Reasoning with complementary pathways, not competing processes

Jon May

Department of Psychology, University of Sheffield

And

Philip Barnard

MRC Cognition and Brain Sciences Unit, Cambridge

Draft paper for presentation at the

In Two Minds Conference, Cambridge, 5th-7th July 2006.

Abstract

The core of our argument is that the human mental architecture is composed of nine subsystems of **equal** status that interact as parts of a coherent overall system, and therefore one mind. Two of these subsystems represent qualitatively different types of meaning, one propositional in nature and the other a more abstract holistic representation, called implicational meaning (Barnard & Teasdale, 1991). Implicational meaning integrates over sensory, conceptual and bodily inputs and so captures affective states. Two aspects of this model relate to the claims of dual process theory. First, the two semantic subsystems stand in rather different relationships to the seven others. Implicational meanings receive direct and therefore fast inputs from visual, acoustic and body state subsystems while the construction and use of propositional meanings relies on inputs derived from longer, and therefore slower, processing routes. Interactions between these two meaning systems are argued to form the central engine of human ideation (Teasdale & Barnard, 1993). The second aspect of the model is that in these interactions processing activity can reflect properties of the two representations to differing degrees as a function of **the mode** in which meaning is processed. The mode of processing also directly relates to conscious experience. When implicational meanings dominate processing activity over time the same kinds of properties as are proposed for System 1 would be emphasised but when propositional meanings dominate the characteristic properties of System 2 would be more in evidence.

In his review of dual process accounts of reasoning, Evans (2003) argues provocatively that they "quite literally propose the presence of two minds in one brain", and concludes that "an important challenge is to develop models to show how such two distinct systems interact in one brain". This paper argues against key aspects of the 'two minds' hypothesis, and uses an information processing account of human cognition and affect (Interacting Cognitive Subsystems or ICS (Barnard, 1985, Teasdale & Barnard, 1993) to support the argument. This account encompasses the two modes of reasoning required by dual process theories, but embedded within a unified cognitive architecture. Although it has not been directly applied to formal reasoning paradigms, the architecture has been used in several areas of applied psychology in which thought and affect interact, most notably within clinical psychology, but also in human-computer interaction and working memory research.

The core of our argument is that the human mental architecture is composed of nine subsystems of **equal** status that interact as parts of a coherent overall system, and therefore one mind. Two of these subsystems represent qualitatively different types of meaning, one propositional in nature and the other a more abstract holistic representation, called implicational meaning (Barnard & Teasdale, 1991). Implicational meaning integrates over sensory conceptual and bodily inputs and so captures affective states. Two aspects of this model relate to the claims of dual process theory. First, the two semantic subsystems stand in rather different relationships to the seven others. Implicational meanings receive direct and therefore fast inputs from visual, acoustic and body state subsystems while the construction and use of propositional meanings relies on inputs derived from longer, and therefore slower, processing routes. Interactions between these two meaning systems are argued to form the central engine of human ideation (Teasdale & Barnard, 1993). The second aspect of the model is that in these interactions processing activity can reflect properties of the two representations to differing degrees as a function of **the mode** in which meaning is processed. The mode of processing also directly relates to conscious experience. When implicational meanings dominate processing activity over time the same kinds of properties as are proposed for System 1 would be emphasised but when propositional meanings dominate the characteristic properties of System 2 would be more in evidence.

Defining two modes of thought

Hobbes (1651/1982) declared that 'Reason is nothing but reckoning', the addition of elementary facts to form a new fact, and this approach has characterised attempts to understand the way in which humans reach conclusions about arguments, and decide between options. Reasoned argument has historically been seen as superior to decisions based on preference, affect, or emotion. Unfortunately, evidence consistently points to everyday human reasoning as being more often based on irrational judgements than rational processing, even though people are clearly able to reason rationally when pushed to do so.

Stanovich & West (2000) introduced the terms ‘System 1’ and ‘System 2’ to contrast these two styles of human reasoning. System 1 can be characterized as rapid, parallel, automatic, effortless, experiential, with little or no consciously reportable components other than its concluding products. System 2 is everything that System 1 is not: it is slow, serial, controlable, of limited capacity, requires effort, and is open to introspection. Mithen (2002) suggests that System 1 is an evolutionary old mode of reasoning that we share with other species, while System 2 is relatively new and its emergence marked the differentiation of homo sapiens as a distinct species. It is, in other words, what makes us human: systematic and rational, it allows human thought to be different to the reactive, domain-limited thought of other creatures.

On its own, however, System 2 thinking would clearly not be a very useful or adaptive feature: Zajonc (1980) famously critiqued serial models of reasoning as unhelpful to the rabbit who hears a rustle in the grass, and begins to process the information, only to be eaten by the snake before it has reached a rational conclusion. He argued for two routes of processing: one focussing on the *discriminanda*, the aspects of a stimulus that allow you to distinguish it from others; the other operating on the *preferenda*, those aspects that tell you whether or not you like or fear the stimulus. Rapid, automatic, and biased preferenda modes of thought are very useful in most situations precisely because they are based on experience gained in situations similar to the ones that most frequently occur, and can be executed in information-poor contexts or under uncertainty (e.g., Tversky & Kahneman 1974). Discriminanda processing is valuable in novel and unfamiliar situations, where experience has to be transferred across domains; where deductions and inferences have to be made.

Meaning and mental architecture

Dual process theory is targeted at explaining qualities that apply to thinking and reasoning. System 1 is seen as is based upon associative learning and may itself be decomposed into several subsystems (Evans, 2003). Rapidity, parallelism, automaticity and effortlessness may well be shared between animals and humans in System 1 processing, but a key feature of human ideation is the centrality of meaning and language. Indeed, those tasks whose evidence supports the case for System 2, depend on language and meaning. Matching biases are one important source of evidence (Evans, 1998, 1999) for the distinction between System 1 and System 2 processes. Here information that perceptually matches the lexical content of the problem is taken as relevant while information that does not match is neglected. Yet the bias varies as a function of the abstractness of the material, with System 1 processing competing with System 2 processing more effectively when prior knowledge and belief is less likely to come into play.

There are numerous wider examples where some characteristic features of System 1 may well apply in the moment-to-moment processing of meaning and in memory. Examples include: processing the pragmatic implications of sentences (Brewer, 1977; Harris & Monaco, 1977), emotional inferences in text comprehension (e.g. Gernsbacher, Goldsmith & Robertson 1992), or the Moses illusion (Erikson and Mattson, 1981). In the case of the Moses illusion, when faced with the simple question "How many animals of each kind did Moses take into the Ark?", most respondents will rapidly answer "Two", apparently not noticing that it was Noah not Moses who took the animals into the Ark. They don't make the same mistake of providing a direct answer when the question mentioned Nixon (Erikson & Mattson, 1981). Moses and Noah are sufficiently similar to allow the processing of the false presupposition to pass undetected. Both happen to be prominent old testament male figures with two syllable names. Just as Zajonc argued for the case of the rabbit, this is useful for real time comprehension. We attend, in both abstract (Duncan, 2000) and semantic tasks (Barnard , Scott, et al. 2004), to what is salient in the context. This is practical, efficient and adaptive. If all the possibilities had to be serially checked and evaluated by System 2 mechanisms then much natural cognition would be unwieldy. While these kinds of phenomena could, of course, arise from competition between different processes, they could equally be an important design feature of parallel mental architectures in which the processing of form and meaning concurrently occurs at different levels.

The defining features of System 2 reasoning are that it is reflective, slow, sequential and makes use of a central working memory system of limited capacity. Again, these same properties can equally well be applied, and have been, to a far wider domain of tasks than those typically encompassed by the classic reasoning tasks. Ruminative thinking is, for example, a common attribute that accompanies depressed states (Nolen-Hoeksema et al., 1991), This kind of thinking can relate to the kind of abstract hypothetical entities to which System 2 mechanisms are devoted. It is reflective and the content of thought is posted in consciousness. It is slow, serial and persistent, and arguably uses executive mechanisms

(Hertel, 2000) or resources not unlike those of working memory (Ellis & Ashbrook, 1988). Yet these thoughts are also repetitive, routinised and often considered to be invoked automatically across a wide range of circumstances (Beck, 1976). It can even relate to logical properties. Counterfactual reasoning that can accompany Post-Traumatic Stress Disorder (e.g. Dalgleish, 2004), and more widely depressed states and rumination co-occur with apparent deficits on means-end problem tasks (Watkins and Baracaia, 2002). While, it would again be easy to argue that such maladaptive thought patterns simply result from competition with System 1 mechanisms winning because ruminative thoughts are just strongly cued by prior knowledge, this tells us little about the precise details of that mechanism. Indeed, Evans (2003) acknowledges that this requires a more detailed specification of computational architecture.

Any move towards a more detailed specific of architecture forces us to confront the issue of exactly how concurrency (parallel processing), distributed knowledge representation and control should be implemented. Dual process theory, in its current form, posits that System 1 is composed of multiple autonomous subsystems that process information in parallel, but does not specify the identity of those subsystems, the encodings of information they use, the architectural constraints on information flow among them or how distributed control might work. Likewise, the arguments concerning System 2 mechanisms focus on classic features of a central processor, or Von Neumann architecture – seriality and a central working memory of limited capacity with executive powers. Yet in contexts where multiple subsystems are invoked, distributed control of multiple processing units can itself give rise to the characteristics of a limited capacity working memory (Barnard, 1999; Barnard & Bowman, 2003).

This commitment to an evolutionary recent limited capacity component is central to the idea of two minds in one brain. System 1 is seen as having qualitatively different characteristics from System 2 processing. The same commitment is also central to the challenge of integrating dual process theory with other domains of enquiry that should inherently be related – such as research on the topics of working memory, or executive processing (Evans, 2003). The list of obvious extensions can also be taken to include language and meaning as well as the relationship between reasoning and emotion. Such extensions immediately take us into the territory of unified theories of cognition (Newell, 1990, Kieras & Meyer, 1999) or yet wider macro-theories of mental architecture encompassing affect and embodiment (Barnard, May Duke and Duce, 2000). If it can be shown that System 2 could itself be composed of autonomous subsystems, using the same processing capability as those of System 1, but whose interactions give rise to seriality and limited capacity, then a key distinction within dual process theory would be called into question. Some existing "Multi-level" models of cognition and emotion (for a review see Teasdale, 1999a) have just this characteristic. In the remainder of this paper we explore how a multilevel model composed entirely of autonomous subsystems with the same processing capabilities could in principle give rise to the kinds of phenomena on which the System 1:2 distinction is based.

Language understanding, for example, is widely viewed as progressing through a series of stages involving inputs, semantic representations and output stages (e.g. see Harley 2001, p395). Although theorists often do argue that language acquisition and use depends on limited capacity mechanisms, (Gathercole & Baddeley, 1993), this need not necessarily involve the concept of a limited capacity working memory. The Interacting Cognitive Subsystems architecture (ICS) relies only on a defined set of autonomous subsystems, each with its dedicated memory system (an image record). In this particular model, (Barnard, 1985, Barnard, 1999, May, 2000, Teasdale & Barnard, 1993), a heard (or read) speech stream is converted into a series of propositions where meaning is encoded in a referentially specific format that specifies entities and their semantic properties and relationships (see Figure 1). A sound stream containing speech is converted by the acoustic subsystem into an abstracted representation of the linguistic sound units (the morphonolexical level), from which the propositional content of the speech is identified. Such serial processing and a focus on propositional material are the stuff of System 2 thinking, typical also of influential approaches to symbolic modelling (e.g, Newell, 1990). To explain inference, however, ICS makes a case for another level of semantic representation at which prior experiential knowledge could be integrated with propositional representations.

This "implicational" level of representation is seen as abstracted from an individual's propositional experience in exactly the same way that propositions were abstracted from acoustic structures in speech, that is, over experience. All levels of representation in this architecture model statistical regularities over time in the patterns of information input to them. Repeated co-occurrences of sound units led an individual to associate them with a propositional meaning, whether it was a name, an action, an attribute, or a grammatical modifier. Similarly, repeated co-occurrences of propositional sequences in similar contexts could lead them to be associated with implicational schemata, or schematic models, whose content reflected themes in human experience, not only of our cold cognitions but also of motivation and emotion including danger, intention, affection, reward, threat, and so on. Gaps in the propositional content of any speech stream could then be bridged by calling on generic relationships encapsulated in the currently active implicational schema, previously inferred from experiences propositionally similar to the current context. Successive propositions allow an implicational schematic model, to be abstracted concerning the current global meaning of the speech stream, which can then be used by the implicational subsystem to access records of previous situations and generic schemata, to derive additional propositional content relevant to the situation, but crucially, not explicitly contained within the speech stream. So, for example, when faced with the content of a sentence like "John saw Carol drop the plate on the kitchen floor", a process in the Implicational subsystem might draw the pragmatic inference that it broke and feed that meaning back to the propositional subsystem (Teasdale & Barnard, 1993). Similarly, the propositional subsystem can access its records to derive morphonolexical content that can be combined with the content derived from the actually heard speech, to clarify ambiguities and cope with the vagaries of less than perfect input. The morphonolexical subsystem can also produce verbal output plans, which an articulatory subsystem converts into actual speech.

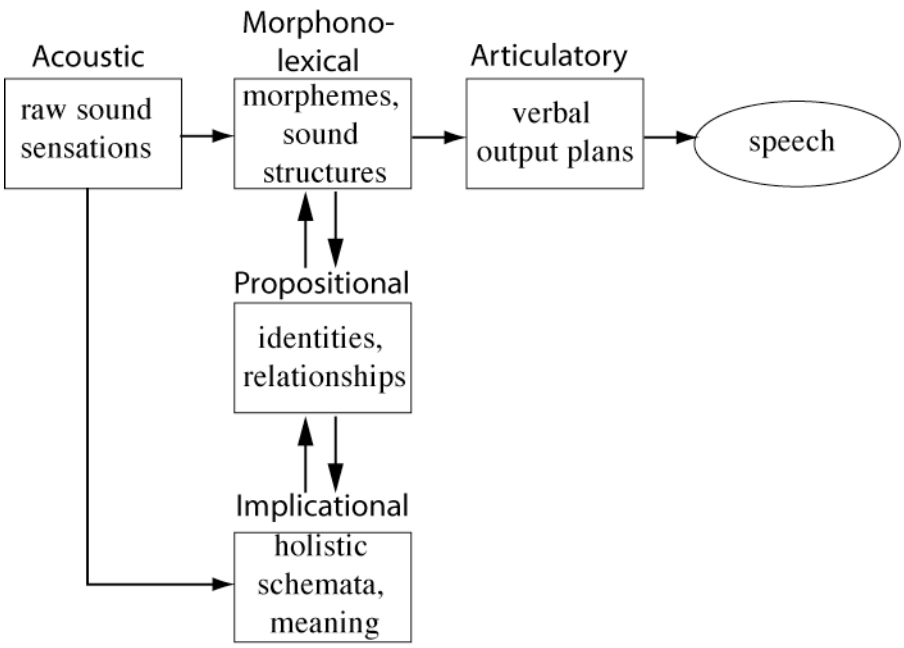

Figure 1: A sound stream containing speech is converted by the Acoustic subsystem into an abstracted representation of the linguistic sound units (the Morphonolexical level), from which the Propositional content of the speech is identified. Successive Propositions allow an Implicational schema to be abstracted concerning the meaning of the speech stream. At the same time, the affective qualities of the speech stream allow an Implicational pattern to be inferred. The resulting Implicational representation is derived from two sources, and feeds back to

influence the derivation of propositions from the speech stream. The Propositional representation also feeds back to influence the identification of the morphonolexical representation

The reciprocal loops between the propositional and implicational subsystems, and between the propositional and morphonolexical subsystems, gave this architecture a powerful combination of bottom-up and top-down processing, with local long-term memory access within each subsystem supporting multiple levels of representation, similar in some ways to Craik and Lockheart's (1972) Levels of Processing, although with the levels, or subsystems, explicitly defined *a priori*. Crucially, there is no limited working memory in this theory, merely intercommunicating autonomous subsystems. The property of limited capacity emerges as a function of the restriction that any given process can only handle one stream of information at a time (see Barnard, 1999, May, 2001 for a more detailed treatment). Limited capacity simply lies in the interaction of processes. While the model was originally developed to integrate short term memory and language understanding (Barnard, 1985), it was subsequently extending to deal with emotion and thinking (Teasdale & Barnard, 1993). In this extension, it was suggested that the affective nature of the implicational schemata made it likely that a pathway might exist from the sensory subsystems directly to the highest level of representation, and that auditory and visual cues in the world (such as facial expressions and tone of voice) could trigger affective reactions and lead to a downward cascade of inference, directing action immediately from the sensation, without requiring the structural and propositional levels to have yet interpreted the sensation. Thus, the pace, timbre, intonation of the acoustic representation of speech could be used as a source of implicational representations about the general meaning of the speech, even if the speech were in a foreign language, or otherwise degraded to prevent conventional propositional analysis.

This allowed the model to deal with a much wider range of inferential situations, albeit in a coarse and global manner, from Cherry's Cocktail Party effect (Cherry, 1953) to connotative associations of shape and sound (Davis, 1961). It also allows a System 1 mode of reasoning – the affective influence of speech upon interpretation – to be envisaged within an architecture originally specified to account for tasks not unlike those characteristic of System 2 thought.

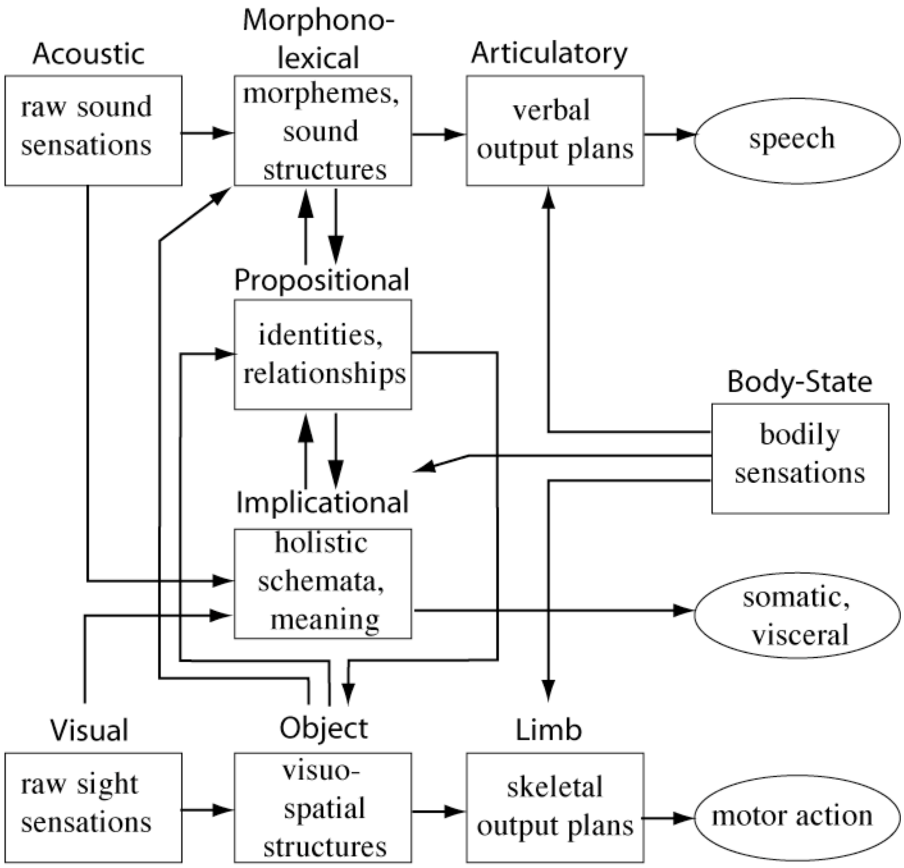

Figure 2: The complete Interacting Cognitive Subsystems architecture, including the visuo-spatial pathway (Visual and Object), cognitive-emotional loop (Implicational and Body State), and effector representations (Limb and Articulatory subsystems). Representational subsystems are shown in rectangles; transformation processes are shown by arrows; ellipses show behavioural or bodily output.

The complete ICS is shown in Figure 2. Although, it makes no formal distinction between System 1 and System 2 ***mechanisms***, there is a quite straightforward conceptual mapping. The connotative qualities of the visual representation provide what amounts to a "System 1 pathway" directly to the implicational level. The implicational level also receives information from a third collection of sensory inputs, representing the body-state, and the generic schemata activated within the implicational subsystem drive somatic and visceral changes in the body. These can be detected as body-state representations, providing a feedback loop for cognitive-emotional effects through the body. Action in the world is accomplished through the limb motor output subsystem, driven by visuospatial representations in the object subsystem. Both the articulatory and object subsystems receive proprioceptive feedback from the body-state level.

Information can arrive at the implicational subsystem in this model by longer (and therefore slower) routes. To deal with reading, for example, the architecture includes a visual pathway to the morphonolexical subsystem. This cannot be done directly from the raw visual input, since word forms vary considerably in size and typeface: an object level of representation is needed to build abstract visuospatial structures. These visual and object subsystems provide an analytic visuospatial pathway to the propositional level akin to the acoustic and morphonolexical pathway; but the object level can also support reading of written word forms through the output of morphonolexical representations. The propositional meaning of word forms is not obtained directly from seeing them, but through the object subsystem producing a sound-based image of them for the morphonolexical subsystem to parse. These longer processing routes can be thought of as serial and therefore slow, having some of the qualities assigned to System 2 mechanisms.

The two key differences between this architecture and other models of cognitive function lie in the inclusion of the direct pathways from sensation to the highest level of schematic meaning, and the feedback loop between the implicational schemata and their effects in the body. This made the model of interest to clinical psychologists who were trying to model the thought of individuals whose affective states were at variance with what they rationally knew to be the facts about their lives, in particular the clinically depressed and anxious. Teasdale & Barnard (1993) built upon the affective interactions of bodily states and implicational schemata to explain the development and maintenance of depressive modes of thought, and to suggest ways in which cognitive therapy could be focused upon changing clients' implicational models, rather than dealing with the propositional content of their thoughts. Clinical psychology remains the domain in which the model has received most interest, with applications in anxiety, insomnia, intrusive thoughts (Teasdale, 1995), schizophrenia, autism, addiction (May et al, 2004), and eating disorders (Park & Barnard, 2005). However, it has also been used in more classically 'System 2' domains, such as working memory research Scott et al, 2001), causal reasoning (May, Buehner & Duke, 2001), perception (May, Barnard & Dean, 2003), attention (Barnard et al, 2004) and task analysis (May & Barnard, 2003).

Multiple routes through a single architecture.

As a single architecture encompassing both System 1 and System 2 thinking, ICS explicitly indicates how both types of thinking interact and does not require the claim that there are 'two minds' within the human brain. Barnard & Teasdale (1991) variously describe the direct route from sensory representations to implicational schemata as hot, holistic, and affective;

while the route via perceptual and propositional interpretation is cold, rational, and analytic. The direct inference of implicational patterns from sensory representations corresponds closely to Zajonc's preferenda route, while the more analytic Propositional routes correspond to the discriminanda route. A parallel can also be drawn between these two routes and the peripheral – central distinction of the Elaboration Likelihood Model (Petty & Cacioppo, 1986) that has become influential in social psychological research into decision making. This postulates that when an individual is in a negative affective state, they will be motivated to examine their circumstances and any information available to them rationally, in order to seek out and alter the cause of their negative state. When they are in a positive affective state, however, they will not be motivated to change their circumstances and so will not critically evaluate information or argumentation, and so will be susceptible to presentational biases. A notable difference is that in ICS the two pathways are not alternatives, one of which will be gone down depending upon the individual's motivation to change their circumstances, but complementary and simultaneous routes through the mind, both of which will influence each other, in well defined ways. Crucially, there are no qualitative differences in mechanisms. Nor do slow and fast components compete. Indeed, the highly concurrent architecture highlights the complementary roles of contributions from different sources as adaptive components of one mind. The wider system shown in Figure 2 has separate pathways through one system that enable humans to walk, talk, think and feel at the same time. The functioning of the architecture is not unconstrained. Any one process in a given subsystem can only process one stream of information at a time and cannot enter into two configurations simultaneously and from this restriction capacity limitations arise (Barnard, 1999, Barnard & Bowman, 2003).

Within the reasoning and working memory literature, ICS has been proposed as a principled and well specified candidate for understanding the operation and behaviour of what has been loosely known as central executive (CE) function (May, 2001). In place of the homunculus-like system controlling attention, co-ordinating slave-subsystem processing and mediating long-term memory access, ICS places reciprocal interactions between the Propositional and Implicational subsystems, with successive abstraction generic schematic models and elaboration of specific plans providing a contextual, top-down influence on the other subsystems. Scott, Barnard & May (2001) used four variants of a classic CE task, random number generation, to show that subtle propositional cues in the way the task was described to participants had systematic and dramatic effects upon their responses, explained in terms of the schematic models of number activated to generate responses to the task demands. When asked please give me a number between one million and ten million, numbers with characteristic properties were generated. Although differing in range by only one, when asked please give me a number between one million and nine million, nine hundred and ninety nine thousand nine hundred and ninety nine, the responses were numbers belonging to a set with other properties.

As in the working memory literature, the potential value of highly concurrent architectures, such as ICS, to the debate on System 1 and System 2 modes of reasoning lies in their detailed specification. The communication between each level of representation is defined, as is the activity within subsystems, and even activity within components of subsystems. The principles of operation of each subsystem are the same, so what is learnt about one level of processing can help us understand other levels, and to understand thought as a whole (see Figure 3). Distinctions between the very short term processing activity (milliseconds), the medium term interleaving of phases of activity (seconds), and the longer term development of knowledge (minutes to years) can be handled within the same conceptual framework.

The ICS architecture has also makes direct claims about the relationships between mental processing activity and the nature of diffuse consciousness and the unitary nature of focal consciousness (May, 2004; Teasdale & Barnard, 1993). Images are constructed concurrently at multiple levels and this is what corresponds to our diffuse awareness of information encoded in different codes (e.g. visual, propositional, body states etc.). Processes in each subsystem can handle information arriving in one of two modes – directly mapping inputs to outputs or by reconfiguring to access information in the image record (Figure 3). When information in the image is operating in buffered mode that information equates with the content of focal awareness, and only one of the nine images can be in buffered mode at any given time. So, for example, while we can attend to sounds, body states propositions or implicational senses of generic meanings and so on, we can only look at one of these domains of mental life at a time. In reasoning tasks buffering will typically oscillate among levels, and within this dynamic fast responses based on feelings, intuitions or abstract senses (System 1) will reflect a predominance of buffering at the implicational subsystem with those slower, more measured responses involving carefully evaluating the content of specific propositions, will reflect a predominance of buffering propositions and their verbal products (System 2).

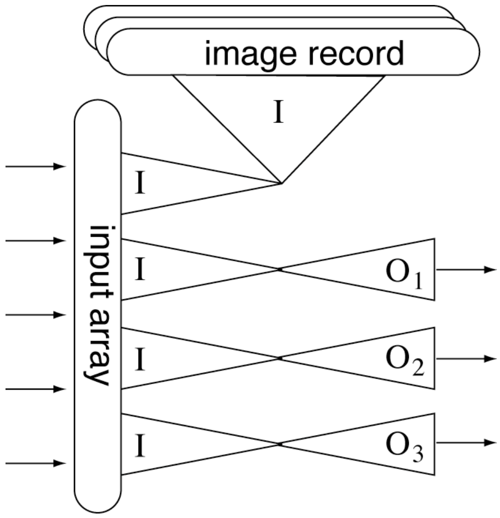

Figure 3: Each of the nine subsystems is autonomous, but functions in the same way. Representations arrive at the Input Array, and are copied (without transformation) into a long-term Image Record. This gives rise to peripheral awareness of the representation. Transformation processes ($I\text{-}O_n$) use procedural knowledge to turn information represented in the Input Array directly into output representations usable by other subsystems. One process at a time can operate indirectly upon representations revived from the Image Record by the activity of the Copy process. When the revived representation corresponds to the most recently arrived information, the process is operating in 'buffered mode', bringing the content of the input representation to focal awareness.

An essential component of the argument about what is and isn't "posted in conscious awareness," is that images are automatically constructed, but only optionally used to augment current processing activity. One crucial aspect of a concurrent system is that all processes remain active allowing the generation of thought content to continue in a context where inputs are still being dealt with and outputs generated. The systemic view allows meaning to be processed in different modes and alternative modes of thinking have been directly related to what may determine entry into and recovery from some clinical states. Paradoxically perhaps, recovery from depression can be argued to rely on processing activity with System 1-like qualities while system 2-like qualities may act to perpetuate the state (Barnard, 2004; Teasdale, 1999b).

In the kind of wider view we are arguing for, the characteristics of System 2 processing rely on interactions between multiple subsystems that processes either structural descriptions of auditory verbal form (morphonolexical code), visuospatial sequences (object code), or propositional meanings. The idea that all of the subsystems have a common internal architecture can also be grounded in evolutionary arguments. All that differs between subsystems is the code in which information is represented and this suggests the possibility of an evolutionary sequence in which successive subsystems were progressively added by differentiation of coding systems. Elsewhere we have developed just such an argument (Barnard, 2005; Barnard, Duke, Byrne & Davidson, in submission). If the articulatory, object, morphonolexical, and propositional subsystems are removed from figure 2, what is left is an architecture with a single central subsystem, three sensory subsystems and a single effector subsystem for skeletal control. This would essentially be a System 1-like core, but importantly one in which interactivity among levels is strictly limited to a serial sensory input, central selection, and serial effector control. The evolutionary mechanism is based on two key assumptions (1) where there is complexity in two inter-related sources of information, the potential exists to abstract dimensions that they have in common (e.g. rotation in visual space and the attributes of skeletal control of rotation will have correlated features); (2) when such features are uncorrelated with other features in action control, the potential exists for separate computational units in an underlying network and hence a new coding space.

According to this argument our ancestors would first have added an object subsystem that interacts with the central multimodal subsystem (proto-implicational subsystem). This would have enabled two developments: the ability to re-organise elements of an action sequence purely internally via the interaction of two central subsystems – an additional layer of concurrent processing. It would also have enabled **more abstract components** related to sequencing to influence the nature of the encoding adopted in the proto-implicational subsystem. Successively, if speech articulation were then added the possibility of extracting what is in common between verbal input and output would be in place creating conditions for the emergence of a morphonolexical subsystem that works with their common underlying invariants. Crucially, once this evolved two sources of complexity over time (word sequences & object dynamics) exist from which a further level can be extracted (referentially specific propositional meaning) and once this coding space becomes statistically independent of other implicational dimensions a fully modern human architecture is reached. At no point in this sequence to the basic mechanisms change. What happens is that each development involves the abstraction of a new mental code and allows increasingly abstract relationships to be captured and it also allows **greater concurrent processing**.

The architecture we started from could only control action from low order derivates of sensation. The next could control action and concurrently augment that by a simple form of “imagining” actions in space, later developments enabled it to speak and control action concurrently. The progressive functional elaboration is argued to have reached its current peak with human thought, with the secession of the propositional subsystem from the perceptual-implicational pathway, creating the internal loops necessary for self-reflective thought, and full System 2-like rationality. A key point about this stepwise succession of functionality from a single subsystem is that at each stage the overall architecture is functional; the immediate precursor to modern humans proto lacked only a propositional subsystem. It would have had speech and the ability to re-organise verbal components, its mental architecture would have had the potential speak and walk at the same time, but it would have required its proto-implicational subsystem to control those output streams directly. Only fully modern humans would have had the capability to think about what they are doing **while they are doing it**, On this view, advanced capability arises from greater concurrency enabling re-ordering of successively higher order regularities in information content at the different levels to be co-ordinated and controlled in real time.

Multiple routes to meaning

There is an apparent paradox in arguing that the human mind has retained a quick and dirty direct line from sensation to holistic meaning which seems to be more often used than the more recently evolved analytic mode of information processing that is computationally and metabolically expensive. Why bother evolving the latter when it appears to be ignored? This is to misrepresent the relative contributions of the two modes of thought. They work in the way that they do because for the vast majority of situations outside psychology laboratories, the affective and connotative aspects of a situation are congruent with the abstract content of the visual and sound sensations, and with the state of the individual's body. The two routes to meaning in ICS would normally be working together to complement each other's operation, with the stream of information recombining at each of the four central subsystems. The direct routes provide a kick-start to the top-down contextualisation of the analytic processing, resolving potential ambiguities and filling in missing information. Incongruency between the routes is in itself informative, because when a speaker's mode of speech contrasts with the content of their speech, it suggests they are dissembling. When a context does not 'feel right', the individual is motivated to step back and re-evaluate their assumptions about a situation.

It is only when the tasks are intentionally constructed to set the information streams against one another that the apparent paradox arises. When syllogisms are denuded of real-world content, they can only be solved analytically, but the mind cannot turn off its direct processing routes, and so System 1 thought interferes with the System 2 logical interpretation of propositions. When selection tasks conform to previous experiences, and mental models are consistent with beliefs and expectations, rigorous evaluation of alternatives is cut short by a top-down implication that things are as expected. When people are asked to make judgements about stimuli or on the basis of rules or covariances that they have been exposed to implicitly and so have no explicit access to, they will be able to respond on the basis of experiential records within both the direct and analytic routes, but will not be able to accurately explain how they are making their correct-above-chance responses.

Understanding affect, rational thought, consciousness, their interactions and their evolution is not a small task. Neuropsychological correlates of cognitive operations can help us to reify postulated functions, to relate functions that are anatomically adjacent functions and to dissociate those that are anatomically distinct; but without a global sense of how the whole machinery works, successive naming of parts gives the impression of a modular set of domain specific processes in need of a co-ordinating homunculus whose existence will always be elusive. Dual process theory gives us a framework within which functions can be ascribed to modes of reasoning, but this should not be confused with neurological differentiation, let alone mental dissociation. Common processing resources can give rise to different modes of reasoning, when configured in different ways and given different operational requirements; the problem is to understand the configurations and the task requirements. Existing models of cognitive processing, including ICS, can help us to do this.

References

Barnard, P.J. (1985). Interacting Cognitive Subsystems: A psycholinguistic approach to short term memory. In A. Ellis (Ed.) *Progress in the Psychology of Language*, (Vol. 2), Chapter 6, London: Lawrence Erlbaum Associates, 197-258.

Barnard, P.J. (1999). Interacting Cognitive Subsystems: modeling working memory phenomena within a multi-processor architecture. In: A. Miyake, & P. Shah, (Eds.) Models of working memory. (pp. 298-339). Cambridge: Cambridge University Press.

Barnard, P. (2004). Bridging between basic theory and clinical practice. Behaviour Research and Therapy, 42, 977–1000.

Barnard P.J. (2005). Emotion and meaning: arguments for two levels of representation in the control and experience of ideation. Paper presented at International Society for Research on Emotion, General Meeting, Bari, Italy, 11th-15th July.

Barnard, P. J., & Teasdale, J. D. (1991). Interacting cognitive subsystems: A systemic approach to cognitive-affective interaction and change. *Cognition and Emotion, 5,* 1–39.

Barnard, P. J. & Bowman, H. (2003). Rendering Information Processing Models of Cognition and Affect Computationally Explicit: Distributed executive control and the deployment of attention. Cognitive Science Quarterly, 3, 297-328.

Barnard, P.J., May, J., Duke, D., & Duce, D. (2000). Systems, interactions and macrotheory. ACM Transactions on Human-Computer Interaction, 7(2), 222-262.

Barnard, P.J., Duke, D., Byrne, R. W. & Davidson, I. (in submission). Differentiation of emotional and non-emotional meanings: an evolutionary analysis.

Barnard P.J. , Scott S, Taylor J, May J, & Knightley W. (2004). Paying attention to meaning. *Psychological Science, 15*, 179-186.

Brewer, W. F. (1977). Memory for the pragmatic implications of sentences. Memory and Cognition, 5 673-678.

Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and two ears. *Journal of the Acoustical Society of America,* 25, 975-979.

Craik, F. I. M. & Lockhart, R. S. (1972). Levels of processing: a framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*, 671-684.

Dalgleish, T. (2004). What might not have been: an investigation of the nature of counter-factual thinking in survivors of trauma. *Psychological Medicine*, 34, 1215-1225.

Davis, R. (1961) The fitness of names to drawings. *British Journal of Psychology*, 52, 259-268.

Duncan, J. (2000). Visual attention in mind and brain. In: J.J. Bolhuis (Ed.), Brain mechanisms of perception, learning and memory: Essays for Gabriel Horn. Oxford: Oxford University Press.

Ellis, H. C., & Ashbrook, P. W. (1988). Resource allocation model of the effects of depressed mood states on memory. In J. Forgas (Ed.), *Affect, cognition, and social behaviour* (pp. 25-43). Toronto: Hogrefe.

Erickson., T.D., & Mattson, M.E. (1981). From words to meaning: a semantic illusion. Journal of Verbal Learning and Verbal Behavior, 20, 540-551.

Evans, J.St.B.T. (1998). Matching bias in conditional reasoning: do we understand it after 25 years? *Think. Reason.* 4, 45–82.

Evans, J.St.B.T. (1999). The influence of linguistic form on reasoning: the case of matching bias. Q. J. Exp. Psychol. 52, 185–216.

Evans, J. St. B. T. (2003). In two minds: dual-process accounts of reasoning. *Trends in Cognitive Sciences, 73,* 454-458.

Gathercole, S. & Baddeley, A. D. (1993). *Working memory and Language*. Hove: Lawrence Erlbaum Associates.

Gernsbacher, M. A, Goldsmith, H. H, & Robertson, R. R. W. (1992). Do readers mentally represent characters' emotional states? *Cognition and Emotion*, 6, 89-111.

Harley T. (2001). The Psychology of Language: from data to theory, Hove: Psychology Press

Harris, R. J., & Monaco, G. E. (1978). Psychology of pragmatic implication: Information processing between the lines. Journal of Experimental Psychology: General, 107, 1-22

Hobbes, T. (1651), *Leviathan* , London. ISBN 0140431950, Penguin Press, 1982.

Kieras, D. E., D. E. Meyer, et al. (1999). Insights into Working Memory from the Perspective of the EPIC Architecture for Modelling Skilled Perceptual-Motor and Cognitive Human Performance. Models of Working Memory, Mechanisms of Active Maintenance and Executive Control. A. Miyake and P. Shah. New York, Cambridge University Press**:** 183-223.

May, J. (2001). Specifying the Central Executive may require complexity. In J.Andrade (ed) *Working Memory in Perspective*. Psychology Press: Hove. pp 261-277.

May J, Bühner M.J. & Duke D (2002). Continuity and Cognition. *International Journal on Universal Access in the Information Society*. 1, 252-262.

May, J., (2004). An Information Processing View of Fringe Consciousness. *Psyche, 10(1)*. URL: http://psyche.cs.monash.edu.au/symposia/mangan/pdf/may.pdf.

May, J. & Barnard, P.J. (2003). Cognitive Task Analysis in ICS. In D. Diaper & N. Stanton (Eds) *The Handbook of Task Analysis in Human-Computer Interaction*, pp. 291-325.

May, J., Barnard, P.J. & Dean, M. (2003). Using film cutting in interface design. *Human-Computer Interaction, 18*, 325-372.

May, J., Andrade, J., Panabokke, N. & Kavanagh, D. (2004). Images of Desire: Cognitive Models of Craving. *Memory*, *12(4)*, 447-461.

Mithen, S. (2002). In The Cognitive Basis of Science (Carruthers, P. et al., eds), pp. 23–40, Cambridge University Press. Newell, A. (1990). Unified Theories of Cognition. Cambridge, Massachusetts: Harvard University Press.

Nolen-Hoeksema, S. (1991). Responses to depression and their effects on the duration of depressive episodes. Journal of Abnormal Psychology,100, 569-582

Park R. J. & Barnard, P.J. (2005). A process account of Anorexia Nervosa. Poster presented at *Eating Disorders Research Society Annual Meeting*, Fairmont Royal York, Toronto, Canada, 29th September - 1st October.

Petty, R. and Cacioppo, J.T. (1986). The Elaboration likelihood model of persuasion. In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology, 19*, 123–205.

Scott, S. Barnard, P.J. & May, J. (2001). Specifying executive function in random generation tasks. *Quarterly Journal of Experimental Psychology, 54A*, 641-664.

Stanovich, K.E. & West, R.F. (2000). Individual differences in reasoning: Implications for the rationality debate. *Behavioural and Brain Sciences*. *23*, 645 – 726.

Teasdale, J.D. (1999a). Multi-level theories of cognition and emotion. In: T. Dalgleish and M.J. Power (eds), The Handbook of Cognition and Emotion, Chichester: John Wiley & Sons.

Teasdale, J.D. (1999b). Emotional processing, three modes of mind, and the prevention of relapse in depression. Behaviour Research and Therapy, 37, S53-S77.

Teasdale, J.D. and Barnard, P.J. (1993). Affect, Cognition and Change: Re-modelling Depressive Thought. Hove: Lawrence Erlbaum Associates. .

Teasdale, J. D., Dritschel, B. H., Taylor, M. J., Proctor, L., Lloyd, C. A., Nimmo-Smith, I. & Baddeley, A. D. (1995). Stimulus-Independent Thought Depends on Central Executive Resources. *Memory & Cognition, 23*, 551-559.

Tversky A. & Kahneman, D. (1974). Judgement under uncertainty: heuristics and biases. *Science, 125,* 1124-1131.

Watkins, E., & Baracaia, S. (2002). Rumination and social problem-solving in depression. Behaviour Research and Therapy, 40, 1179-1189.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35,* 151–175.