AUGUST 10 & 11

Kauro Amano

"Toward the neural cause of visual perception"

&

Shinji Shimoto

"Experimental approaches to deciphering perceptual experience"

(Report by Maksoda Akhter, Takuya Niikawa, Satoshi Nishida, James Wallbridge, & Eran Agmon)

ISSA report on the Amano and Nishimoto lectures and lab tours

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On August 10th, 2015, Professors Kauro Amano and Shinji Nishimoto of CiNets at Osaka University presented their research to the ISSA summer school. The following day, August 11th, they show us their labs at Osaka University. This report summarizes these experiences.

1. Kaoru Amano

Kauro Amano conducts research aimed to pick out the neural *causes* of perception. Current neuroscientific research mainly focuses on the neural *correlates* of mental states/activities, partially because it is methodologically more difficult to specify the neural causes of these states/activities. In order to work this out, Amano conducted three experiments. The first experiment aims to demonstrate that alpha oscillation is a clock signal for visual processing. In the second experiment, he tries to find the neural causes of color perception. The aim of the third experiment is to pick out the neural causes of perceptual confidence. In what follows, we will first explain these experiments as he presented them during the ISSA summer school. Then, we will describe the lab tour he gave us at Osaka University.

In relation to the neural causes of perception, Amano discussed alpha oscillation as a possible clock signal for visual processing. The functional role of neural oscillations, of which alpha waves cover the 8-13 Hz frequency range, is still unclear. Amano suggested that alpha oscillations may arise through interactions between the brain's ventral and dorsal pathways, and determines the characteristic transmission time between them. We saw one experiment where a visual illusion arises in subjects, in which they perceive a jitter of a visual stimulus that in reality has no jitter. Amano demonstrated that the perceived frequency of jitter matches the subjects' alpha frequency recorded with magnetoencephalography (MEG). Interestingly, the peak alpha frequency during this perception was highly correlated with that of the resting state. This suggests that the alpha frequency of individuals' brains is a neural cause for the perceived frequency of jitter in the illusion.

Next, Amano introduced a procedure called decoded neurofeedback (DecNef) as a tool to study the perceptual effects of specific brain activity patterns. A brain pattern (such as the pattern associated with the presentation of the color red) is first identified as a desired target, the subject is put in a brain scanner (such as fMRI), and his brain signal is recorded. Algorithms determine how close the decoded signal is to the desired target pattern, and visual feedback is sent back to the subject; in Amano's case, the size of a dot in the middle of a screen correlated with how close the brain signal was to the target pattern. The subject is asked to regulate the visual feedback, by trying to make the dot as big as possible. What the subject does not know is that this changes his brain, and induces an association between the target pattern and other stimuli presented in conjunction with the neurofeedback-modulated dot. In his lecture, we saw evidence that this can influence both the visual perception of color and the subject's confidence of visual assessment.

In the Amano lab tour, we were taken to the university's MEG system, and were then presented with an experiment that demonstrated the enormous possibilities of DecNef. In the experiment, DecNef was used to extinct fear memory. Typically, fear memories are hard to extinguish because exposure to a fear stimulus will lead to an aversive response, and even if exposed to the stimulus, the fear response can return later. To extinguish a specific fear memory, Amano and his colleagues identified a neural pattern associated with the memory. Subjects were then put in an fMRI, and DecNef was used to activate the memory's target pattern. Because the feared stimulus is not present, the aversive response is not initiated, and the brain can grow accustomed to the target's activation. This can lead to positive associations, such that at a later time the activation of the target pattern will no longer induce an aversive response.

In summary, Amano and his colleagues have demonstrated the neural causes of several types of perception. This can be regarded as an important contribution to the study of perceptual consciousness. Moreover, their research has not only theoretical importance but also practical value, and can be used to help patients who suffer from post-traumatic stress, and need assistance with reducing the the harmful effects of traumatic memories.

2. Shinji Nishimoto

Humans are constantly flooded with complex, diverse, and dynamic visual information in naturalistic situations. To understand how the brain works under such situations, Shinji Nishimoto and his colleagues have conducted functional magnetic resonance imaging (fMRI) experiments using natural visual stimuli. In particular, they built quantitative models that explain the relationship between visual stimuli and evoked brain activity. This approach allows not only to reveal the quantitative representation of information in hierarchical visual processing of the brain, but also to decipher individual's perceptual/cognitive experiences from their brain activity. Nishimoto introduced us to his modeling approach and recent findings through his lecture and lab tour.

In his lecture, Nishimoto presented his approach to decode and reconstruct people's dynamic visual experiences using fMRI and predictive computational models. There is a lot of information in the brain scans obtained by fMRI. To analyse these patterns, the brain is segmented into little boxes called voxels — the three-dimensional equivalent of pixels — and researchers typically look to see which voxels respond most strongly to a stimulus, such as seeing a face. By discarding data from the voxels that respond weakly, one can conclude which areas are most strongly correlated in the brain's processing of information. Subjects are exposed to a training set of natural videos, and their brain states are recorded. Algorithms find correlations between the videos and the brain states. Next, the subjects are exposed to a prediction set of natural videos they did not see previously, and their brain states are again recorded. From these recording, the algorithms can reconstruct the visual content of the prediction set. This reconstruction can be seen as a way to read peoples brains and infer their perceptual experience.

Nishimoto used this approach to show that brain regions represent the world in a fixation-independent manner. During natural visual search, humans move their eyes to bring target objects to the center of their visual field, the point of greatest visual acuity. However, eye movements effectively alter the visual stimulus that falls onto our retinas, and hence they can potentially confound the results of visual attention studies. For this reason, Nishimoto recorded participants' eye positions during the experiments, and showed that regardless of where their eyes were pointed, the same higher brain regions became active.

A helpful way to reinforce concepts presented in Nishimoto's presentation was a visit to his lab at CiNet in Osaka which features a 7T fMRI scanner with which his data is recorded. Nishimoto prepared a room of activities in which we could interact with the data his collaborators have generated. The most interesting experience was an interactive image of the brain depicting various brain regions. Clicking on a specified region warped a corresponding image in semantic space in a way that highlighted the areas of semantic space experimentally verified to be activated by that region. This allowed us to observe how stimuli corresponding to dozens of different categories influenced the brain's activation. This kind of research may assist our understanding of learning deficiencies, disease and the problem of decoding subjectivity.

The modeling approach with fMRI introduced by Nishimoto has wide-ranging implications. His studies shed light on how our perceptual, cognitive, and unconscious experiences are processed and represented in the brain. This could reveal quantitative representation at each level of hierarchical visual processing in the human brain. In addition, neural decoding techniques offer a powerful tool for visualizing subjective experiences, and he argued that these techniques have a potential to uncover unconscious experiences via the inference from brain activity. For more practical applications, it can potentially allow scientists to observe and decode the minds of people who cannot communicate verbally, such as stroke victims, coma patients, and people with neurodegenerative diseases. Finally, it can also provide groundwork for brain-machine interface, which may someday allow people with cerebral palsy or paralysis, for example, to guide computers with their minds.