Chapter 7
Comparison of the Mathematical Formalism of Associative ANN and Quantum Theory

Important note. From now on, in all the following Auxiliary Chapters and Appendices, all terms will be used exclusively in the context of ANN theory, i.e. the computational model, not in the context of neuroscience. Terms like "cell" or "neuron" could rather be understood formally (as in Perus, 2000a), i.e. as "formal neurons" or as processing "units" of connectionists, or could be identified (e.g., cardinal units) with whole cortical columns (For the purpose of model simplification).

7.1 MAIN NEURO-QUANTUM ANALOGIES AND THEIR INFORMATIONAL SIGNIFICANCE

It is best to introduce quantum associative nets by first presenting parallels between quantum processes and neural-net processes. Many mathematical analogies of the

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theory of Hopfield- like associative ANN and the quantum theory can be found. Because we know that our

ANN simulations perform well (e.g., Perus, 2002, and refs. within), we can infer, using the correspondence list below, about similar effective information-processing capabilities on the quantum level also. Here is an overview of neuro-quantum analogies:

1. Neuronal State-Vector ↔ Quantum Wave-Function:

In artificial neural network (ANN) theory, the state of the system of neurons[1] is described by $q(\vec{r}, t)$ which denotes the activity of an individual neuron (located at $\vec{r}$) at time *t*. Neuronal patterns are special neuronal configurations $\vec{q}$ which represent some meaningful information. In quantum theory, the state of the quantum system at location r and time t is described by the wave-function $\Psi\ (\vec{r}, t\ )$ (Bohm, 1954; Messiah, 1965). They both represent a state vector describing a parallel-distributed configuration of a complex system.

2. Neuronal State is a Superposition of Neuronal Patterns ↔ Quantum Wave-Function is a Superposition of Quantum Eigen-Wave-Functions:

A neuronal configuration q may be described as a linear combination of neuronal patterns $\vec{v}_k$ $(k = 1,..., P)$. *P* is the number of patterns represented simultaneously in the combination. Similarly, a wave-function Ψ can be described as a linear combination of eigen-states Ψ_k (”quantum patterns”):

$$q(\vec{r}, t) = \sum_{k=1}^{P} c_k(t) v_k(\vec{r}) \tag{7.1}$$

$$\Psi(\vec{r}, t) = \sum_{k=1}^{P} C_k(t) \psi_k(\vec{r}) \tag{7.2}$$

Neuronal patterns and eigen-wave-functions can represent some object of conscious experience on different levels. So, as opposed to other configurations, they represent informational states which have a meaning, because they are correlated with some environmental objects.

3. Both sets of pattern-vectors, $\vec{v}_k$ and Ψ_k, usually have the properties of Orthogonality (mutual scalar product is zero) and Normality (their ”length”

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