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BEYOND CONSCIOUSNESS?

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A discussion is given as to the possibility of creating machines which have more powerful consciousnesses than our own. The approach employs, in particular, a brain-based model of human consciousness. From that model a general discussion is developed of the need for a unique central control system in any machine to enable it to be efficient in decision-making. The resulting features of the machine's consciousness, as the highest order controller, is seen to need to be similar to our own. We conclude that beyond consciousness very likely lies only similar consciousnesses.

Keywords: Attention; control; inner self; hierarchy; unity of self; purpose of consciousness.

1. Introduction

Are we too fixated on consciousness? Should we not try to go beyond it? We might thereby

(a) Obtain a system of control more powerful than that which we presently possess;
(b) Look at something different than plain unvarnished consciousness;
(c) By looking at something different so avoid the present problems we are having over pinning consciousness down.

But what do we go beyond? In a general manner we can say that we are trying to detour round or go beyond such features of consciousness as are generally accepted:

(1) Knowing oneself;
(2) Possessing an "I" as the center of our existence (our inner self);
(3) Possessing an "I's Eye View" of the outer world;
(4) Possessing a crucial inner control system.

So going beyond consciousness might allow us to create an even more efficient inner control system, leading to more effective machines than we humans. Such is the hope. What about the reality?

To attain some higher order control system it looks as though we should at least consider carefully the control systems we already possess in our brains, so as to try to build on them. The purpose of this paper is to explore possible extensions of human consciousness, preserving the features (1)−(4) above but hopefully trying to gain one or more of the advantages in (a)−(c).

The extension in terms of a hierarchy of such control systems would be natural, such as follows from the upgrading of the MOSAIC system of motor control models[1] to the hierarchical HMOSAIC system.[2] Motor control is only one of the control systems of the brain; we should also consider attention and emotion as important features of control there. These latter two are important components of consciousness itself, and certainly cannot be left out. The emotions give "colour" to consciousness, making life worthwhile. Attention is regarded now by most neuroscientists as the gateway to consciousness; without attention there is no consciousness. Thus we must take careful account of these two components of brain processing.

We will start in the next section to consider the control features of consciousness. We relate it to models of motor control, and extend such ideas to consciousness. We then take the CODAM model (Refs. 3, 4 and references therein), based on extending attention control, as a version of how attention can function as a basis for consciousness with the various features (1)−(4) mentioned earlier. The manner of inclusion of emotion into such a control framework is then developed briefly. In Sec. 3 we turn to consider how a hierarchy of consciousnesses, as coupled control systems, might arise. Such a hierarchy appears already to be present in the brain due to the different modalities used in our sensory system. A range of senses requires some form of hierarchical control to prevent "split brain behavior", which could arise if there were a number of competing but separate control systems but no overarching controller to prevent clashes of response. We turn to consider in Sec. 4 the more general possibility of a hierarchy of such controllers in a given modality, and consider if that might provide a more efficient guidance system for a machine. The last section contains conclusions to our study.

2. The Control Nature of Vanilla-Flavored Consciousness

Vanilla-flavored consciousness is undoubtedly part of the overall control system provided by the brain. In sleep or when drugged or under alcohol there are drastic changes to behavior, in some cases, very tragic. A person may say and do things when drunk which they greatly regret when they have sobered up. The control system in these cases has been altered so that normal (and normally acceptable) behavior has been modified to be "beyond the pale". What has happened?

In general we can say that attention control, especially the correcting of attention errors, and the biasing of attention and resulting thoughts arising from the emotional maps built up from childhood, has been severely distorted by what has been ingested as drugs or alcohol. The basic structure at risk is that of attention control — it cannot prevent usually unconscious emotions and drives from playing too large a role in determining behavior in terms of goals set up. So we need to consider the attention control system and its biasing by emotion as our first task: How do we understand it, and especially how can we model it?

Much progress has been made in the modeling of motor control programs in the brain by engineering control theory.[5] The simplest ballistic control model just uses the commands for a soldier: "*Take aim — fire.*"

Here the projectile fired from a gun by a soldier continues on its way until it reaches either its target or something else altogether. No error correction is available to prevent lateral damage brought about in the poorer aim case. But that is inefficient, and nature has improved motor control by the use of feedback error correction which is fast. To achieve fast error correction (needed since feedback is slow) a predictor of the future state is made available. This uses a copy of the motor command (termed the corollary discharge or efference copy) which leads to an early prediction of the next state of the environment when sent to a suitable predictor. Such a motor copy prediction is then used to create an error signal to modify the movement, if so needed.[5]

A similar improvement of attention control can similarly be assumed to have occurred during evolution so as to allow attention both to be sped up as well as have error correction (such as preventing a distracter stimulus representation from displacing an attended or target stimulus representation). This leads to the attention copy model of attention introduced initially in Ref. 3 and extended in numerous references since then (Ref. 4 and references therein). This model, termed the CODAM model (for Corollary Discharge of Attention Movement), also provides a space for consciousness, as required in a suitably complex and all-embracing model of attention.

The CODAM architecture is shown in Fig. 1. It is supposed to represent the manner through which attention control is achieved in a given modality, in this case more specifically in vision. Much of the complexity of visual processing, such as the hierarchy of feature analysers and the hierarchy of temporal lobe representations, has been compressed in Fig. 1 so as not to complicate the figure. In a similar manner, each of the other modules in Fig. 1 may correspond in the brain to a network of actual modules; this possibility is again presently left out of the figure.

The crucial component of CODAM is a corollary discharge or copy of the attention feedback signal originally created by the inverse motor controller or IMC of Fig. 1. This copy signal is sent to the MONITOR module through the buffer COROLLARY DISCHARGE module of Fig. 1. This copy of the IMC signal is used both to support the target activity from the object map accessing its sensory buffer, and to be compared with the requisite goal from the goal module by the monitor module. The resulting error signal from the monitor module is then used to enhance the IMC attention movement signal; it also helps speed up access to the sensory buffer and reduces activities of distracters. At the same time the corollary discharge signal is used to produce a predicted attended state estimate of the visual cortical activity. This is not an estimate of the total visual cortical activity, as would occur in applying

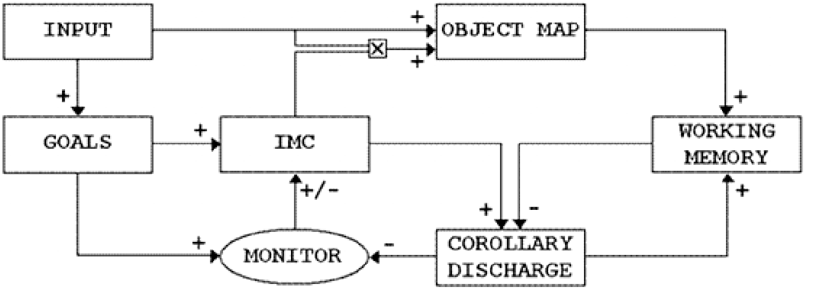

Fig. 1. The CODAM Architecture. Visual input enters the INPUT module to proceed to the hierarchy of visual processing modules culminating in the OBJECT MAP module. In the exogenous case the input rapidly accesses the GOAL module, so causing bias to be sent to the inverse model controller (denoted IMC in the figure) to move the focus of attention; in the endogenous case the goal bias is already present in the GOALS module before any stimulus enters, so biases the IMC during a pre-stimulus period. The attention signal modulates activity on the object map to amplify requisite target activity entering that map. If this activity becomes strong enough it will access the WORKING MEMORY buffer to be available for report. Before that happens, the COROLLARY DISCHARGE module, acting as a predictor, is assessed in comparison with the current goal on the GOALS module, to generate an error output from the MONITOR module. This is used to enhance the attention signal from the IMC, whilst the COROLLARY DISCHARGE module protects the representation of the attended stimulus attaining the WORKING MEMORY module by inhibiting distracters.

standard engineering control theory; such a reduction to working only with attended activity corresponds to the filtering property of attention.

The existence in the brain of some of the modules of CODAM are supported by brain imaging observations,[6–8] although these provide no immediate evidence of the critical corollary discharge signal or its buffer. But the CODAM model extends numerous models of attention control, such as the "biased competition" of Ref. 9 and the more neurally based models of Refs. 10−12 in a natural manner. These latter models can be seen to be based mainly on ballistic control, rather than the more efficient and sophisticated control by means of forward or prediction models (given by use of the corollary discharge to predict future attended states) and error correctors (provided by the monitor module). Moreover the pre-motor theory of attention lends support to the existence of a copy of the attention movement control signal in parallel to that of the motor movement control signal mentioned earlier. Further evidence comes from the attention blink.

Event related potentials (ERPs) arise from input processing up and down the hierarchy of modules in Fig. 1, with a stimulus entering low-level sensory cortex and attempting to reach its relevant sensory buffer (working memory). This is aided or inhibited by the corollary discharge signal so as to allow access of the buffer to a target stimulus and prevent such access to any distracters. As seen from Ref. 13 these ERP signals give a description both of activity at the various sites as processing time proceeds as well as how the various sites interact through either excitatory or inhibitory feedforward or feedback effects, as observed by the cortical layer in which the activation commences.[14] These interactions are now being observed in considerable detail in the attention blink (AB) paradigm,[15] and included in related models.[13]

The neural basis for consciousness has been suggested in CODAM[3,4] as created by the corollary discharge signal of the attention movement control signal being buffered for a short time on the corollary discharge module of Fig. 1. It is the sequential process: "*First ownership, second content owned*", which is posited as the basis of the two separate components (content and ownership) of consciousness. Each component would be lost without the other: no owner implies "no-one" to experience the content (which therefore loses its attribute of being "content"), and no content would imply absence of the external world. However the owner might still be able to experience itself, as might occur in the controversial experience of pure consciousness.[16]

The attentional blink is an important and highly relevant paradigm, where two targets must be detected by subjects in a stream of similar stimuli presented at about 10 Hz. Awareness can be manipulated in this paradigm by specific parameter changes, such as the time delay between the first and second targets, with a 300 ms delay corresponding to most difficulty of detecting the second target, so in what is called the "blink". The loss of the P3 in the blink, for the second target, has been discovered to have an associated loss of its N2 ERP;[17] the N2 is therefore also involved in the creation of consciousness, and is possible to relate to the assumed corollary discharge in CODAM.

Immunity to error in the CODAM model arises from the dedicated relationship between the corollary discharge signal and the lower-level stimulus which is about to be attended to and so become content. The corollary discharge signal speeds up attaining the sensory buffer by the stimulus activations, as well as giving a 1:1 relationship between the identity of the owner's signal and that of the content to be experienced. Thus the CODAM model contains in its dynamics not only an explanation of immunity to error but also a functional characterization of consciousness itself:

> "*Consciousness arises through a speeding-up process by employment of a more powerful attention control than of purely ballistic form, using a corollary discharge of the movement of the focus of attention.*"

Such a functional grounding of consciousness makes up for the apparent functionless character it has presented to philosophers in the past.

The owner activity is signalled by some aspects of the higher cortical level N2 activity 180−250 ms post stimulus. There are various inhibitions (of distracters) and excitations (of the target) that this signal produces to speed up the target activity reaching its buffer, as contained in the distribution of the N2 about the brain. The attention copy signal activates modules coding at a high information level, too high to produce any experience of content (which supposedly arises from correlated lower level activity carrying feature information of higher level object concepts). This agrees with the experience of the owner being "content-free".

3. A Hierarchy of Consciousnesses: The United Self?

On the basis of the CODAM model of consciousness of the previous section, we must now turn to understand how there can arise the experience of a united self, given that there are numerous modalities and, therefore, numerous CODAM-style attention control systems. How do these separate systems combine their activity to provide such a self?

The unity of the self is one consistent with our experience. "I" am the one who owns my experiences. The content flows about me and in my brain, but there is apparently an ever-constant "I" who is "having" this experience. But is this unity real or only apparent? In the CODAM approach to consciousness, the "I" arises only from a copy of the signal to move attention. If that movement occurs about three times per second then a new "I" will arise at such a frequency. Is each of these "I's" the same as the preceding and successive one? Or are they all different and another mechanism altogether provides the sense of continuity of the self?

One such mechanism to provide the apparent unity of the self could be the persistent activity on the working memory of the CODAM model of Fig. 1. This could allow some form of continuation of experience from one moment to the next. However, this does not seem sufficient to achieve a feeling of the unity of "I", especially since the sense of "I" is not provided by activity on the sensory working memory buffers but on those supposed to exist to produce such a sense at any one time. In other words we need to concentrate on the corollary discharge buffers such as that in Fig 1. The problem we face is how a unique or single "I" can be created from a sequence of such activities on different corollary discharge buffers.

Given a sequence of corollary discharge buffer activities we can unify them by

(i) Making them be local activations on a larger connected network (the "I" net);
(ii) Sending the corollary discharge activities to a single module which, through competition between the incoming activities, leads to a unique (but moving) activation on the single module (the "I" module).

The geometric extent of the two cases above is most likely to be very different. In the case (i), we know that the I-network is very likely spread quite widely across the brain (assuming each corollary discharge buffer is close to, if not attached to, each sensory working memory buffer). Various instances of the latter are known to be sited in various parts of the brain:

(a) The phonological store in the parietal lobe;
(b) The visuospatial sketchpad; again in the parietal lobe, as well as being associated with the frontal eye fields;
(c) The object working memory store in mid-temporal regions.

On the other hand there should be a single module associated with the I-module, one which has been searched for by brain imaging studies on the self but which seems not to be easily observed. This is because any subtraction results have removed such a module since it should be active at about the same level throughout the varied responses of the subjects in any experiment. The same result holds, of course, if "I" was represented by activity on the I-network, when experimenting in a given modality.

We can summarize by saying that there is presently no experimental reason to choose between the two possibilities of I-net or I-module; it is possible we may be able to do so in the future by carefully designed brain imaging experiments. However there are differences between the two cases we can tease out by further analysis of the nature of "I" created in each.

In the CODAM model of consciousness[3,4] the ownership aspect occurs in association with a given input being attended to, through the coding of the attended input that is present on the corollary discharge module. Such coding must be present if the corollary discharge module is to function as a correct predictor of what is about to enter onto the buffer working memory. Such predictions must be particular to each stimulus. Thus the ownership carried by "I" is ownership of a particular stimulus, not of a general one. Thus the content of the activity associated to "I" is particular to each stimulus on the I-network. Such particularization is not the case for the I-module, in which it appears most appropriate to code for a universal ON or OFF of the module when the system or person is conscious: such a module is trivially constant in activity when there is consciousness, and not when not conscious.

Such constancy of activity is not the case, however, for the I-network. In this case the activity would vary on a given module (for a given modality), corresponding to the different coded stimulus representations in vision, for example. It can also move across modules of the I-network when modality switching occurs. Thus in this case there is detailed variation of coding going on all the time for "I". How can that correspond to a purely unified and apparently constant "I"?

It has been proposed in CODAM that "I" arises as content-free due to its high-level coding of the nodes on its buffer. Such absence of content was related to the "nothingness" of Ref. 18 and to the lack of content in the pure conscious experience (PCE).[16] That may be so, but in any case it may be difficult to disentangle any actual "coloration" of "I" through such content by the input of decidedly content-full stimulus representation input to its working memory buffer within a hundred or so milliseconds.

Thus we meet an impasse: we still cannot decide between the I-network or the I-module version of "I" that corresponds most appropriately to the unity of "I".

4. A Hierarchy of Consciousnesses: Beyond the Self?

Given the conclusions we have reached on the unity of "I" in humans, let us turn to the possibility of developing machine systems with conscious experience which are superior to our own. Would we not expect such a possibility to be used in evolution so that we can, by such an analysis, look into the future of the human race?

To develop this argument further we might suppose the appropriate way ahead is by means of the use of suitably powerful genetic algorithms. Given a set of cost functions we might use a co-evolutionary technique[19] that would evolve structures that might possess some form of consciousness, and hence might even evolve beyond to a higher level of consciousness, if one such exists. But it is difficult to design a suitable set of cost functions that would achieve that. In any case we note that the CODAM approach, through attention, would seem to have attention as a pre-requisite stage of such evolutionary development. This stage itself does not seem to have been reached in such simulations, so this route seems presently blocked to us.

Be that as it may, we can continue our argument much further in terms of the results of the previous section. Let us consider the following hypotheses that might be produced by evolutionary analyses or by the real evolution of humanity in the future:

(1) Only one over-arching controller is appropriate to be created in each human or machine brain;
(2) The over-arching controller is that involved with consciousness;
(3) The over-arching controller uses attention as its main mechanism of control;
(4) Both in humans and machines there are separate modalities employed by sensors so that some form of unifying mechanism is essential.

Let us discuss these various hypotheses separately.

For hypothesis (1) we only need to consider the problems beset by split-brain subjects to realise how crucial a suitably well-connected brain is to each of us. To see a split-brain subject wrestling with her left hand as it tries to do the opposite of her right hand is quite disturbing and her account of her methods for dealing with this are also. A similar feature arise with some frontal patients, as in the case of the woman whose left hand kept trying to strangle herself, so much so she had to resort to essentially "tying it down". Her case was discovered, on autopsy, as arising from a tumor on her anterior corpus callosum. This produced a limited form of split brain, one especially split in the control of left and right arms and actions thereof. We therefore accept the hypothesis (1) on these grounds.

There is however a further powerful argument of a more general kind: how can a decision be made if there are a multiple (more than one) of decision makers. In particular, if attention is the over-arching control mechanism of the human (or machine) assuming hypothesis (2) then attention processing would be inefficient if there were several sites that needed to be attended to at once, each with its own focus. It may be possible that some animals, such as the eagle, have a number of attention foci at once. In the eagle's case this is for horizontal and vertical viewing, for where the bird is going and what prey might be down below. But if the ultimate deciders as to where it goes are separate then there would be a battle at the directional response level (as in the split brain women). That decision has to be taken before the response level is reached.

This leads us naturally to hypothesis (2), that consciousness is the topmost controller. That is evident from our own experience: without being conscious we are at the mercy of the elements around us. We may sidestep our consciousness by working at an automatic level, such as in over-learnt responses. But if these are in error then we immediately need to attend to the source of the error and try to modify our responses so as to be effective again. Thus when I go to sea for a day or so then I acquire "sea-legs", which allow me to move automatically around the deck. When I return to land I have to attend to the way I walk for a short while until I have re-learnt how to walk automatically on dry land.

We have already noted the difficulties of sensible behavior if consciousness and attention are distorted by alcohol or drugs. The extreme case of loss of consciousness is when, for example, a boxer is knocked out by his opponent. But the less extreme but much sadder situation arises when the boxer, after many bouts, becomes "punch drunk" — his consciousness becomes "fragile". The case of the world champion boxer Mohammed Ali is famous for this terrible effect. A similar but more extreme case of the reduction of consciousness occurs progressively in dementia: as the subject becomes more and more demented their memory vanishes and finally so does their ability to recognize their nearest and dearest. These cases tragically demonstrate so vividly the validity of hypothesis (2).

Hypothesis (3) partly follows from hypothesis (2), but also from the nature of attention itself. For attention acts as a filter to extract interesting goal or salient stimulus representations from those abundantly being analyzed at lower cortical level. It is very difficult to think simultaneously about several objects; the ability we have been evolved to possess allows us to single out only one and process that by suitable manipulations on its relevant working memory buffer representation. Thus for efficiency we need attention to allow us to proceed to filter out what is worthwhile from the rest. The work in our heads is thus of two sorts: the unattended (down in lower level cortices, and coded at feature level in the main) and the attended (coded at a high level for rapid and further manipulation in prefrontal and parietal cortices).

Hypothesis (4) is straightforward: if there is no fusion of control of responses to various different sensor inputs, then yet again there would be difficulties in response to the environment, which would lead to inefficiencies.

Let us suppose that evolution leads us to evolve at various levels: at sensor level, at lower and intermediate processing level and at the highest consciousness level (as in the heading of this section). This first level might be from more acute eyes or similar sensors, or the evolution of a new, sixth sensor modality. The intermediate level evolution could lead to ever more precise object identification, or a larger number of objects which we can identify. It is only the third type of evolution that could lead to something radically new. So let us consider that in more detail.

Where could consciousness evolve to? If we accept hypotheses (1)−(4) then we see that there should still only be a single-centered attention focus to produce a single focus in consciousness. Thus the control structure involved in any evolution of attention and consciousness (by hypotheses (1)−(3)) should still have the character provided by hypothesis (1): it can only ever have one center of control at a time. Since a unifying mechanism is essential for efficient control, from hypothesis (4) above, then evolution can only lead to a unified attention control system, and thence by the other hypotheses, to a unified consciousness. In other words we get back to the situation discussed in the previous section and the solutions (i) and (ii) proposed above to achieve it.

The results we have now arrived at imply that even if there were higher or broader levels developed for attention and consciousness, there would effectively not be any consciousness arising of a different character from what we already possess. Such new consciousness may be built on a larger base of modalities and detailed maps at lower levels. It may also have layers of attention-type of stimulus extraction layers beneath the top layer. But that layer will still need, so will therefore lead to, a single unified consciousness.

When we turn to machine consciousness we can conclude the same result: for most efficient high-level controller, we must duplicate what has been achieved by nature already in the human, and then expand it in breadth and depth where necessary. But we should not try to make something more exotic beyond our own plain vanilla-flavored consciousness. Exotics here would lead to inefficiencies, and so destruction (in either a literal or metaphorical form).

5. Conclusions

In this paper the possibility of somehow going beyond consciousness was discussed. It is possible to do so, but either the system develops "several minds of its own", so becoming less efficient, or it ends up being an expanded version of our own consciousness control system. We can readily say, in this year of the 200th anniversary of the death of Charles Darwin, that "survival of the fittest" would lead to "survival of those with human or a very similar consciousness". Machine systems developed to be autonomous and with the greatest control efficiency can now be seen as falling under that result: take heed of the human, it has been created by millions of years of evolutionary filtering, and is a solution to be greatly respected.

There are several interesting questions which arise from the discussion in the paper, among them being:

(a) As children develop from infancy, how in detail does their consciousness control system develop? In particular how does their I-network (or I-module) develop?
(b) Which one does develop: a localized, module-like system (so more like the I-module) or a set of geographically separate components becoming increasingly correlated in activity (so like an I-network)?
(c) Can children be helped to develop their I-system earlier by suitable mental exercises?
(d) In what manner do various mental diseases (schizophrenia, dementia, etc.) affect the I-system as the disease progresses?

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