

7. Directions for Future Research.

Von Neumann's formulation of quantum theory brings human minds explicitly into brain dynamics via the operators $P(e)$, which specify the neural correlates of a person's conscious experiences. A principal task is now to map out these mind-brain connections, and understand in more detail the principles by which they operate.

These tasks are facilitated in quantum theory, vis a vis classical theory, by the fact that the mapping between the two domains enters explicitly into the dynamical equations in a way that allows conscious intentions and efforts to causally influence brain activity in a way generally concordant with William James's theory of ideo-motor action and volition. The explicitly represented causal connection between effortful choosing and experiential feedback allows the functional efficacy of the intentional conscious thought to enter naturally, through trial-and-error learning, into the determination of the mapping $P(e)$: each of us conditions by practice his own brain so that his felt intentional efforts will produce the intended experiential feedbacks. The fact that this sort of conditioning works would seem to imply that our conscious efforts do have physical consequences.

A closely connected issue is the nature of the causal origin of the choices described by Process 1. How do the prior '*states of the brain*' and '*states of consciousness*' conspire to fix or influence these choices? Quantum theory opens up the physical theory in a way that accommodates causally efficacious consciousness, and it also imposes strong conditions on how it works. But it does not specify the model completely. The general formulas of Newton did not completely specify all of the details of classical physics, and, similarly, the general formulas of von Neumann do not completely specify all of the features of quantum theory.

Throughout this survey I have generally adhered to the pragmatic scientific perspective, rather than the ontological one. The pragmatic view is that science is a human effort involving human thoughts, and their useful consequences in the realm of human experiences, not an attempt to comprehend the ultimate nature of reality. Within that restricted scientific framework human thoughts stand out, because

the entire conceptual structure is within human thought, and basically about human thought. Thus, within that tight framework, dogs, horses, and chimpanzees are treated as parts of the world that always evolve in accordance with the local mechanical Process **2**. On the other hand, science broadly conceived encompasses evolutionary biology, and that leads to the central question of under what conditions do the Process **1** and the associated Process **3** come into play. The problem here is primarily not that of creating an answer that will be compatible with the available data but rather that of creating data that will distinguish between a plethora of conceivable possibilities.

The existence of these outstanding issues emphasizes an important fact: the possibility of advancing our scientific understanding of consciousness that is opened up by requiring that understanding to be compatible with the laws of physics has just barely begun. Success of this program will require the efforts of many kinds of scientists other than physicists.

- Acknowledgements. I thank Don Lichtenberg and Joseph O'Neill for valuable suggestions pertaining to the presentation of the material described here.