A computational model of conscious and unconscious level processing

Consciousness is module combinations formed on the fly

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Abstract

We firstly examine the characteristics of conscious level processing, and point out a distinctive feature: new action patterns and new thought patterns can be composed on the fly without a training period.

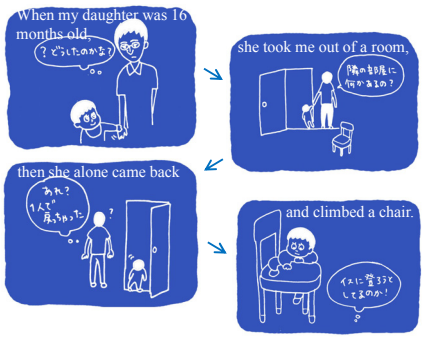
Then we propose a computational model consists of many modules each of which has elemental function such as recognition, prediction, and action selection. Complicated processing can be realized by combining these modules. The inputs/outputs of the modules gather around working memory. Each input/output has a gate, and the states of the gates are controlled by the modules.

While useful action patterns and thought patterns are learned by trial and error on the unconscious level, new action patterns and thought patterns are formed on the fly on the conscious level. New action patterns and thought patterns can be created either by imitation, by analogy, by planning, or by being told.

The poster reports the computer simulation results of learning action patterns and thought patterns by trial and error, and also describes research plan toward forming novel module combinations, namely novel thought patterns, on the fly by being told.

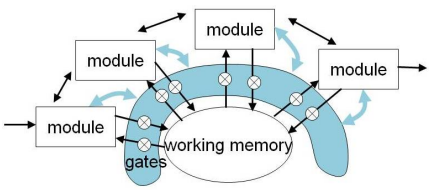
Introduction

Conscious level processing has a distinctive feature: new action patterns and new thought patterns can be composed on the fly without a training period.



Computational model

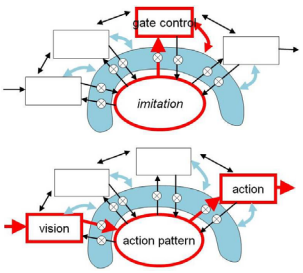
We propose a computational model of conscious and unconscious level processing.

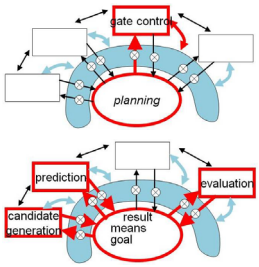


The model consists of many modules each of which has elemental function such as recognition, prediction, and action selection. Complicated processing can be realized by combining these modules. In order to change the combination freely and variously, a place where the inputs/outputs of the modules gather seems necessary, which we call working memory. Each input/output has a gate, and the states of the gates are controlled by the modules.

Imitation and planning are two basic thought patterns that generate novel action patterns without a long training period.

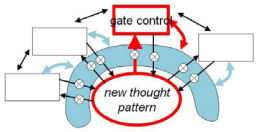
Imitation is a thought pattern consists of recognition and action. As an example, a schema of visual imitation is shown in the right figure. The specific combination of the recognition and the action module is formed by a gate control module which is fed with imitation *input.*





Planning is realized by combining an action candidate generation module, a prediction module, and an evaluation module. The specific combination of the modules is formed by a gate control module which is fed with planning *input.*

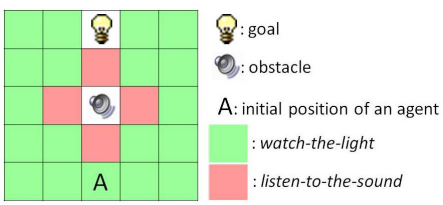
If we can provide the working memory with the representation of a new thought pattern, and if there exists a gate control module which can interpret the representation, the new thought pattern can be generated as a combination pattern of modules.



It is important to note that the newly acquired thought patterns can be used for generating further new action or thought patterns, and that the circular structure of this kind will give rise to the emergent properties of our model.

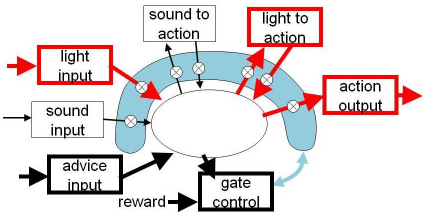
Computer simulation: task

An agent learns to reach a goal (light source) avoiding an obstacle (sound source). Although the task is simple, the learning is not easy because the agent must find an appropriate module combination pattern as well as appropriate actions.



The agent has light sensors and sound sensors, and perceives the direction of the goal and the obstacle. It receives a reward when it reaches the goal, and a punishment when it runs into the obstacle. It also receives an advice, watch-the-light *on the green tiles and* listen-to-the-sound *on the red tiles, at each position. The action of the agent is either move forward, backward, rightward or leftward.*

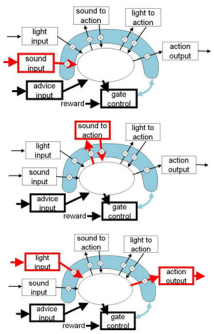
Computer simulation: model



The gate control module learns the combination pattern of five modules: sound input, light input, sound to action, light to action, and action output, in order to get as much reward as possible. Sarsa, one of the reinforcement learning algorithms, and ε-greedy policies were used for the simulation.

Computer simulation: results

The red lines in the above figure show a typical module combination pattern which was formed by trial and error when the advice, *watch-the-light*, was given. Note that the three modules in the led lines operate in parallel, which means that the learning system found the idea of **pipelining** which increases the throughput of the system.



The left figures show another typical example of module combination pattern which was formed when the advice, listen-to-the-sound, *was given. The bottom figure indicates that the gate from the light input module opens simultaneously with the gate to the action output module. This kind of speed-up technique is well known as* ***speculative execution*** *in computer science.*

The simulation demonstrated that the model successfully learned module combination patterns after a long training, and that the learned patterns are labeled with given advices. The learned patterns, however, depend strongly on environments in which the learning proceeds, and they cannot be used on other occasions as they are.

Conclusion

The poster proposed the computational model of conscious and unconscious level processing that can generate novel action patterns and thought patterns by trial and error.

We are trying to build reusable thought patterns, namely reusable module combination patterns, which are labeled with comprehensible symbols such as *look!*, *listen!*, *hurry-up!*, *with-care!*. We hope that new thought patterns can be built on the fly utilizing the reusable thought patterns with comprehensible labels.

For further information

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