A consideration of decision-making, motivation and emotions within Dual Process theory: supporting evidence from Somatic-Marker theory and simulations of the Iowa Gambling task.

Kiran Kalidindi*
*Centre for Cognitive Neuroscience and Cognitive Systems Computing Lab, Univ. of Kent Canterbury, Kent, UK. CT2 7TR
kk49@kent.ac.uk

Howard Bowman*†
† H.Bowman@kent.ac.uk

Brad Wyble*‡
‡ B.Wyble@kent.ac.uk

Abstract

For many years there have been lay people, philosophers and scientists who have made the distinction between affect and 'cold' cognition. This paper examines the potential value of this dichotomy in relation to understanding ventromedial lesion (VMF) patients behaviour in general and on the Iowa Gambling Task (IGT). We use a combination of dual-process and somatic-marker theories and inferences based on simulations of normal controls and VMF patients on the IGT.

1 Introduction

Two closely related dichotomies. In recent years some researchers in the field of thinking and reasoning have been proposing dual-process accounts for the 'non-rational' results of human performance on normative logical tasks. The main evidence comes from deductive reasoning paradigms, particularly the Wason selection task, both abstract and deontic versions, the belief bias found in syllogistic reasoning (Sloman, 1996) and neuropsychological data (Goel and Dolan, 2003). These dual-processes are said to emanate from two quite separate cognitive systems that have distinct evolutionary histories. "System 1 is old in evolutionary terms and shared with other animals: it comprises a set of autonomous subsystems that include both innate input modules and domain-specific knowledge acquired by a domain-general learning mechanism. System 2 is evolutionarily recent and distinctively human: it permits abstract reasoning and hypothetical thinking, but is constrained by working memory capacity and correlated with measures of general intelligence." (Evans, 2003). This dual-process split is similar to another often mentioned dichotomy of affect and 'cold' cognition, where traditionally, motivation and emotions are considered to be part of affect.

Such dichotomies have long been a staple for philosophers and psychologists alike, stemming from Plato and Aristotle to James (1890) and to current work in journals like Cognition and Emotion. By placing affect and 'cold' cognition within the context a seemingly similar theory, like dual-process theory, it becomes possible to further constrain our models and move towards an elucidation of what emotions are, how emotions might help in reasoning by seeing when they occur and what causal effect they may have. These are particularly important issues since currently we have no clear accepted definition of what phenomena emotions include (Evans, 2002; Sloman, 2004).

Bringing the two dichotomies together. These two dichotomies seemingly represent the same functional split, but are not currently considered together within the literature. A key question concerning the systems in these dichotomies is how each system interacts with one another. Do they have different memory systems? What might be the method of internal communication between them? Can they interact individually with the external world? Does one system become more dominant than the other in certain types of situation and/or context? A useful starting point in such research can be to look at a theory that seems to represent the affect/'cold' cognition dichotomy and see what happens when the systems become somewhat disconnected, i.e. when they work with limited support from the other type of processing. We will argue that such a separation arises in VMF patients.

2 Somatic-Marker Theory and the Iowa Gambling Task

One theory we can examine is the idea of somatic-markers. It proposes that body states act as a valence that can be associated with potential choices based on prior outcomes, and thus aid decision-making, both by limiting the search space and allowing an affective evaluation of choices. The main supporting evidence for this theory arose from clinical interviews of subjects with ventromedial prefrontal cortex (VMF) lesions and their performance on the Iowa Gambling Task (IGT) (Bechara et al., 1999), compared to normal controls and those with lesions in other brain areas. The gambling task consists of four decks that subjects can pick from; two decks, A and B, which yield high wins but higher losses (Disadvantageous) and the other two, C and D, that yield low wins with lower losses (Advantageous). Normal subjects start by picking from the disadvantageous decks but learn to pick from the advantageous decks, unlike the VMF patients who, as in their real social and personal lives, continue to pick non-advantageously.

Going back to the potential dichotomy of affect and 'cold' cognition, it has been suggested by Damasio (1994) that patients with VMF lesions are no longer able to automatically produce somatic-markers when making social decisions. Unlike laboratory experiments, such decisions often have large numbers of choices and unlimited consequences. Some somatic-markers can be considered synonymously with 'feelings' as the conscious component of emotions. VMF patients possess most of their 'cold' cognitive faculties, as shown by normal verbal test, tower of hanoi and IQ scores, but seem to have blunted emotions when describing situations, even when they are intimately involved. Parts of the affect system are still intact in VMF patients, as they can be classically conditioned and they get SCR responses when they are rewarded and punished in the IGT (Bechara et al., 1999). This could suggest that the VMF region is where social event knowledge is held (Wood et al., 2003), and is an important link between the 'cold' cognitive system (explicit memory) and the affect (emotional memory) system. Alternatively, is it just an important part of a single overall system? There are often many interpretations to data concerning the brain, mind and behaviour. However, one way forward is to propose hypotheses and then see how they stand-up to current experimental results and to new direct hypotheses tests, i.e. following the Popperian view of scientific discovery (Popper, 1959).

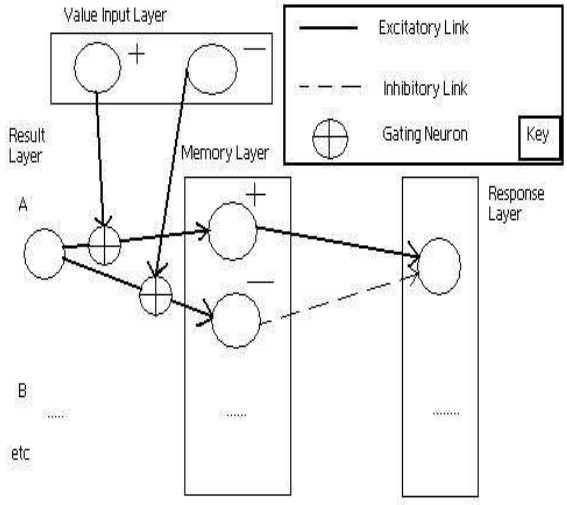

Figure 1: **Diagram of Neural Network used for the Iowa Gambling Task. It shows the repetition of the basic architecture for each choice in the problem space.**

3 Neural Network Model of the IGT

A dual system account for VMF behaviour arose from the current literature and neural network simulations examining the different behaviours of normal controls and VMF patients on the Iowa Gambling Task (IGT), at a level of abstraction above and, in this case, inclusive of both the 'cold' cognitive and affect systems (Kalidindi et al., 2005). An explanation that accounts for the difference in behaviour between normal controls and VMF patients on the IGT is 'myopia' for future consequences, in that they are driven by immediate reward and are less interested in uncertain future loss or gain (Bechara et al., 2000b). This simulation investigates the implications of this 'myopia'. The current literature lacks a model that both accurately reproduces these experimental results, and is abstracted from specific anatomical details, which underlie other models (Wagar and Thagard, 2004). A diagram of the neural network can be found in Figure 1. It shows the Memory Layer where the affinity for each choice in the choice space is represented by a positive and negative pair of units.

The simulation begins by using a random number generator to pick one of the four decks, this choice/result is represented by an activation value of 1 in the relevant Result Layer unit. Then a card is picked from the chosen deck and the result is fed into the Value Input Layer, where the positive neu-

ron is activated by money won and the negative unit by money lost. The activation is simply the amount divided by $2000 (the amount of money the player starts with) or the largest card result seen so far, if that is larger. Through gating neurons (McClelland and Rumelhart, 1986) this activation is passed onto the relevant Memory Layer pair (See Figure 1) by multiplying the activation in the Result Layer units with that from the Value Input Layer; as only one Result Layer unit is active, only the units associated with that choice will recieve new activation. Next, the Response Layer units will recieve excitatory input from the linked positive Memory Layer unit and inhibitory input from the linked negative unit. Then a normally distributed random activation is added to each Response Layer unit to encourage exploration. This is followed by a winner-takes-all competition, where the winning unit in the Response Layer becomes the deck choice for the next trial, by activating the relevant Result Layer unit and returning its' own actiation to zero. This process continues through the trials of the task, with a build-up of knowledge about each deck being held in the Memory Layer units. (Note, all the units, except those in the Memory Layer and the active unit in the Result Layer (representing the next choice), are set to zero after each trial.)

To explore the difference between normal controls and VMF patients, a time-averaging equation (See Figure 2) was used to describe the decay of information, and how new and old information influences Memory Layer units. This relationship between old and new information can be altered by changing the parameter τ, which is a real number between 0-1. Thus, if τ is close to 1 then previous activation (i.e. information) is almost completely preserved while current activation (i.e. information) has little impact on the representation of the valence of a choice. It is felt that VMF patients might be less able to integrate past information into current decision-making than normals. We suggest that this might be the cause of VMF patients' 'myopia' for future consequences. An exploration of the state space of τ was performed to confirm which values of τ best matched the normal control and VMF patient behaviour on the IGT.

The results showed that a constant value for τ, across cycles, equal to 0.52, gave the closest deck choice profile to that of the VMF patients (a 2% difference between the simulated and the human data across the 5 data points, that occur every 20 selected cards, (Bechara et al., 2000b)), whereas increasing τ over trials was required to reproduce the normal controls deck choice profile. Various increasing functions over cycles gave almost exact replicas of the

$$act(t) = \tau \cdot act(t-1) + (1-\tau) \cdot y_\beta$$

Figure 2: **Time-Averaging Equation - act(t) is the activation in the unit at time t, τ is the time-averaging parameter and y_β is the gated input from the Value Input Layer.**

normal human subjects profiles (a 6% difference between simulated and real data). Therefore, it seemed that an increase over trials was the key point. Overall, this could suggest that VMF patients always treat any new trial information as they would treat the first trial in the task, suggestive of their inability to progress from disadvantageous decks to advantageous decks in the IGT. However, in normal subjects, as experience over trials increases, less value is put on current-input (information/activation) and more value is placed on holding onto past experience. The next question for investigation could be what are the underlying causes of this?

4 Conclusions

Implications of the model. Our modelling work suggests that (normal) humans have an effective mechanism by which the weighting applied to past vs present information changes during an "exploration" task, such as the IGT. Furthermore, it may in fact be the case that such strategic adjustments are central to optimum decision-making, especially decision-making in non-initial phases of such "exploration" tasks. The results further suggest that VMF patients have lost this capacity to strategically adjust this past vs present weighting as an "exploration task" proceeds. Our finding here is largely consistent with the 'myopia' for future consequences theory of VMF patient behaviour (Bechara et al., 2000a).

It is well accepted that the ventromedial prefrontal region is implicated with emotion and body-state influences on decision-making. Somatic-markers are one theory of such affective influences on decision-making. If we accept the somatic-marker theory, our modelling results suggest that somatic-markers play a particularly significant role in encoding, maintaining and utilising (in future decisions) past information and further, that such somatically-driven memory and retrieval is particularly important in post initial stages of an "exploration task". Indeed, such mechanisms may become progressively more important through-

out the time course of such a task. Such strategic adjustment of past vs. present weighting during exploration also has relevance for the construction of artificial agents, especially those that seek to take inspiration from somatic-marker theories of human decision making.

General Implications and Proposals. More generally and speculatively, it could be proposed that dual process theory's System 1 and the affect system can be considered as largely synonymous. We propose that the goals, and therefore System 1 alone, are motivated by fairly basic needs, such as quenching thirst, satiety of hunger, obtaining what is envied and sexual encounters. This is in-line with the proposal that System 1 is shared most closely with animals.

If we suggest that a main cause of VMF behaviour is due to a weakening of the connection between System 1 and System 2 and that System 1 normally has greater influence during social and personal situations, then, as System 2 has even less influence over System 1 in VMFs than in normal subjects, we would expect VMF patients to become almost whimsical in social, personal or uncertain situations, and that System 2 responses might even be ignored. This lack of influence by System 2 is shown in the IGT when, normals (70%) and some VMF patients (50%) gain conceptual (conscious) knowledge (Bechara et al., 2000a), by around the eightieth cycle/card, of which decks are advantageous. But unlike normal controls the VMF patients fail to use this knowledge and do not improve their deck choices/strategy. A further cause for VMF behaviour is, during the build-up of knowledge about the IGT, normal subjects develop representations or access to representations of explicit events and their associated affect content through the VMF. This claim is supported by the VMF's known reciprocal connections with the amygdala (important in affect) memory and the hippocampus (important in episodic memory). VMF patients do not gain a build-up of this knowledge and therefore, have a constant τ. Our simulations would also suggest that VMF regions in normals reduce the impact of new information about a situation as the associated information/experience increases. This combination of explicit (System 2) and affect (System 1) memory is used to 'hypothesis' test against the expected outcomes of a choice. Access to this combination of System 1 and System 2 information can be considered equivalent to the effective use of somatic-markers. Therefore, the VMF regions provide a representation link between System 1 and System 2, allowing for an 'affect' assessment of the combination of potential reward and punishment outcomes for an explicit choice, without the need for explicit rules.

References

A. Bechara, A.R. Damasio, H. Damasio, and G.P. Lee. Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. *The Journal of Neuroscience*, 19(13):5473–5481, 1999.

A. Bechara, Damasio H., and Damasio A.R. Emotion, decision making and the orbitiofrontal cortex. *Cerebral Cortex*, (10):295–307, 2000a.

A. Bechara, D. Tranel, and H. Damasio. Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain*, (123):2189–2202, 2000b.

A.R. Damasio. *Descartes Error: Emotion, Reason and the Human Brain*. New York: Grosset/Putnam, 1994.

D. Evans. The search hypothesis of emotion. *British Journal of Philisophical Science*, (53):497–509, 2002.

J.St.B.T. Evans. In two-minds: dual-process accounts of reasoning. *Trends in Cog Sci*, 7(10):454–459, 2003.

V. Goel and R.J. Dolan. Explaining modulation of reasoning by belief. *Cognition*, (87):B11–B22, 2003.

W James. *The principles of psychology*. New York: Dover, 1890.

K. Kalidindi, Bowman H., and Wyble B. An investigation of the myopia for future consequences theory of vmf patient behaviour on the iowa gambling task; an abstract neural network simulation. In *Proceedings of the Neural Computation and Psychology Workshop 9*, 2005.

J.L. McClelland and D.E. Rumelhart. *Parallel Distributed Processing: Explorations in the Microstructure of Cognition: Foundations*. MIT Press, 1986.

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

A. Sloman. What are emotion theories about? Invited talk at AAAI Spring Symposium, March 2004. See - http://www.cs.bham.ac.uk/research/cogaff/sloman-aaai04-emotions.pdf.

S.A. Sloman. The empirical case for two systems of reasoning. *Psychological Bulletin*, 19(1):3–22, 1996.

B. Wagar and P. Thagard. Spiking phineas gage: A neurocomputational theory of cognitive-affective integration in decision making. *Psychological Review*, (111):67–79, 2004.

J.N. Wood, S.G. Romero, M. Makale, and J. Grafman. Category-specific representations of social and nonsocial knowledge in the human prefrontal cortex. *Journal of Cognitive Neuroscience*, 15(67), 2003.