Human Behaviour Modelled as a Statistico-Deterministic Turing Machine.

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Abstract: 'Free will' and its corollary, the concept of individual responsibility are keystones of the justice system. This paper shows that if we accept a physics that disallows time reversal, the concept of 'free will' is undermined by an integrated understanding of the influence of genetics and environment on human behavioural responses. Analysis is undertaken by modelling life as a novel statistico-deterministic version of a Turing machine, i.e. as a series of transitions between states at successive instants of time. Using this model it is proven by induction that the entire course of life is independent of the action of free will. Although determined by prior state, the probability of transitions between states in response to a standard environmental stimulus is not equal to 1 and the transitions may differ quantitatively at the molecular level and qualitatively at the level of the whole organism. Transitions between states correspond to *behaviour*s. It is shown that the behaviour of identical twins (or clones), although determined, would be incompletely predictable and non-identical, creating an illusion of the operation of 'free will'. 'Free will' is a convenient construct for current judicial systems and social control because it allows rationalization of punishment for those whose behaviour falls outside socially defined norms. Indeed, it is conceivable that maintenance of ideas of free will has co-evolved with community morality to reinforce its operation. If the concept is free will is to be maintained it would require revision of our current physical theories.

Key-Words: - Turing machine, behaviour, determinism, free will, nerve synapse, criminal justice

1 Introduction

“All religions, nearly all philosophies, and even a part of science testify to the unwearying, heroic effort of mankind desperately denying its contingency” Jacques Monod.

Behavioural determinism has profound implications for social organization and the judicial system. It impinges on the concepts of individual responsibility, morality and guilt. The debate on determinism versus 'free will' has its origin in the age old debate on the existence of original sin. In the 20th century the question of behavioural determinism was debated extensively, particularly since the 1950s, with Turing notable for bringing a far sighted approach to his discourses on machine intelligence [1]. It was also raised by the work of ethologists (for example, Lorenz [2], Hinde [3], Wilson [4] and Tinbergen [5]) that provided extensive evidence for the evolutionary connection between animal and human behaviour and the heritability of behaviour. In these works behaviour is regarded as just another (albeit complex) selectable phenotype. The early work of Huxley [6] advocated de-coupling the origins of morality from biology and this view seems subsequently to have permeated the related debate on the existence of free will. More recent analyses favour the view that more than a mere capacity for thinking is genetically predetermined or at least has a genetic component (for example, Flack & Waal, [7]), but these have been criticized [8] on the basis that they take inadequate account of capacities for guilt and the apparent human ability to suppress or veto actions (i.e. by implication an ability to exercise free will). The latter author used this to argue for a fundamental discontinuity between primate and human behaviour. Geneticists and other s have discussed energetically these ideas since the 1940s.

Although many behaviours develop with the maturing nervous system and are apparently unconnected with experience, perhaps the most important general insight of recent years from behavioural research in animals has been the recognition that life experience can shape brain chemistry in significant ways, and that experience and neurophysiology form webs of feedback loops. Gene expression itself is profoundly influenced by experience (Van Erp and Miczek, [9]). This profound influence of experience does not diminish the strength of the case for behavioural determinism, for reasons that will be outlined below.

In the present work a 'state machine' that is a variant of a Turing machine [10] is introduced. This state machine is neither deterministic or non-deterministic, but is *statistico-deterministic*. The model draws on some basic statistical concepts of neurophysiology [11] , but in fact the only assumption needed, regarding the physics of the system, is that time reversal is not permitted. This is used to model the journey through life and to support the arguments proferred by other recent authors [12,13] that violations (or transcendance) of known physical laws must occur to allow mental influence on neural events. This necessitates either a modification of physical laws or an abandonment of the concept of free will.

2 The Problem of 'Free Will'

2.1 Theory, axiom and evidence.

It is surprising that the existence of 'free will' is often accepted as *axiomatic*, whereas behavioural determinism is relegated to the status of a *theory*. This position is a paradox because there is a wealth of evidence (ibid.) for at least a degree of influence by genes on behaviour (the magnitude of influence will of course vary for different behaviours). In fact it is reasonable to suggest that the contrary position should be the starting point for discussion, i.e. the determinist view recognized as having some empirical basis whereas 'free will' is an unsupported theory.

Biology teaches (based on experimental evidence) that genes, in the context of environment, control the structure and function of the body. In humans and other animals with a nervous system, some of the genetically controlled structures (e.g. muscles) perform behaviours under the direction of electro-chemical signals carried by the nervous system (which includes the brain). The brain is no different to other organized structures of the body in that its development and construction is controlled by genes expressed in a programmed sequence in the context of environment. Given that behaviour is controlled by the brain, and given that the structure of the brain is controlled by the genes, the inescapable conclusion is that behaviour is influenced by the genes. That influence is manifest in pathological states with gross behavioural signs (e.g. Alzheimer's disease, Huntingdon's disease, Down's syndrome, Fragile-X syndrome). It would be illogical to suggest that no genetic influence is present in less extreme behavioural anomalies or indeed to suggest that genes are not involved in modulating behaviour in non-pathological states.

2.3 Genetics and legal defence

Genetic determinism has not been used successfully as a defence in a legal case (Australian Law Reform Commission, [14]). There is good reason to suggest that this situation may change as our understanding increases, in the not too distant future. Other circumstances beyond the control of the accused person are commonly used in defence. For example, environmental circumstances are used (deprived childhood, abuse as a child, continuing abuse by a spouse). People affected by mental illness are often acquitted and not held to be responsible for their actions. In so far as mental illness is a disease with a contributory genetic component, then it is arguable that acquittal on the basis of genetic determinism has already happened. In view of this, it would be inconsistent to require proof of complete (or 'absolute') genetic determination of behaviour to allow the use of genetics as a defence. It should be sufficient to demonstrate that the genes had some influence on the behaviour and that the influence was a significant factor contributing to the aberrant behaviour. Environmental factors would obviously contribute the residual influence on behaviour and these could also be used as a defence or mitigation.

2.4 Genetic and environmental components determine behaviour.

It is commonly argued that behavioural determinism is invalidated by the fact that behaviour is influenced by both genetic and environmental factors. Indeed, this destroys the case for absolute genetic determinism, but when subjected to analysis it fails to destroy the case for behavioural determinism. Neither does it support the concept of 'free will'. This analysis will be elaborated in the next section.

3 Behaviour Modelled as a Novel Variant Turing Machine

It is taken as axiomatic that the only possible influences on an individual's behaviour are the genes and the environment. The influences on behaviour can come from nowhere else- *unless* we accept supernatural controls that come from outside corporeal structure and our spacial and temporal experience. The salient question then becomes "Can an individual exercise independent or 'free' control of either of these two controlling factors throughout life?" That is, can the individual exhibit 'free will'?

A newborn human has no control over its inherited genetic complement and is born into a place and time (environment) beyond its control. It is a fact that the individual has no control and can exercise no 'free will' over the initial conditions of its journey through life. Can a human exercise free will subsequently?

If we call the initial state of a newborn human individual 'State 1' and its state *in the next instant of time* 'State 2' we can consider this question. A 'state' consists of all the physical and mental attributes of a human at one instant in time. The transition from State 1 to State 2 is what we commonly call the exhibition of behaviour (refer to Fig. 1).

In Fig. 1 a 'State 0' is shown. It represents the condition of the baby in the womb. 'State 1' is entirely dependent on the genetic make-up of the individual and his/her intrauterine history. In the transition from State 0 to State 1 physiological responses to environmental stimuli are possible, but it is reasonable to suggest that opportunity for the exercise of free will (if it exists) would be limited.

We will consider in detail the transition from State 1 to State 2 in more detail, because in this transition there is the possibility of the intervention of 'free will' at the point of response to environmental stimulus (marked with an asterisk in Fig. 1). State 1 of the individual has been determined by the genetic make-up of the individual and the intrauterine environment. The response to 'stimulus 1' will be completely conditioned by that State at the instant in time of the stimulus. Thus, it follows that State 2 is completely determined by State 1 and the intervening response 1. If 'free will' were to intervene it would have to do so from sources independent of the instantaneous physical attributes of state 1 (i.e. sources of super-natural origin).

If we now consider the transition from State 2 to State 3 we can reiterate the same arguments (see Fig. 2).

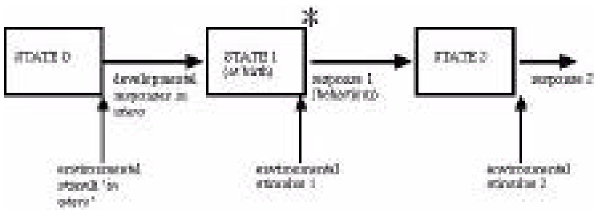

Fig 1. *Life as a series of transitions between states. States 1 and 2 (and each succeeding State) take place in succeeding instants of time.*

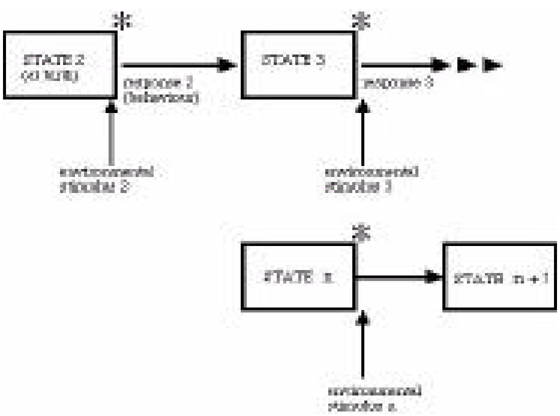

Fig 2. *Generalization of the transition model to any number of States.*

3.1 Proof by Induction of the Non-existence of 'Free Will'

It has been shown in the previous paragraphs, that State 2 is determined by State 1 and response 1. The response to environmental stimulus 2 will be determined by the characteristics of State 2 at the instant in time when the stimulus takes place. The same argument can be reiterated indefinitely (or at least until the death of the individual -the achievement of a perpetually unresponsive state) for a transition from any State 'n' to its successor State 'n + 1'. Thus we have a proof by induction that the journey through life, as a series of responses to environmental stimuli, is completely determined. This does not mean that the journey is *predictable*, as I will discuss in the next section.

In summary, the ability of a human to exhibit behaviour and modify its environment is a function of its current state.
The current state is in turn a function of inherited genetic complement and its prior interaction with the environment. To suggest that 'free will' exists is to suggest that behaviour comes neither from genes nor environment, nor an interplay of these. In other words it requires the violation of physical laws.

3.2 Determination does not imply predictability. A 'thought experiment' using human clones.

Ridley [15] urges us not to mistake determinism for *inevitability*. However, in view of the reasoning outlined in the previous paragraphs, which shows that behaviour is necessarily a function of the prior state, inevitability is inevitable. It is more relevant to urge people not to mistake determinism for *predictability*. Conversely we should not be led into the trap of mistaking unpredictability for the operation of 'free will'.

In addressing the question of the relation between determinism and predictability we should ask whether (in Fig. 1) any responses other than 'response' 1 were possible. To answer the question we should conduct a thought experiment.

Consider two hypothetical genetically identical individuals (e.g. identical twins or clones) who have had an identical intra-uterine environment and who have arrived at identical States '1'. (In practice this is impossible because the intrauterine environment is never identical for both foetuses, because the position in the uterus will be different for each foetus and the umbilical circulations may be different-but for the sake of argument we will consider the ideal scenario). If the two individuals are then subjected to an identical environmental stimulus would they necessarily exhibit the same behaviour? In a more general framing, is more than one response possible from identical States '1' (see Fig. 3)?

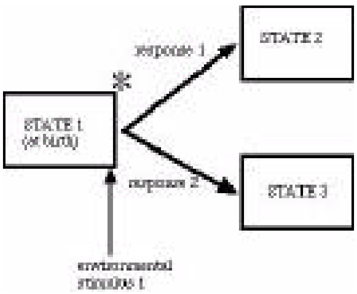

Fig 3.. *Alternative transitions from a prior state.*

To answer this question we must consider the physiology and physical chemistry of biological responses to environmental stimuli. When a human is exposed to an environmental stimulus (e.g. light, heat, sound) the nervous system generates an electro-chemical impulse. The physiological responses to this impulse are dependent on statistico-chemical events (as noted by Schrodinger [16]). These are statistico-chemical events involve threshold effects at nerve synapses or at neuro-muscular junctions. Let us consider a single neuro-muscular junction (Fig.4).

In this system the threshold requirement for a muscle contraction response is the binding of a minimum number 'n' of neurotransmitter molecules. Fig. 4b depicts the situation where 'n' neurotransmitters have bound to receptors on the muscle and a muscle contraction results. By contrast, in Fig. 4c, an identical electrochemical impulse reaches the nerve ending, but there is a statistical variation in the number of neurotransmitters released for the nerve ending. This in turn results in the binding of fewer neurotransmitters to cognate receptors on the muscle. This lesser number ('n-x') is less than the required threshold and no muscle contraction response takes place. In general, the random fluctuation either side of 'n' in physico-chemical systems will be approximately √n (Schrödinger [16]). More precisely, for neuromuscular junctions the release of packets (or 'quanta') of neurotransmitters is described by the Poisson distribution, which predicts a finite number (n_0) of failures of neurotransmitter release in response to a standard size electrochemical impulse along the nerve [11]. For N observed responses with n_o failures, where 'm' is the average number of neurotransmitter quanta per response (equation (1)):

$$\frac{n_0}{N} = e^{-m} \quad (1)$$

In many biological systems, the responsiveness of cells to molecular stimuli is also conditioned by prior exposure to stimuli, chance fluctuations in those prior stimuli and the time elapsed between stimuli. These variables will influence the end response in a complex fashion (Gurevich and Barnard, [17]). In other biological response systems a threshold effect is not observed, but over a finite concentration range the response to signalling molecules (e.g. hormones - which can have dramatic effects on behaviour) is continuous. Even in the latter cases the magnitude of the end response will be sensitive to chance variations in the number of signalling molecules and the prior stimuli to which the system has been exposed [17].

All biological responses (i.e. behaviours) involve release and binding of signalling molecules (including neurotransmitters and hormones). They are therefore all subject to the statistical variations inherent in any chemical system. At the level of the whole person, the end response to an environmental stimulus is the result of the integration of many thousands of such threshold or dose-dependent events and is inherently unpredictable. This is in contrast to large scale mechanical systems with which most people are more familiar.

If we return to the neuromuscular junction model in a situation where the nerve has received an environmental stimulus that produces an electro-chemical impulse. The electro-chemical impulse in turn results in the release of a number of neurotransmitters close to the threshold number required to produce a muscular response. From the foregoing exposition on the statistical nature of chemical signalling it is clear that on one occasion the stimulus may produce a response, while on another occasion, from the same initial conditions, it will not (or in a non-threshold system it may produce a response of different magnitude).

By extension, if we take two genetically identical individuals with the same environmental history such that they are in an identical 'State 1' (see Fig. 3) and expose them simultaneously to the same environmental stimulus, it is by no means certain that they will exhibit the same response.

Unpredictability is inherent in statistico-chemical events. Despite the fact that behaviours are determined by genes and environmental stimuli, they are not completely predictable.

It is easy to see how this inherent unpredictability and the complex interaction between genotype and environment from birth to death can create the illusion of the operation of 'free will'. At the level of populations the illusion is reinforced by the fact that Mendelian (sexually reproducing) populations are exceedingly heterogeneous aggregates of largely heterogeneous genotypes (Lerner, [18]).

3.3 Other physical bases for unpredictability in biological responses.

Schrödinger [16], in his classic work on the physical basis of life, considered a possible role for quantum indeterminacy in biological responses and discarded it, as did Wilson [13] in a more recent consideration of the possible role of quantum indeterminancy in the mind-brain interaction. There has been a recent resurgence of interest in the involvement of quantum indeterminacy in biological randomness or indeed as an explanation of human consciousness (Hameroff, [19]; Penrose, [20]; Penrose, [21]; Penrose and Hameroff, [22], Grush and Churchland [23], Wilson, [13]).

Indeed, the quantum behaviour of microtubules has been suggested as the repository of consciousness [19]. In these models, in contrast to the present one, consciousness or 'free will' becomes embedded in and is inseparable from the physical system. If the latter model is correct, it remains true that the structure of the physical system will be determined by the inherited genetic program and environmental stimuli. In so far as 'free will' is a property of the physical sytem then, transitively, it must be determined (but not necessarily predictable) and the limits of its operation prescribed by factors beyond the control of the individual. Because the limits of operation of 'free will' are defined by the physical system, the implications for the criminal justice sytem are the same as those discussed in subsection 2.3. We cannot, after all, be held responsible for the microtubules we inherit.

The work of Penrose and colleagues focusses on the internal structure of the 'States' (shown as boxes in Figs 1 and 2). In contrast, the work of Turing was not concerned with the internal workings of the 'States' but with the responses they exhibit. Penrose [20] argues that human mental processes, including consciousness, are non-algorithmic. Whether or not this is true, non-algorithmicity does not imply a non-physical basis.

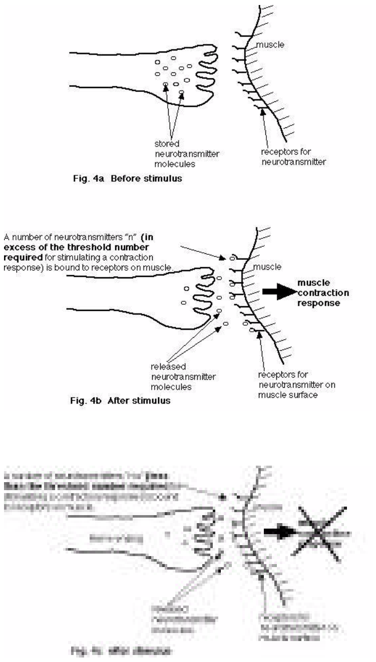

Fig. 4. ***Variable response to Release of neurotransmitters at a neuromuscular junction***

3.4 Free will implies a time reversal paradox.

The salient feature of the model presented in the present paper, is that apart from the fact that it is a physical system we do not need to know what is 'inside the boxes' and there is no limitation placed on physical laws apart from a restriction on the direction of time. The model maintains that one cannot instantaneously step outside one's current state to change that state. If it were possible to "step outside" (or at least wait a moment and reconsider) then intervene in one's own decisions- that reconsideration process would necessarily be dependent on one's current physical state which, in turn, is dependent on the immediately preceding physical state and stimulus. For consistency with our 'State transition' model such an exercise of free will or "stepping outside" would require a suspension of the normal sequence of events i.e. a reversal of time. In its exclusion of such an occurrence, the model is consistent with the thesis of Hawking [24], that the psychological 'arrow' is determined by the thermodynamic arrow and that these two arrows necessarily point in the same direction. If we start from the premise that a physical basis for behaviour exists and that this follows physical laws in which time moves in the same direction as the thermodynamic arrow, it follows from our model that the mind/body interaction and the operation of free will requires a violation of these physical laws. Using different lines of reasoning Mohrhoff [12] and Wilson [13] have reached a similar conclusion. Mohrhoff [13] resorted to modification of electromagnetic theory to attempt to accommodate these deviations.

The work of Libet [25, 26] appears to circumvent the 'time paradox' required by the exercise of free will, by showing that there is a finite time interval between volitional 'readiness potential' and the execution of the motor act. On this experimental basis Libet [26] argues that there is a temporal window of opportunity for the conscious veto of the act by the operation of free will. However, although the work reveals this window of opportunity, it does not resolve the question of whether free will exists or the question of the physical basis for the intervention itself. Nor does it detract from the argument that the "act of veto" must also have its origin in prior physical states of the nervous system.

The only requirement for the proof by induction presented at 3.1 is that the biological response to a stimulus at a given instant in time will depend only on the physical state at that same instant.

3.5 Free will as a socially useful construct or belief.

Wells [27] noted that excuses create problems of line drawing and threaten the social control functions of the criminal justice. Indeed,. In this context the concept of 'free will' is a convenient construct because it allows blame to be fixed on an individual and other factors to be ignored or minimized. The concept also allows society to rationalize separation or persecution of those individuals whose behaviour falls outside socially defined norms. It is pertinent to recall the abhorrent treatment of the mentally ill until the early 20th century. Only with increasing understanding of the physical and chemical bases of mental illness was individual guilt alleviated and treatment of these people improved.

4 Conclusion.

In this paper a statistico-deterministic 'state machine' is used to model behaviour as a series of transitions between instantaneous states. The statistical nature of the transitions arises naturally from the stochastic nature of chemical events at the neuromuscular junction or nerve synapse. The model shows how behaviours are determined by prior states and environmental stimuli, but not predictable. This characteristic of biological sytems can lead to the illusion of the operation of 'free will'.

Many cultures maintain belief in concepts like free will and use them to build a framework for regulating social behaviour. Indeed, Boehm [28] has built on the early assertions of Darwin [29] to argue that morality has evolved because of its selective value as a means of social control and conflict resolution. Could it be that a belief in 'free will" has co-evolved as part of this morality phenotype? It may have had selective value in evolving communites of the type described by Boehm [28] if the belief reinforced the application of interventionist behaviour. However, the retention of a concept because it is useful rather than because it is true seems dubious in ethical and legal contexts, even if it had selective value in human evolutionary history.

Based on the model presented here, it could be argued that ideas of guilt, innocence and punishment, which derive from the idea of' 'free will', are outmoded. Instead, it should be acknowledged that the legal system is the pragmatic arbiter of socially defined, acceptable and unacceptable behaviours. The incarceration of individuals who perform unacceptable behaviours would be viewed as a necessary action for the harmonious function of society, but could not carry moral sanction or any element of retribution. A practical implication of this reasoning is that physical conditions for incarcerated individuals should be improved.

In the latter conclusions the present work concurs with the view of Blakemore [30]. Blakemore argued that it is illogical to distinguish between acts that result from conscious intention and those that are reflexes or the outcome of brain damage or neuropathy. All neural activity is physical, and determined by physical laws, and therefore it is inconsistent to distinguish between one set of acts for which someone is personally responsible and another set for which they are not. This being so, it is inappropriate to make personal responsibility the basis of a system of retributive justice.

Freeman [31,32] takes the pragmatic view and argues that people should accept responsibility for those actions for which they feel responsible, but urges forgiveness based on the recognition that choice is not completely unfettered. The position of Freeman [31,32] is inconsistent with the model presented in the current paper because *feelings* of responsibility or guilt must also be functions of prior experience and genetics- albeit with a large experience component, given that guilt is regarded by most psychologists as a 'higher cognitive emotion' rather than 'innate' (Evans, [33]).

The other conclusion of the present work is that a belief in the concept of 'free will' logically requires violation of laws of physics (or at least those that disallow time reversal), whereas behavioural determinism does not. In this regard, the present work supports the arguments proferred by other recent authors (Mohrhoff, [12]; Wilson, [13]) that violations (or transcendance) of known physical laws must occur at points of mental influence on neural events. This necessitates either an abandonment of the concept of free will or a modification of physical laws, perhaps as suggested by Lowe, [34] or to allow time reversal and non-Turing calculations of the type described by Etesi and Nemeti [35]. The physical conditions (high gravitational field) required for the latter situation are far outside those encountered in biological systems. It seems fitting to conclude with a quotation from Heisenberg [36] in relation to the limitations of our formulations of physical laws: "Any concepts or words which have been formed in the past through the interplay between the world and ourselves are not really sharply defined with respect to their meaning;……..The concepts may, however be sharply defined with regard to their connections. This is actually the fact when the concepts become part of a system of axioms and definitions which can be expressed consistently by a mathematical scheme. Such a group of connected concepts may be applicable to a wide field of experience and will help us to find our way in this field. But the limits of applicability will in general not be known, at least not completely."

Given the dependence of conventional theology on concepts of free will, it is ironic that the biblical entreaty for forgiveness is quite consistent with the implications of behavioural determinism.

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