noise participates in desynchronization, infinite time is theoretically needed for desynchronization, since in the case of noise λ is zero.

Thus, we conclude that the cause of the damping is the existence of inherent chaotic oscillators. At the moment it is difficult to estimate the correct value of the orbital separation of the neural oscillations; it seems plausible, however, to estimate it as the order of one per one cycle of oscillation. Hence, as an order-estimation, the desynchronization takes 20~25 msec. Taking into account a cut-off-frequency of around 100 Hz in the experiments, the unit time of the observed oscillations should be 10 msec. Then λ is estimated at around 0.5 per unit time, which is a reasonable value from the viewpoint of dynamical theory. Thus, the reasoning of S&A must be amended in its "biological interpretation" of their theory. Actually, our preliminary numerical simulation of the chaotic model for cortical neuro-oscillations shows much faster desynchronization than the theoretical estimation. In most cases, a time less than one-half cycle of oscillation is required.

The neural (de)synchronization is a more rapid process, so the synchronized state cannot be sustained for the few hundred milliseconds supposed by S&A. It is plausible that the neural synchronization makes rapid judgments by feature detection (Gray et al. 1989), or by initiating cognitive processes (Koerner et al. 1987). Throughout the process of thinking, including "reflexive reasoning," a chaotically itinerant motion among "attractors" (we call it "chaotic itinerancy") seems much more plausible, one that can generally appear in systems with large degrees of freedom (Davis 1990; Ikeda et al. 1989; Kaneko 1990; Tsuda 1991). In such itinerant motions, the system is temporally expressed as a "small" system, where "small" means the participation of only a few dominant modes accompanied with a number of inactive modes that could be active at the next period of the process. These modes can be activated as a chaotic mode by a large number of interactive neurons (Freeman 1987; Skarda & Freeman 1987). The temporal reduction of the number of active modes must stem from spatial coherency (Freeman 1991), but not from "phase locking."

Related to the above discussions, I would also like to comment on the possibility that von der Malsburg's model for the cocktail party effect (von der Malsburg & Schneider 1986) has nothing to do with the neural synchronization observed in the experiments. The cocktail party effect is more dynamic and complex, hence its explanation needs such a mechanism of dynamic information processing that both coherence in space and chaotic itinerancy in time play a role in sustaining memories during a period of a few hundred milliseconds to a few seconds, and in searching and linking appropriate items in the LTKB (long-term knowledge base). Here, spatial coherence is necessary for the dynamic link of neural activities over wide cortical regions, especially related to auditory processing, short-term memory, and thinking. Chaotic itinerancy creates the dynamic sustaining of memories and the processing of meaning, namely, a dynamic link of memory items (Tsuda 1991). We have shown that a coupled chaotic system and a chaotic neural network, which can exhibit chaotic itinerancy, sustain any information fed from outside by means of propagating local chaotic activities despite the elementary chaotic process (Matsumoto & Tsuda 1987; Tsuda 1992).

In addition, I recommend S&A to the following literature concerning the roles of neural synchronization. It has been hypothesized, for example, that synchronization of neural oscillations may participate in the processes of rapid interpretation, image synthesis, relation formation in knowledge base, and parallel byte-formation in the sequential flow of visual information (Holden & Kryukov 1991; Koerner et al. 1987; Reitboeck et al. 1990; Shimizu & Yamaguchi 1987). Furthermore, concerning dynamic features in coupled oscillator systems, studies by "coupled map lattices" (Kaneko 1989) and

Dynamic-binding theory is not plausible without chaotic oscillation

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Dynamic binding of knowledge is one of the essential processes for both "reflexive reasoning" and "reflective reasoning" in the human cognitive system. Shastri & Ajjanagadde (S&A) deal with reflexive reasoning in terms of connectionist models of dynamic binding. This approach may assure a plausible model of the process of dynamic computations. Indeed, S&A propose a reasonable model of reflexive reasoning. To justify the model biologically and from the viewpoint of dynamical theory, however, they refer to the synchronization or phase locking of periodic oscillations that was observed in the visual cortex of the cat (Eckhorn et al. 1988; Gray et al. 1989) and monkey (Kreiter & Singer 1992). This commentary is devoted mainly to the question: Could synchronized or phase-locked periodic oscillations provide a plausible basis for the dynamical model of reflexive reasoning?

In the Gray et al. (1989) experiments, rapid damping of both auto- and cross-correlation functions was found. There are two possible causes of the damping: One is due to inherent chaos, and the other is perturbation by noise. The latter possibility can be rejected. We see an apparent feature of the observed correlations, namely, time symmetry of autocorrelations but time asymmetry of cross-correlations (see Fig. 1–3 in Gray et al. 1989). When the periodic oscillation is perturbed by noise, cross-correlation between two such oscillators should be symmetric in time as well as in autocorrelations because of the statistically stationary motion. The assumption of the existence of chaotic oscillators, however, leads us to a reasonable explanation of the distinct feature of correlations that a transient process accompanied by desynchronization between chaotic oscillators brings about time asymmetry of cross-correlations, preserving time symmetry of autocorrelations due to inherent stationary chaotic motion.

In addition, we examine whether or not desynchronization can be achieved by noise, since there is still a possibility of the participation of noise in the transient process, which may give rise to asymmetric cross-correlations. Desynchronization is due to a separation of corresponding orbits and the degree of separation can be measured by the degree of orbital instability indicating an exponential separation of nearby orbits. The Lyapunov exponent is the average rate of this separation in unit time. Since desynchronization should start unless all components of the Lyapunov spectrum are negative, the value of the nonnegative Lyapunov exponents determines the degree of desynchronization. The contribution especially of the largest one, λ, will be dominant. It is reasonable that the time necessary for desynchronization is of the same order as the inverse of the largest Lyapunov exponent, $O(\lambda^{-1})$, since λ^{-1} is the time necessary for the e magnification of a tiny initial separation. If "phase dynamics" (Kuramoto 1991) should not be overlooked. The latter concerns mainly a periodic and synchronized regime, and the former treats various kinds of complex dynamic regimes.

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