? Such a suggestion is consistent with the idea that people are not processing the two alternatives either sequentially or in parallel (a dichotomy), but rather that the level of awareness of an alternative varies continuously as one reasons about it, depending on the situation. According to this interpretation, the experience of two concurrent, yet conflicting, states might be similar to the experience of the phi phenomenon, in which motion is generated when two stable sources of stimulation are successively switched rapidly on and off (Steinman, Pizlo, & Pizlo, 2000).

Second, even if one could show the existence of two concurrent contradictory mental states, both mental states might be generated by the same mental system and thus can not be taken as adequate evidence for two systems. For instance, consider again Tversky and Kahneman's (1983) Linda problem. The fact that subjective probability judgments violate a normative prin-

[6]The McGurk Effect (McGurk & McDonald, 1976), which shows that visual articulatory information is integrated (automatically and unconsciously) into our perception of speech, is a good example.

[7]Although not discussed by Sloman (1996), the reversible or Necker cube illusion (e.g., Rock, 1975) is an even better example. The Necker cube can be perceived as either standing on its rear lower edge or, alternatively, resting on its base (with the retinal image remaining the same). While perceiving one alternative, the perceiver is obviously aware of the other alternative ostensibly leading to a conflict, yet no one would suggest that the two alternative percepts are handled by two different systems.

ciple, in that the conjunction of two events is judged to be more likely than the probability of either of the two events occurring separately, is compatible with explanations based on linguistic analysis of the task and nature of mental models people use to represent the events in question (Betsch & Fiedler, 1999).

Kelso and Engstrom (2006) have recently discussed the existence of a large set of phenomena that are all both contrary and complementary. According to their analysis, contradictory mental states are to be expected in any sufficiently complex system. Indeed, intrasystem conflicts are not difficult to produce. Consider a student who practices a binary system that includes two numbers, 0 and 1, and an addition operation such that $1 + 1 = 0$. Assume that our student practices this system religiously, so that it becomes automated. At this point, we ask the student whether $1 + 1 > 1$? Our student may be faced with conflicting responses, having two meanings for $1 + 1$. Can such a conflict be taken as evidence for two systems, one for binary math and another for decimal math? Note that if the answer is affirmative, any number of systems might be generated by associating each system with a number-based math system.

As another example, consider the research of Evans and Curtis-Holmes (2005) who characterized belief bias as "a within-participant conflict between logic-based (analytic) processes and belief based (heuristic) processes" (the former attributed to System 2, the latter to System 1). According to the authors, such a conflict is to be expected based on contemporary dual-system theories. Moreover, assume one derives the prediction that the extent of belief bias should increase when participants are required to respond rapidly, because System 1 is more likely to dominate System 2 under time pressure. In fact, Evans and Curtis-Holmes (2005) reported that time-pressure manipulations did increase the amount of the observed belief bias. It is tempting to conclude that a two-system model is supported by such a pattern of findings.

This kind of reasoning, frequently employed by two-system researchers, is actually flawed. One has to distinguish between empirical findings that are compatible with a particular theory and empirical findings that are uniquely predicted by a given theory. The belief bias, and the fact that it is strengthened under time pressure, is equally compatible with a one-system model. Specifically, one may consider logical validity and believability to be two different types of external criteria that the (single) system can use to evaluate statements. Because verification of logical validity requires more cognitive resources and is slower than testing believability, it stands to reason that time pressure would impede the former more than the latter and therefore increase the likelihood of the belief bias. The problem with much of the empirical evidence in support of the two-system models is that it is not diagnostic in the sense of being predicted equally well by a single-system or multiple-system framework.

Finally, consider the conflict between intuitive and rational choices. Denes-Raj and Epstein (1994) asked participants to choose between two alternative lotteries where they could win $1 on every trial in which they drew a red jelly bean from a bowl. Participants frequently chose the bowl containing a greater absolute number but a smaller proportion of red beans (e.g., 9 in 100) over the bowl containing fewer red beans but better odds (e.g., 1 out of 10). Clearly, the latter choice is congruent with normative considerations, whereas the former choice is not. Yet, this incompatibility is also congruent with an alternative account proposing that the two choices are based on different sets of criteria, one that reflects formal normative considerations and another that is based on less rigorous principles such as, for instance, the temptation associated with large quantities. Therefore, the existence of such a conflict cannot be taken as evidence for the reality of two systems.

Generally, then, the findings about conflicting perceptions, beliefs, thoughts, or attitudes are consistent with a two-system model. Yet, such conflicts do not require the existence of two (or more) systems to be accounted for, and it is unclear how postulating two systems is derived merely from the existence of a conflict. What is missing is a link to the other attributes of the systems. If, for example, intuitive choices are carried out by one system and rational choices by another, then one should be able to predict that conditions that induce a particular type of choice (say, intuitive) also lead to all of the other attributes of performance associated with the relevant system. To the best of our knowledge, none of the current two-system models has been able to formulate such predictions, let alone demonstrate them successfully.

Double-Dissociation Studies

The existence of two systems has also been inferred from findings gathered in process-dissociation procedures (e.g., Lieberman et al., 2004). This method is used in both cognition and neuropsychology for inferring the existence of separate mental processes (Dunn & Kirsner, 2003). The basic underlying logic is to investigate two independent markers for a system and show that they converge. Double-dissociation methods have been the subject of long debates, and a detailed discussion of the issue is beyond the scope of the present article. There are two points, however, that need to be stressed in the present context. First, as of yet there has been no clear demonstration that the method can do what its proponents claim (Dunn & Kirsner, 2003), and several researchers have suggested that the method is simply unable to support the inferences for which it was designed (e.g., Bedford, 2003; Chater, 2003; Juola & Plunkett, 2000; Van Orden, Pennington, & Stone, 2001). Second, even if one accepts the method, dissociations are primarily used for "inferring functionality and not to map different functions onto different parts of the brain" (Dunn & Kirsner, 2003, p. 2). We propose that the same argument applies to systems defined by structural constraints.

Let us consider the logic of the double-dissociation paradigm for demonstrating the existence of two systems. Assume *a* and *b* denote two manipulations and let *A* and *B* be two tasks, each of which is associated with a different response variable. A double dissociation occurs if *a* affects performance on *A* but not on *B*, and *b* affects performance on *B* but not on *A*. Considering, for example, the visual and the auditory systems, *a* might consist of comparing blind individuals with sighted individuals, whereas *b* might consist of comparing deaf individuals with hearing individuals. In this case, *A* might be reading comprehension, and *B* might be listening comprehension. Our double-dissociation experiment is straightforward. We demonstrate that *a* (blind vs. sighted persons) influences performance on *A* (reading comprehension) but not on *B* (hearing comprehension). Conversely, *b* (deaf vs. hearing persons) influences *B* but not *A*. We take the double-dissociation findings as evidence that the two systems, vision and audition, are indeed two different and independent systems.

Our example, however, is misleading because there is a big inferential leap from observing a double dissociation to arguing for the existence of two systems. The example might seem compelling because we started with two systems that are known, a priori, to be isolable. However, if we do not know a priori whether we are dealing with two isolable systems, then double-dissociation data may not be useful in determining whether we have a single system or two systems.

Chater (2003) offers an illuminating argument challenging the validity of the double-dissociation method for establishing the existence of two systems. Suppose that the mental mechanisms that carry out Tasks A and B overlap almost completely except for a small component (C_A) specific to Task A and, similarly, a small component (C_B) specific to Task B. Now assume some damage knocks out (or impairs) just one mental component, C_A or C_B, supposedly leading to dissociation between performance in one of the tasks. It would undoubtedly be wrong to conclude that Tasks A and B are subserved by different systems when in fact they are under the same system, except for the tiny specialized components C_A and C_B. The crucial point for present purposes is that dissociation indicates the existence of a particular component that is differentially sensitive to a particular manipulation. Double dissociation may therefore point to existence of two different components that affect performance in two tasks. However, the two components may or may not be associated with two independent systems.

To illustrate, let us briefly describe an example suggested by Chater (2003). Consider two persons: one allergic to prawns but not to peanuts, and another allergic to peanuts but not to prawns. It might be tempting to conclude that prawns and peanuts are digested by different systems, yet we know that there is a single digestive system and only some subtle chemical differences, quite late in the process of digestion, may characterize the two persons. The bottom line is that double-dissociation paradigms can demonstrate the sensitivity of components to manipulations, but not the division of components into systems.

Differentiating Between Systems on the Basis of Neural-Psychological Evidence

Some authors (e.g., Kahneman & Fredrick, 2007; Lieberman et al., 2004) made further attempts to promote two-system models by claiming neural evidence for their existence. For instance, Kahneman and Fredrick (2007) cite De Martino, Kumaran, Seymour, and Dolan (2006), who used MRIs to demonstrate differential neural activation associated with the amygdala as a result of framing effects. These authors further reported a correlation between activity in the orbital and medial prefrontal cortex and susceptibility to framing effects. De Martino et al., and subsequently Kahneman and Fredrick, interpreted these findings as evidence for the importance of emotions in decision making, and stress the differential emotional involvement in different types of decisions (e.g., risky vs. nonrisky). However, employing these results as evidence for the existence of two systems seems to us unwarranted. Although many of the two-system models suggest, implicitly or explicitly, that the distinction may also hold at the brain level, the neurological evidence is scarce and does not warrant such a conclusion. Indeed, several authors (e.g., Fodor, 1999; Nee et al., 2008; Rubinstein, 2008) have cautioned not to force hasty psychological conclusions from scant and often vague neurological findings. Nee et al. (2008) are particularly relevant as their discussion relates to the well-known (yet controversial) two-system distinction between short- and long-term memory.

THE PREDICTIVE POWER OF TWO-SYSTEM THEORIES

In previous sections, we remarked about the lack of conceptual precision of two-system theories, questioned the evidence supporting their existence, and wondered about their theoretical status. We have raised the possibility that the two-system models under consideration would not satisfy the stringent requirements of a scientific theory. In particular, this section discusses the models' lack of predictive power.

There is, we propose, a fundamental difference between what is customarily referred to as a scientific theory and what may be termed a theoretical framework. Briefly, we suggest that a theoretical framework contains a set of related concepts that may serve as a starting point for a potential future theory. However, a theoretical framework lacks the conceptual rigor required from a well-formulated scientific theory and consequently does not lend itself to the derivation of precise and unambiguous hypotheses. Our reading of the different two-system theories considered in this article is that they should at best be treated as theoretical frameworks. Because of the complexity of the phenomena they propose to explain, they are, at present, too imprecise to allow the derivation of unequivocal predictions.

A major characteristic of many two-system frameworks is that they were constructed in retrospect to account for known phenomena. By itself, this should not be a cause for concern as long as we are not fooled into believing that this is the end of the road. To ensure that a proposed framework is scientifically useful, one has to show that it not only offers a retrospective explanation, but that it also yields reasonably good (forwards) predictions. The problem with most, if not all, two-system theories reviewed in the present article is the lack of any predictive power and the tendency to employ them as an after-the-fact explanation.

For an example of the post hoc nature of two-system model, consider the recent chapter by Kahneman and Frederick (2002) in which the heuristics and biases research program is embedded in a two-system framework. Clearly, this research, initiated at the beginning of the 1970s, was devoid of any idea of two separate systems, being initiated by the insightful observations that intuitive judgments follow different rules than those dictated by the formal normative models. Yet embedding the entire research program in a two-system framework makes it more appealing and seemingly provides a natural explanation for many phenomena. Nevertheless, there is no evidence, aside from the dissimilarity in the outcomes between intuitive and normative decision processes, that intuitions and "rational" reasoning are under the control of different systems. In fact, very similar concerns to those we raised about the predictive power of two-system models were used against the original heuristic-and-biases research program (e.g., Gigerenzer, 1996; Yates, 1983). Thus, ironically, the modern interpretation of the program in terms of a two-system model does not provide an answer to the earlier theoretical questions.

WHAT IS THE COGNITIVE APPEAL OF TWO-SYSTEM EXPLANATIONS?

Recently, Dawes (1999) proposed that "mere predictability does not matter like it should (without a good story appended to it)" (p. 29). Indeed, the idea of two systems offers a good story, makes good sense, and seems to resolve apparent inconsistencies. Not only do two-system models offer a good story, they also provide a useful classification scheme that seemingly facilitates the understanding of complex phenomena. Indeed, classification and categorization are basic cognitive functions essential for making sense of the world around us, through ordering and structuring our knowledge.

Having a good story, however, is a double-edged sword. Although the idea feels right and feeling right increases one's confidence in the correctness of the proposed explanation, the history of science has shown many times over that confidence is not a good indicator of truth. Brewer, Chinn, and Samarapungavan (1998) suggest the following criteria for evaluating the merit of explanations: empirical accuracy, scope, internal consistency, simplicity, precision of predictions, formalism, and fruitfulness (guidance for future research). Our assessment of two-system frameworks is that they excel in scope and simplicity, but they do not fare well with respect to empirical accuracy, precision of predictions, and formalism. Indeed, one's intuitive impression (System 1, one is tempted to say) is that two-system models can accommodate a great range of empirical findings quite well. However, we submit that this reflects the imprecision with which the models are defined.

We are aware of the fact that currently we may be in the minority, and we wonder why two-system theories have become so widely accepted. Why do so many researchers seem to believe that a two-system framework offers a better understanding than does a single comprehensive system? Below we speculate about several possible reasons for this trend.

One main reason for the popularity of two-system models may have to do with the apparent alignment between different features of processing and system characteristics. Disregarding the questions raised earlier concerning the nature of the different features that characterize the two systems, most people consider the high correlations between the defining features and the corresponding systems as evidence for the existence of the latter. It tells a good story that provides an interesting and coherent narrative confirming the hypothesis about the existence of two systems. A possible reason for the prevalence of two-system models is the absence of disconfirmation attempts (Wason, 1960). For instance, we are not aware of attempts to perform negative tests—namely, to invalidate the two-system models or to search for possible hybrid models. Such attempts are more common in the memory area (e.g., see Berry, Shanks, & Henson, 2008, for a recent analysis of the explicit–implicit memory system).

Another reason for the seductiveness of two-system models might be related to their simplicity. William James (1890/1950) pointed out that mere classification is "for some unknown reason, a great aesthetic delight for the mind" and that "the first step in most of the sciences is purely classificatory" (p. 646). Beyond the aesthetics, he further noted that "a world whose real materials naturally lend themselves to serial classification is pro tanto a more rational world, a world with which the mind will feel more intimate, than a world in which they do not" (p. 647).

Although any classification might be pleasing, the ability to divide a large set of phenomena into two meaningful subsets might be especially satisfactory. Photos and Chater (2002) proposed what they termed the *simplicity principle*, which posits that, as in perceptual organization, people prefer categories that provide the simplest encoding. Dichotomies, as used to describe the defining features of the two systems (and not more than two) are optimal for satisfying this principle. The appeal of dichotomies is further explained by noting that a dichotomy is exclusive and exhaustive (items are either in A or in B, and if an item is in A it is not in B, and vice versa), thus leaving little uncertainty and providing the feeling that one has a simple (and complete) model or understanding of an entire corpus of data (i.e., the entire world). Correspondingly, Keren and Teigen (2001) have shown that people strongly prefer probabilities approaching 0 or 1, even when they are inaccurate, simply because they provide certainty and unequivocally divide the world into certain versus impossible events.

A related advantage is based on the (questionable) assumption that the two systems can be characterized by a relatively small number of discrete features that are well defined. Accepting the above characteristics makes the two systems, from a cognitive perspective, more palatable and easier to comprehend. Unfortunately, psychology is more complex in the sense that a phenomenon can rarely be explained by a few well-defined discrete variables that have an unambiguous demarcation line. A similar claim has been recently made by Feldman Barrett et al. (2007) in the domain of emotions.

Our analysis is consistent with Kelso and Engstrom (2006), who proposed that "dichotomizing seems central to human cognition, one of the only ways human beings have of trying to capture reality and their own existence" (p. 5). Accordingly, they developed a framework in which cognition is based on idealized (extreme) poles that are contradictory and complementary at the same time. Notwithstanding, it is important to remember that the cognitive need to search for complementary dichotomies, though satisfying the mind and producing a feeling of understanding, is not always a veridical reflection of reality.

The satisfaction people derive from dichotomies might also be predicted from theories about how explanations are constructed. Hilton (1990) highlighted the role of Mill's method of differences in causal explanation. He suggested that, during the process of causal explanation, the features of the to-be-explained target are contrasted with features of background cases and that differences are selected as the cause. From this perspective, a binary split is particularly informative because it highlights the differences. Any more refined classification requires more effort in contrasting the categories and therefore, we speculate, is less appealing as explanatory mechanism.

Of course, this tendency is not unique to two-system researchers. More than four decades ago, in a frequently cited paper, Newell (1973) noted that psychology tends to conceptualize in terms of binary opposites (e.g., nature vs. nurture; serial vs. parallel processing). He proposed that researchers, implicitly or explicitly, believe in formulating questions in terms of binary oppositions. Following Newell, many believe that "the proper tactic is to frame a general question, hopefully binary, that can be attacked experimentally" (p. 290). Newell's conclusion, however, was that "unfortunately, the questions never seem to be really answered, the strategy does not seem to work" (p. 290). This is reminiscent of a recent plea by Kruglanski and coworkers (Kruglanski, Erb, Pierro, Mannetti, & Chun, 2006) to replace dual-process approaches in social cognition with a single parametric model (unimodel) that can take different values of parameters while using the same mental machinery (Kruglanski & Thompson, 1999).

Psychologists in general tend to dichotomize quantitative measures despite the loss of information associated with such a practice (MacCallum et al., 2002). Even in cases in which a continuous dimension may be more appropriate (in that it provides a more accurate and reliable depiction of a phenomenon), a dichotomy is more appealing because it is easier to comprehend. In part, this may reflect people's (as well as scientists') tendency to think in true/false terms. A particular effect is present or absent, a hypothesis is rejected or not. We all use the strict, yet arbitrary, rule $\alpha = .05$ as the criterion for accepting or rejecting the null hypothesis. As noted by Loftus (1996), most people will agree that there is no essential difference between an experimental finding of $p = .050$ and $p = .051$. Loftus suggests that investigators, journal editors, and reviewers alike, implicitly treat the cutoff line of .05 as real rather than arbitrary. Accordingly, he claims, "the world of perceived psychological reality tends to become divided into 'real effects' ($p < .05$) and 'non-effects' ($p \geq .05$)" (p. 164).

Another source of the appeal of two-system models is the mutual support the authors gain from each other. In their analysis of causal explanations, Hilton, Smith, and Kim (1995) proposed that explanations are also derived through the method of agreement, which reinforce the presupposed similarities among theories and foster one's confidence in them. From this perspective, it is not surprising that two-system researchers cite each other, even though the different models do not always imply the same two systems. Citations may also refer to models that are similar in name only, such as dual-process models in persuasion (e.g., heuristic vs. systematic). To illustrate, Stanovich and West (2000) refer to many different theories as instantiations of a latent generic two-system model, suggesting that although "the details and technical properties of these dual-process theories do not always match exactly, there are clear family resemblances" (p. 658). Similarly, Kahneman and Fredrick (2002) suggest that by now the two-model theory has been widely embraced, and although the different models come in "many flavors," they all support the same idea. However, as noted by Newstead (2000), such mutual support may not be warranted. He convincingly claims that "there is little or no evidence that they [the different models] amount to the same thing, and considerable reason for believing that they do not" (p. 690). A similar sentiment was expressed recently by Evans (2008). Thus, such cross referencing may have little scientific value, and it merely creates a false sense of a unified theoretical framework that has been explained.

No scientific model is completely true, or, to put it differently, every model used currently is false. If so, why spend so much time for arguing against the two-system model? Even if they are incorrect, one may argue that these models are used only as a heuristic device to explain a large set of phenomena. Moreover, the models direct attention to various forms of mental conflicts and their implications at the level of processing (e.g., slow vs. fast; Smith & Decoster, 2000), representation (e.g., concrete vs. abstract; Sloman, 1996), or amount of control (e.g., impulsive behavior vs. reasoned action; Strack & Deutsch, 2004). Nevertheless, we submit that two-system models might slow scientific progress for the following reasons. First, such models may slow progress due to their psychological appeals—that is, because dichotomies please the mind, two-system models may persist as psychological frameworks and not be translated into psychological theories. Second, two-system models emphasize dichotomies. We argued earlier that pure dichotomies are rarely sensible, as many characteristics of mental phenomena are inherently continuous. Therefore, dichotomizing implies oversimplifying. Third, and probably more important in terms of the cost to the scientific endeavor, the emphasis on dichotomies rather than continuous dimensions encourages researchers to test for effects (present vs. absent) and not to estimate parameters. Meehl's (1967) analysis suggests that this leads to a loss of power of empirical tests. Moreover, we propose that it may lead to the proliferation of models that are described qualitatively rather than quantitatively.

CONCLUSION

The major goals of this article are methodological in nature, namely pointing out some necessary tests and corresponding criteria for establishing the existence of two systems. Digressing for a moment, one may notice that psychological methodology in the last few decades has focused far too much on statistical analysis (specifically on significant testing) while failing to critically scrutinize the conceptual arsenal employed in the discipline. Researchers seem to be relatively unconcerned with issues of ontology and with attempts to systematize the realms of empirical phenomena and theoretical constructs, as well as the relationships among them. Notwithstanding, the reader may draw some comfort from the fact that this trend may not be unique to psychology (see Köhler, Munn, Rüegg, Skusa, & Smith, 2006, for discussion and attempts at a solution in genetics).

Our analysis points out the lax approach, both at the conceptual and methodological level, employed by advocates of two-system models. We raise serious doubts regarding the empirical evidence marshaled in support of the different models and note the theoretical ambiguity and lack of coherence associated with these models. The bottom line of our investigation is that the theoretical structure of two-system theories is ill-defined, and consequently, we wonder whether two-system models are testable with currently existing methods.

What, then, is the alternative? Should we opt for a multiple-system model or a unisystem model? An earlier alternative approach is one whereby the hypothesized dual-system split is replaced by a postulate about the existence of many subsystems, often referred to as modules, each of which specializes in solving a specific mission (Fodor, 1983; Tooby & Cosmides, 2005). The suggestion of a modular brain, however, remains controversial as one moves from input-level mechanisms into central cognition. Recently, Fodor (2001), who is probably most strongly associated with the idea of modules, joined dynamical system theorists (Van Gelder, 1998) in arguing against the viability of modules for explaining higher order mental functioning. Indeed, many of the problems raised in this article with regard to two-system models may be equally applicable to the controversy regarding modules.

It might well be the case that pondering about the number of systems is an inappropriate question. A system's definition involves the tasks it performs (Lewontin, 2000; Lyons, 2001) so that a split into k subsystems for one task may be unsuitable for a different task. As Sherman (2006) aptly noted, "there is no one final answer to the How Many question that applies for all purposes across all domains and contexts. Rather, the answer to the How Many question will often be It Depends . . . it is important to not let the How Many question obscure the more important questions" (p. 173).

The system–task correspondence suggests that, at least with respect to higher order mental functioning, it might be scientifically more useful to explore the implications of the natural compliment of dual-system theories, namely a unimodel (cf. Kruglanski et al., 2006). Kruglanski et al. contend with the currently pervasive dual-processing approaches in persuasion that assume people's responses to persuasive communication can be based either on detailed analysis of the persuasive message (systematic processing) or on heuristic cues that are unrelated to the message content (e.g., the attractiveness of the source, the length of the message). According to dual-processing approaches, systematic processing and heuristic processing are based on qualitatively different sets of operations. Kruglanski et al. argue cogently that the apparent differences between the two modes of processing can be explained by assuming that the nature of processing (i.e., heuristic or systematic) has to do with the goals of the individual as construed at the time he or she uses the information. Accordingly, the appearance of two modes of processing is an epiphenomenon: a creation of research programs that aim at maximizing differences. As the unisystem model assumes that the extent of processing of a given informational cue varies continuously as a function of its task relevance (e.g., Erb et al., 2003), research should attempt to identify how tasks are understood and should consequently explore the goals of individuals and how information-processing strategies serve these goals.

More generally, rather than having two qualitatively different subsystems that carry the higher order functions of the human mind, one can assume that our (single) mental apparatus is capable of shifting between many different mental states, each of which aims to solve a particular task. These states might be described by different combinations of characteristics, such as speed of processing, awareness, control, level of affect, nature of internal codes, etc. In this view, the mental machinery is conceived as being divisible into small parts that are joined in alternative ways when the mind has to deal with different constraints imposed by the environment.

Thus, in contrast to k-system models, there need not be a fixed partition of parts to fixed subsystems. Rather, parts could interact in different combinations, depending on the goals and context (cf. Bechtel, 2008). For instance, Magen and Cohen (2007) recently proposed three basic mechanisms for solving problems of visual perception: one mechanism for handling colors, one for shapes, and one for verbal information. Each mechanism is responsible for perceiving information in its content area and selecting responses based on the content. It is important to note that most tasks require the applications of more than one mechanism, so that the mental system can combine the mechanisms according to task demands. By allowing the multitude of parts to interact with each other, the mental system is able to select a subset of parts into a mechanism according to the demands of a task (i.e., criteria), the context, and the system's past behavior. It is noteworthy to mention that a unisystem approach, as briefly outlined above, is congruent with both Gibson's (1966, 1979) and Brunswik's (see Hammond, 1966) theoretical frameworks.

Another alternative to the *k*-system models is exemplified in Bruner's (1984) analysis of two modes of thought, which we briefly alluded to in the beginning of this article. Despite the apparent similarity between Bruner's modes of reasoning and the other two-system models under discussion, we suggest that they are different in essence. As we discussed above, a fundamental requirement of any two-system framework is that the systems be isolable (Carruthers, 2005)—namely, that each can function without depending on the mental machinery of the other. Bruner's modes of reasoning, according to our interpretation, are free of this requirement. Following Bruner, the two modes of cognitive functioning reflect different ways of interpreting reality and organizing internal representations, and consequently, each mode has its operating principles based on different criteria for establishing truth. Whereas truth in the paradigmatic mode is determined by the use of formal procedures (based on mathematical and logical principles), the narrative mode establishes what Bruner calls truth-likeness or verisimilitude.

For a concrete illustration of the different accounts offered by the two-system and two-mode frameworks, consider the findings of Evans, Barston, and Pollard (1983), who studied the conflict between logic and believability in syllogistic reasoning, referred to as the *belief bias*. Specifically, they proposed that the truth (or falsity) of a syllogism can be judged either according to the formal rules of logic or through the extent to which the syllogism sounds believable (admittedly, there is no well-defined criterion for believability).[8] They showed that the believability criterion often overrides logical considerations. For instance, faced with the premises "No addictive things are inexpensive" and "Some cigarettes are inexpensive," 71% of their participants endorsed the conclusion that "Some addictive things are not cigarettes." This is not a (logically) valid conclusion, yet it is evidently perceived as such because the content of the conclusion is congruent with reality. On the one hand, this might be considered as essential evidence for the two system conjecture, attributing logical-based inferences to one system and associative-based inferences to the other. However, the belief bias can be equally explained by assuming that the validity of a syllogism is judged either by paradigmatic (i.e., logic) or by narrative (i.e., believability) standards, both of which can operate within the same system. Thus, whether the belief bias can serve as evidence for the existence of two systems is highly questionable.

Bruner's framework, in contrast to the two-system frameworks, emphasizes the criteria people employ to evaluate the mental system's outcome. These criteria (e.g., logical rules) are external in the sense that they are agreed upon by people and are not presumed as part of the mental architecture. The mental operations and transformations information undergoes are derived from the criteria. In contrast, in the two-system frameworks the mental operations and transformations are given (i.e., postulated in advance) and the systems are defined by them. The criteria, when used, are just one characteristic of the system. We view the emphasis on the mental system's goal and its success in achieving these goals to be a key ingredient in an architecture of mental systems.

As an extension of Bruner, one may conceive of the mind as capable of activating a large number of modes, all of which use the same tool box. Each mode handles a different task by selecting tools deemed useful for the task and relevant criteria relating to the person's goals while performing the task in the environment.

Some may argue that the question of whether there are two systems is not an empirical one. Indeed, there is probably no single critical experiment that can provide a final and definitive answer. Notwithstanding, we maintain that, in the final analysis, the answer can only be made on the basis of accumulated empirical evidence. Nominal definitions are arbitrary, so that any set of *k* components might be termed *k* systems. As one of the reviewers of this article noted, one might argue that in a Prisoner's dilemma there is a conflict between the cooperation system and the defection system. The problem is that such classification may reflect nothing but an arbitrary nominal definition because it does not impose any constraints onto the testable empirical world. And this is the crucial question for the viability and the scientific value of two-systems approaches. The challenge to two-system theories is to explicate the constraints that can be tested and describe empirical outcomes that would be considered a fair falsification. By not giving up on empirical tests, we may become committed to a more precise specification of the theoretical constructs and their links to empirical reality. Our article should be interpreted as a plea for more rigorous conceptual clarity and for rigorous testing of the empirical evidence supporting, or indeed rejecting, two-system models.

[8] Evans et al. (1983) employed an independent group of participants who rated the believability of all the syllogisms. Although this is indeed an appropriate control, it does not constitute a well-defined criterion for believability, which remains a vague concept.

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