

Bill Rowe wrote a review of my book *A Thousand Brains* for the *American Journal of Psychology*. Bill and his colleague Dominic Massaro, both with the University of California, Santa Cruz, asked if I would write a commentary on the review. I was happy to do so, you are reading the result of that request.

First, I would like to thank Bill for the effort he put into his review, it is remarkable. He not only covers what is in my book, he also summarizes several of our technical papers, providing a deeper insight into the science discussed in my book and a bridge to those who want to learn more. He even includes figures from some of our papers, although his are improved over the originals. Readers who are not ready for this level of detail can skim over these sections of the review and still get insights from the rest of the review.

I feel that the review is genuine in its praise and criticisms. I see not much to gain by commenting on the former or being picky about the latter. Instead, I would like to comment on a few unexpected things that I was happy to see in the review.

One theme that Bill brings up is the openness of our research. (I run a research team at a company called Numenta.) For example, we often post recordings of our internal research meetings, including meetings when we fail to make progress or when we openly debate each other. Openness is also why I included personal stories in the book. Science is a messy affair, with its good days and bad days. It doesn't progress linearly as it is often portrayed. To me, being honest about our struggles lends credibility when we claim to have made progress. I was pleased to see that Bill mentioned this and appreciates it.

Another thing I was pleased to see in the review was an emphasis on some of the foundational concepts underlying our brain theory. Our theory is called The Thousand Brains Theory, hence the title of the book. In the book, I emphasize the overarching concepts of the theory, such as how the brain learns by moving, the need for reference frames to store knowledge, and how the brain has thousands of models that work together. I deemphasized several low-level details that are essential to the theory but might be hard for an average reader to understand. Bill saw this as an opportunity and picked up where I left off. For example, he goes into detail about how we model individual neurons and discusses the important topic of sparsity, something that I didn't even mention in the book. His discussion is clear and conveys the importance of these ideas. I am glad he made the effort to describe these things.

Finally, I want to mention what Bill didn't cover in his review. The book has three sections, the first describes the progress we have made in reverse engineering the neocortex. The second section is about

machine intelligence based on brain theory. And the third section is about the future of humanity from the perspective of intelligence and machine intelligence. Bill Rowe's review covers only the first section. I am not surprised. When I wrote the book, I realized that it was almost as if I was writing three books. The three sections are united by the theme of intelligence, but not everyone who is interested in how the brain works is interested in intelligent machines, and vice versa. From the perspective of a psychologist, the first section is most relevant. But I want to take this opportunity to encourage readers to give all three sections their consideration.

Understanding how the brain works will have large consequences for psychology, education, and mental health. However, my team at Numenta is starting to build machines that work on these brain principles and the impact of these machines on society and our planet will be profound. There are simultaneously concerns about the risk of intelligent machines. These are the topics discussed in the second section. The book's third section is about the far future, and consequently it may appear to be less relevant given all the problems we face today. But I believe it is not too early to consider these issues. Long-term problems require long-term solutions. I will leave it at that.

I want to thank Bill Rowe once again for his comprehensive review of *A Thousand Brains* and the brain theory we have developed. The thought and care he put into it shows his deep interest in the topic and our theories. As a scientist and a writer, that is all one can hope for.

Jeff Hawkins. Email: jhawkins@numenta.com