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## - PRESS RELEASE -

### **Brain mechanism for regulation of patience**

#### **— Activation of dorsal raphe serotonin neurons facilitates waiting behavior for delayed rewards —**

Okinawa, Japan, January 12, 2011 — A new role of serotonin in regulation of patience has been clarified by researchers at the Okinawa Institute of Science Technology Promotion Corporation (OIST). The group of researchers, Drs. Katsuhiko Miyazaki, Kayoko Miyazaki, and Kenji Doya, found that serotonin neurons in the dorsal raphe nucleus increased their activity while rats waited for delayed food or water rewards. (*Journal of Neuroscience*, published January 12, 2011).

Would you stand in line for a popular restaurant or take a quick bite at a burger shop next door? Should we keep waiting for a bus caught in a traffic jam or start walking to the station? Having to decide between patiently waiting for something to happen and giving up to try something else is a common problem in our daily life. How does the brain decide between a desired outcome in the future, or a less attractive alternative right now? Animal behavioral studies using rewards such as food or water have shown that depletion of the neurotransmitter serotonin in the forebrain leads to more frequent choices of small, immediate rewards than large, delayed rewards, a behavioral characteristic known as impulsivity. However, up to now there was no direct evidence showing that serotonin neural activity is enhanced during the wait for delayed rewards.

To examine the role of the neurons that release serotonin in the forebrain in tolerance for delayed rewards, the group first used the microdialysis technique to measure serotonin and dopamine levels in the brain while rats moved back and forth between a food site and a water site. In contrast to when food or water rewards were given immediately after the rat approached the food or water delivery site, the level of serotonin released from these neurons significantly increased when the rats had to wait up to 4 seconds before reward delivery (reported in the *European Journal of Neuroscience*, January 11, 2011). In the second, more recent study, the group recorded the electrical activities of individual serotonin neurons in the dorsal raphe nucleus, the major site of neurons that release serotonin into the forebrain, while rats performed a similar task. The researchers discovered that serotonin neurons increased their firing while rats waited for food and water rewards at the reward sites. When the delay was extended, the serotonin neuron firing persisted until reward delivery. In rats that gave up waiting, serotonin neuron firing dropped before the rat left the reward sites. These results suggest that increased serotonin release in the brain by increased firing of the serotonin neurons facilitates waiting for an expected reward and that the extent of serotonin neuron firing regulates whether an animal continues to wait patiently for delayed rewards or gives up.

The present finding provides an important clue to the mechanisms of several very common mental disorders, such as depression, addiction, and attention-deficit hyperactivity disorder (ADHD), in which impulsivity is a major symptom. Furthermore, unraveling the mechanics of the activation of serotonin neurons, which are central to the regulation of patience, can promote a better understanding of human emotions and even lead to the development of more human-friendly software and IT devices.

Journal articles:

1) Journal Name: *Journal of Neuroscience*, January 12, 2011 7 a.m. (Japan time)

Online version: January 12, 2011

Article Title: Activation of dorsal raphe serotonin neurons underlies waiting for delayed rewards.

Authors: Katsuhiko Miyazaki, Kayoko W. Miyazaki, Kenji Doya

2) Journal Name: *European Journal of Neuroscience*, January 11, 2011

Online version: <http://dx.doi.org/10.1111/j.1460-9568.2010.07480.x>

Article Title: Activation of central serotonergic system in response to delayed but not omitted rewards.

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