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The Nature of Causal Action

Qualities Needed to Enable a Causal Action, such as Free Will, that is Initiated in a Mental Realm to Produce a Change in the Physical World

Abstract: *It is not known whether consciousness can affect the physical world, as a result of a free will action or in some other way. To do so, it must be able to produce physical changes that cannot be accounted for by physical laws, an ability we will refer to as causal action, and several issues relevant to this possibility are discussed. 1) Until recently it was thought that the conservation laws of physics would prohibit causal action. It has now been found that such is not the case, but other problems remain. 2) Observations of brain activity show that most of the process for determining a decision is done by the brain. However, the question of whether the final determination is done by mind or the brain is still open. The issue then arises that given the large amount of processing the brain can do, why would mind do this final step and, if it does, why would the amount done by mind be so small?*

Keywords: consciousness; causal mental action; free will; conservation of energy; Lagrangian; uncertainty principle.

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Journal of Consciousness Studies, **21**, No. 3–4, 2014, pp. 60–73

1. Preliminaries: Reflections on Consciousness Studies

I first became interested in exploring the nature of consciousness in 1985. There was getting to be enough interest in academic and scholarly types that they would talk about it at social gatherings. And academically oriented bookstores would always have a few books on the subject. But there were hardly any journal articles on the subject because most journals wouldn't take them (this reflecting a view held at the time that only behaviourism had the proper scholarly attitude toward the subject).

In the late 1980s I decided that I wanted to review the state of the subject — what models there were, the questions they investigated, and so forth. This entailed extensive searching in bookstores and libraries, and I found 17 models. I talked to another person who had done extensive searching, and he had 15 models, so that's probably a representative number. Most of the models were only a few pages long, and the comments were usually fairly simple. On the subject of the source of consciousness, several had comments that said no more than 'The brain is very complex, so I think consciousness arises out of complexity' (nowadays nobody would keep their comments on the source of consciousness down to one sentence). Another scholar said: 'The number of telephone connections in the world is getting to rival the number of connections in the brain, and I haven't seen any signs that the world telephone system is getting conscious. So I don't think consciousness arises out of the number of connections in the brain.'

I had to consult a library reference desk to find a journal that would publish an article on consciousness. To my surprise the librarian gave me a list of about 100 journals that published on the subject. However, nearly all had gone defunct around 1915. Happily, the list also included the *Journal of Mind and Behavior*, a psychology journal. I sent them my article, and they published it (in two parts) in 1990 and 1991.

But the field was changing. In 1994 Stuart Hameroff and colleagues gave their first conference on consciousness, with an emphasis on studying consciousness as a science, and many of the attendees expressed frustration over the difficulty of publishing articles on the subject. There was clearly a need for journals, and by 1994 the journal *Consciousness and Cognition* had been founded and *Journal of Consciousness Studies* and *Psyche* began. This was the beginning of my long association with the *Journal of Consciousness Studies*.

In this opening section I wanted primarily to reminisce about the early days of consciousness studies, but I'll add a personal note. I am a physicist, and my primary interest in consciousness has always been its causal ability, i.e. its ability to affect the physical world, as in a free will decision. I will have to say that this subject remains about as controversial in the scholarly world as consciousness was 20 years ago. I've reviewed the two main controversies in the following sections, and some of my other papers on the subject are posted on the internet and easily found by searching.

2. Introduction

We know very little about the nature of consciousness. We know that it can interact with the physical world because we can experience sensory reports of that world through our conscious experience. Furthermore, we know by comparing observations of brain activity to verbal reports of conscious experience that the content of conscious experience matches encoding in the brain (Freeman, 2003). Yet consciousness and the physical world differ so much in the types of phenomena they present that we can call them different realms (no ontological statement is meant here, but only a recognition that the descriptions of the two types of phenomena are very different). For instance, objects in the physical world have attributes that are physical and are determined by physical laws. But although we can describe a mental experience as 'immaterial', its nature is not understood.

However, studying the ways the realms may interact can provide a means to studying both consciousness and its relationship to the physical world. For instance, a similarity or association can be looked for between some aspect of consciousness and some aspect of the physical world. Such an association provides the possibility that the interaction between the realms is especially connected with that aspect of the physical world. In fact, as I will briefly describe below, a number of models have been made, using a variety of physical principles, that explore this possibility.

That said, there is another way in which the interaction between the realms can potentially be studied. In the above interaction, in which the content of conscious experience follows encoding in the brain, it appears that consciousness is passive and that the only thing the interaction does is to produce conscious content from the encoding. Let us call this the *encoding interaction*. However, if there is a way for consciousness to affect the brain/physical world, the study of possible ways in which this might take place could yield further understanding of the mind/brain interaction and the nature of consciousness in general (let us call an action initiated by consciousness, which produces an effect in the brain/physical world, a *causal action*, with full definition to follow shortly).

Free will (as we will use the term in this article) provides a prime example of causal action, in which mind can make a decision independently of the brain, which then can affect the brain (e.g. through recording the memory of making it). It should be noted that there is no experimental evidence that establishes whether free will exists. However, much of our legal and ethical systems is based on the view that we have it, so such an assumption is reasonable from that perspective.

The sciences provide several objections to free will that we should discuss, however. In physics, essentially all physical systems are subject to a principle called conservation of energy. But it is easily shown that if a system makes a physical change that has no physical cause, it cannot fulfil this principle, and many people have concluded that free will cannot exist on the basis of this contradiction. Yet, as we will discuss further in Section 3 of this article, it has been pointed out by Mohrhoff (1999) that in order for this principle to apply to a system, a certain condition must be fulfilled (namely, that the motion of all particles can be described in terms of a mathematical function called a Lagrangian). Virtually all physical systems satisfy this requirement, provided all interactions are purely physical. However, if a change is made to a physical system without that change having a physical cause, this condition cannot be fulfilled. In that case the principle of conservation of energy does not apply to the system, so there is no reason to conclude from this that free will cannot exist.

The purpose of this article is to identify concepts that seem related to some attribute that causal action may have, and which therefore can suggest directions for further enquiry as to its nature. This will be done in several ways. First, compatibility issues (discussed in Sections 3 and 4) are not only relevant to the question of whether causal actions can exist, but also, by showing what conditions seem important, can suggest directions for further enquiry.

Another way to investigate the nature of causal action is to assume it is related to some particular type of physical process, such as the uncertainty principle, and see what conclusions or questions are arrived at. In Section 5 such a model is set up using the uncertainty principle.

Let us start by defining some terms. Let us note that broad definitions are used, in order to allow for possible variations in the type of phenomena produced.

The term *consciousness* refers herein to that group of phenomena which can be described in terms of conscious awareness. This term is meant to contrast with *physical world*, which comprises phenomena that are not described in terms of conscious awareness (no ontological difference is meant by this distinction, but only a difference in description). The terms *mind* and *consciousness* are used synonymously herein.

I assume that it is possible for consciousness to produce a change in a physical object that cannot be accounted for by physical laws. I will refer to this ability as a *causal action of consciousness* or a *causal mental action* (shorter terms, such as *causal action* or *mental action*, will also be used). I note that after a causal action has produced a change in an object, the interactions of the latter in the physical world continue to take place as they normally would, but now using its new descriptors.

Free will is a prime example of a causal action. However, I want to be able to include the possibility that consciousness can act on the physical world in other ways also and use the above terms for the more general case. I define *free will* as a form of causal action which has the ability to select between alternative possibilities that are present in conscious experience.

I note that the topics in this article are meant for exploration, rather than definitive studies, and the treatment is often somewhat of a rough sketch. Along these lines the treatment of some of the physical phenomena described is done in a range where they can be described classically, to simplify the discussion.

Many proposals have been made about what physical phenomena might enable, or be associated with, the encoding interaction. A wide variety of phenomena have been proposed (Vannini, 2008), such as the implicate order (Bohm, 1980), quantum fields (Jibu and Yasue, 1995), and neurodynamical chaos (King, 2003). Such a model looks for similarities or relationships between its proposed physical phenomenon and various aspects of consciousness that could help explain how the two realms are connected.

A few models also propose that consciousness can affect the brain/physical world through the agency of free will or in other ways and ask how related physical phenomena could be associated with such action. Proposed phenomena include the uncertainty principle (Eccles, 1970), quantum gravity (Hameroff, 2012; Penrose and Hameroff, 2011), and collapse of the wave function (Stapp, 2011).

We should note that some models are made in the context of an ontological status between the realms. However, no particular ontological status has been favoured, and models about the physical phenomena especially associated with consciousness have been made in the context of a variety of relationships, including monism (Perlovsky, 2010), emergent physicalism (Sperry, 1983), dualism (Popper and Eccles, 1977), and panexperientialism (Griffin, 1998).

3. Conservation of Energy

There is a well-known principle in physics, called *conservation of energy*, that states that the total energy of any system of interacting particles must remain constant. On the other hand, as specified earlier, a causal action can produce a change in some physical condition that cannot be accounted for by physical laws, so in a causal action the total energy can change. Therefore, causal action can violate this principle. For that reason many researchers have said that free will cannot occur. However, let us investigate this principle at a little more length and see if there are any conditions beyond the above as to when it applies.

Let's start with a brief description of the conservation principle. There are other conservation laws besides the one for energy — for instance, there is a conservation law that says the total momentum of all the particles in a system must remain constant. But a causal action can violate any of the conservation laws. However, the conservation laws are not fundamental in themselves. Rather, they are derived from the dynamics of the system (principles of the way the particles in it move) by means of a theorem called Noether's theorem. So let's next ask how the conservation laws are derived.

The dynamics of most systems are specified by a mathematical function called a Lagrangian, and such systems will have conservation laws if the Lagrangian has a particular characteristic, namely that the system follows the same dynamics regardless of the value of some coordinate of the system. In that case the Lagrangian is described as *symmetric* with respect to that coordinate, and by Noether's theorem the system will have a conservation law involving that coordinate. For instance, if the Lagrangian of a system is independent of its position in space, the system will follow the principle of conservation of momentum, and if its Lagrangian is independent of time, it will follow the principle of conservation of energy (Goldstein, 1980).

Now the theorem was derived for the case of physical systems only, and as Mohrhoff (1999) has pointed out, in the derivation an assumption was used that is fulfilled for purely physical changes but not for changes resulting from a mental action. Specifically, in order for a system to be subject to the conservation laws, it must be possible to describe all dynamical changes in the particles in it in terms of the Lagrangian. In virtually all physical systems the dynamical changes can be described in this way, and therefore they must follow the conservation laws. But, as we have seen, changes produced by a causal action cannot be described in terms of a Lagrangian, and therefore the conservation principles do not apply to it.

The necessity for the trajectory of a purely physical system to be entirely determined by a particular mathematical function suggests a further possibility for the nature of a causal mental realm. There are many possibilities for types of realms that could interact with our known physical one. If we were to speculate about the properties of a parallel universe which seemed very similar to our physical universe, we would probably consider it likely that it has a dynamical system similar to ours, in which the motions of particles are also determined by a mathematical function, although not necessarily the Lagrangian function we use. But for a mental realm, a reasonable possibility is that, although decisions for causal action can be made entirely using rule-based systems, some other method of evaluation/decision-making can also be included (such as evaluation of incomplete data), with the final decision made by arbitrary choice.

We should note, though, that if deviations in physical quantities can be introduced in a system by causal action, some further rule presumably would be needed to limit their size, as otherwise the original physical system could be perturbed too much. We will discuss this issue further in Section 5.

4. Does Consciousness Have Processing Abilities that are Different than Merely Following Brain Developed Thought?

As has been said earlier, it is not known whether free will, or any causal mental action, exists. But although the central question of whether free will exists may be quite intractable, there can be associated issues that are investigated more readily and can shed some light on the subject. Such issues can be either theoretical or experimental. We discussed a theoretical one in the last section, and in this section we will discuss the extensive series of experiments now being done in neuroscience to investigate the roles of the brain and consciousness in a line of thought that leads to a decision. We will also discuss some processing abilities consciousness may have in addition to that of making a choice.

Making a decision has two components: the thoughts and judgments about it and the decision itself, and in an experiment the various times associated with these activities can be compared in order to investigate the decision process. More specifically, the times when the line of thought begins its activities in the brain can be determined by experimental measurements, as can (in later experiments) the time when the final decision becomes established in the brain. The decision itself is made consciously, and the time can be reported by the experimental subject. A series of such experiments has been carried out, which has addressed various facets of the question of when free will might take place.

In the first experiment, Libet *et al.* (1983a) asked a subject to flex his wrist at a time of his choosing and to note the time on a rotating clock hand. This was the time of his conscious decision. To carry out the action the brain must use a motor programme, and a readiness potential is present in the brain while the motor programme is being processed. The experiment showed that the readiness potential began several hundred milliseconds before the decision, so the brain was getting ready to carry out the movement before the conscious decision had been made. On the other hand, the movement can't be carried out until the motor programme is prepared, and the experiment showed that movement began about 200 milliseconds after the decision. So, as Libet *et al.* (1983b) pointed out, the movement could be cancelled during that 200 milliseconds.

Other experiments have confirmed this result (Haggard, 2008). For instance, Haggard and Eimer (1999) had the subject make a decision of whether to move the right or left hand. Similarly to the results of Libet *et al.* (1983a), they found that the lateralized readiness potential, which prepares for a movement on a specific side, right or left, began several hundred milliseconds before the decision, with movement commencing about 200 milliseconds after the decision.

Soon *et al.* (2008) extended that finding by examining local patterns in high level control areas in the cortex which could be identified with one or the other of the choices available. They found that this local pattern usually corresponded to the choice that was made and that it was present in the area for as long as 10 seconds before the conscious decision was made. One can't tell from this result whether the brain made the decision long before it entered conscious awareness, or whether there was considerable shaping of the decision before the recommended choice entered conscious awareness, with the recommended choice nearly always made. However, it is clear that most of the process for determining the final choice is done before it enters conscious awareness and therefore is done by the brain.

These results show that it is possible that free will can act to confirm or cancel a decision. On the other hand, all the evidence indicates that the various thoughts and judgments relevant to the decision are produced in the brain. So if the brain can make judgments and shape the decision-making process, the question arises, why should it stop short and leave the final decision to the conscious self? What is the advantage?

We know that the brain has the ability to carry out very complex activities, provided it has detailed instructions, certainly more ability than the conscious self has. This suggests that the conscious self has abilities of a different sort, which it can use to carry out activities in unfamiliar circumstances. For instance, an animal might encounter a potential food which seems edible but somewhat noxious in a situation in which little food has been available. Such a situation involves the comparison of incommensurate conditions, and Hodgson (1991) has proposed that consciousness has the ability to do this.

In a similar vein Penrose (1989) has pointed out that algorithmic (rule-based) mathematical problems, even very complex ones, can be solved relatively easily when the methods for solution are known. Non-algorithmic problems cannot be solved by rules at all, but sometimes a person can solve them instantly by visual inspection. Penrose has proposed that the ability to do non-algorithmic processing is an attribute of consciousness.

So it may be that consciousness can use types of processing that the brain cannot, and the advantage of having free will make the final decision is that these special abilities of consciousness can be called into play. As we've seen, these special attributes may include the ability to deal with ambiguity. It has also been proposed that consciousness can provide insight to a problem, with greater understanding often coming in a flash (Eccles, 1989; Goswami, 1993; Penrose, 1989). But this brings up the question, why is the time when consciousness is directing brain/mind action so brief? For continuity, consciousness must be aware of the brain/mind action that the brain directs. Why use the brain so much and consciousness relatively little?

The reason may be that there is a limit on how much change can be made in the physical world by causal action, such as a rule that the magnitude of such changes must be within the limits of the uncertainty principle. We will discuss this possibility further in the next section.

5. Explorations Past and Future

A causal action, as specified in its definition, produces a change in the physical world that cannot be accounted for by physical laws. The object that is changed acts from then on according to physical laws. However, it now will be in a different state than it would have been before the causal change, so any object it interacts with will also be in a different state than it would have been, and the effects will propagate.

In this respect, causal actions are little different than quantum random events, in that in each case the result is not completely specified before it occurs. However, they differ in that a random event occurs in the context of certain physical conditions, such as a radioactive source, and its results are limited to those that would be consistent with those conditions. On the other hand, causal actions have no such limitation. This means that although random events can occur, with their permitted range of results, consistently with other physical events going on at the time, a causal action, together with its chain of propagating effects, could make problems for the system through unplanned changes or internal inconsistency. This could be especially a problem with respect to conservation laws. As we saw in Section 3, causal actions are not subject to conservation laws, but they would generate internal inconsistency in the system if they are not followed.

If such perturbations occurred even occasionally in physical systems, surely they would be observed. But they are not, even in observations made down to the limits of the uncertainty principle. The explanation may be that some other factor is present that circumvents these problems. For instance, perhaps when a causal change is produced, a buffer zone is associated with it, such that inconsistencies within certain limits are smoothed out, and potential causal changes that would have inconsistencies outside those limits cannot be completed.

If there is such a buffer zone, it would not be surprising if the limits were those of the uncertainty principle. This gives us a special reason to take an interest in models of causal action that incorporate this idea and see how outcomes vary when various details about the production of causal action are varied.

The best known model in which causal action is associated with the uncertainty principle is that of Eccles (1970), and the general method for this type of investigation would be as follows. Choose a physical system which seems a likely candidate for a causal action to occur, i.e. it uses well-defined parts or processes, with mental intention proposed as perhaps able to substitute for one (or more) of them. The hypothesis being tested could be roughly expressed as follows: *for a causal action to occur, i.e. for a process to take place that could not occur by purely physical means under specified physical conditions, the magnitudes of the coordinates involved, when they are compared with their uncertainty limits, must fall within those limits.* The magnitudes of the coordinates are determined from a description of the system (and the method to calculate the uncertainty limits can be found in a textbook). Using this general procedure it can be calculated whether the physical system being modelled could carry out a causal change, according to that model.

The physical system Eccles applied it to was the initiation of an action potential in the brain. More specifically, using purely physical means, the brain can produce an action potential by moving a vesicle containing neurotransmitter from one place to another in a synapse, and thereby enabling the vesicle to release the neurotransmitter. When the calculations were done, it was originally thought that the magnitudes of the changes involved were within those limits. In that case, the system would have fulfilled the conditions in Eccles' hypothesis, and such results, although theoretical, would give encouragement to the idea that causal actions can occur.

However, in the original results it had been assumed that the vesicle travelled in a vacuum-like medium, and it was later pointed out by Wilson (1976) that actually the vesicle travelled in the viscous liquid medium within a cell. This meant that the time of travel involved was much greater than previously thought and was no longer within the uncertainty limits.

There are a variety of methods by which the brain can produce an action potential, of which changing the position of the vesicle is only one. So one might wonder whether some of these other methods could pass the uncertainty limit tests. However, later analysis by Wilson (1999) has shown that for all of them the magnitudes of change are outside its limits.

At this point I'll comment that in actuality it is not surprising that such effects are not produced at the cellular level. In making a comparison of particle coordinates with the uncertainty limits, products of pairs of certain coordinates are used, and one of each pair is proportional to the mass. However, the uncertainty limit, $h/2$, is a very small number. So objects at the cellular level, such as a vesicle, are just too massive for the products of changes concerning them to fit within the uncertainty limits (Burns, 2012).

Therefore, it would seem productive to continue enquiry as to how causal action could work using physical objects at a lower size-scale. A system now being investigated, and described more fully elsewhere (Burns, 2012), acts at the molecular level and uses the ordering of randomness to direct the causal components.

6. Summary

We started this endeavour by noting that studying models of consciousness in which causal action could take place could give additional insight about the relationship of consciousness and the brain beyond those in which consciousness is assumed to be entirely passive to the brain. We then reviewed two issues about causal action that are of current interest.

It had been earlier thought that the principle of conservation of energy ruled out the possibility of causal action. However, as we discussed in Section 3, it has been shown more recently that causal action is not subject to conservation laws. This means that causal action is not prohibited from occurring. But in that case it can bring with it internal inconsistency between different parts of the physical system — and with it, the possibility of functional problems.

In Section 4 we reviewed the extensive series of experiments that are investigating what part of the decision process is done by the brain and what part (if any) is done by consciousness. The experiments showed that in decisions that took a considerable amount of time, nearly all that time showed extensive activity by the brain. On the other hand, even in decisions that were relatively quick, there was always time at the end of the process for the subject to make a yes/no decision (if not an extensive verbal one) about her choice. So although we don't know that consciousness was making independent choices, it has not been ruled out.

This procedure prompts a question, however. The brain is evidently good at working out lengthy decisions, and it probably has been assigned this job in evolution. But in that case why hand over the job to consciousness at the final step? The answer may be that consciousness has different skills than the brain, that are best brought into play as a supervisor of what the brain does (for a listing of skills proposed by various researchers, see Sections 3 and 4).

A further question is, in the decision process why is the time allotted to consciousness so brief? Part of the answer may be that the skills used by consciousness don't use as much time. However, the answer may also be related to the problem described earlier, that a buffer zone, or something of the sort, is needed to prevent inconsistencies from developing when causal change occurs between realms that have different properties, with the buffer zone limiting the number and/or magnitude of changes.

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