Can we perceive animacy from artficial agents? -A brain ERP study using a motion Turing Test-

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Abstract: We investigated neural mechanisms working for animacy perception by recording Event-Related Potentials (ERPs) under a motion Turing test. Observing an agent, either of an animate thing (turtle) or an inanimate thing (robot), which was covered in a box and moving, participants were asked to answer whether they felt the agent in the box as animate or inanimate. We compared ERPs when they felt it as animate with those when they felt it as inanimate. As a result, we found that the brain activity in left infero-frontal region was significantly different between the two conditions. Next, we implemented the different types of motion to a robot and examined whether ERPs differed across the different types of the robot's motion. We found that the brain activity in right occupito-temporal region was varied in accordance with the lifelikeness of agent's motion. From these findings, we discuss the possibility of animated agent that is adequate for our cognitive mechanisms.

1 Introduction

One of the goals of robotics research is to create a lifelike robot. Lifelikeness is an important factor to enable a robot to interact naturally with people. However, the robots intended to achieve lifelikeness confront a problem called "Uncanny Valley" [1], a hypothesis that high, though not perfect, levels of realism cause a response of revulsion among human observers. It is thus difficult to create a lifelike robot by designing a robot to resemble a real creature in appearance or movement. To realize lifelikeness in robot, it seems to be necessary to investigate our cognitive mechanism for perceiving animacy and to provide a robot with the features that may appropriately activate our cognitive mechanism working for animacy perception [2, 3], i.e. recognition of lifelikeness.

In this study, we investigated the brain activity for animacy perception in order to examine the cognitive mechanisms underlying animacy perception.

Previous studies suggest that two candidate neural substrates are working for animacy perception: One is Mirror System (MS) and the other is Social Network System (SNS) [4]. MS is said to be biologically tuned [5, 6]; the MS is activated when we imitate another's actions [7], feel empathy [8], or understand another's intention [9]. Besides, recent studies have suggested that MS can be activated even when we observe robotic actions [10, 11]. So the activation of MS is said to be related with attributing goals of action [12]. On the other hand, many studies suggest that SNS, especially rSTS which is a part of SNS, is activated when we observe the motions of an animated geometric figure [13, 14]. SNS is also shown to be activated when we detect eye-direction, face and biological motion [15]. So the activation of SNS is said to be related with detecting animate features [12]. Recent studies suggested that the activation of MS is elicited by top-down process while SNS is elicited by bottom-up process [16].

Therefore, previous studies have suggested that both MS and SNS are related to animacy perception and, at the same time, that these systems may take different roles in animacy perception. However, it is unclear what specific roles in animacy perception these systems take. Previous studies above led us to hypothesize that MS might take the role of attributing animate state to the objects while SNS might take the role of analyzing objects' animate motion.

To verify this hypothesis, we investigated the brain activity when attributing animacy and analyzing animate motion by employing a motion Turing test [17]. In a motion Turing test, observers are asked to distinguish between animate and inanimate things only by observing their motions. So we could investigate the subjective attribution of animacy and analyzing object's motion independently in the motion Turing test using real animate and inanimate things.

We compared the brain activity in the condition that participants subjectively regard an object shown as an animate thing with in the condition that they subjectively regard the same object as an inanimate thing. To investigate the brain activity, we analyzed ERPs' differences between the conditions (Experiment 1). This enabled us to examine the neural mechanism that correlates with subjective attribution of animacy to the object.

In addition, we analyzed ERPs' differences among the objects that move differently in order to how brain activity changed when the degree of similarity between robot's motion and turtle motion increased (Experiment 2). This enabled us to examine the neural mechanism that correlates with our analysis of animate motion which might elicit animacy perception.

By these two experiments, we investigated whether animacy perception consists of two independent neural mechanisms.

2 Experiment 1

2.1 Purpose

In this experiment, we compared ERPs in the condition that participants subjectively felt an object shown as animate with those in the condition that they subjectively felt the object as inanimate, regardless of whether the object was a real animate thing or a robot.

2.1 Method

Thirteen participants (4 females and 9 males, 27.3±5.1 years old) participated in the experiments. All participants were right-handed and normal or corrected-to-normal vision.

A turtle and a small robot (e-puck [18]) were used as a real animate thing and an inanimate thing (a robot), respectively.

Participants were seated in front of a device, controlled by PC, which could limit participants' view. First, participants were asked to observe an object (a turtle or a robot) for 2 seconds by unblocking their views; the object was covered in a small box, whatever it was a turtle or a robot, so that participants could not judge by appearance whether the object was a turtle or a robot. The robot's motion is almost the same as the turtle's motion in that both the average and validity of speed and the average size of direction changes in the robot's motions are the same as those in the turtle's motions.

Their views were then blocked and they and were asked to answer on 5-points scale whether they felt that the object was a real animate thing or an inanimate thing (motion Turing Test). After that, their views were unblocked again and they were asked to reach and touch with right arm the same object. We recorded their EEG activity during this reaching action. Each participant performed 200 trials of observing and reaching an object (100 trials for turtle conditions and 100 trials for robot conditions). The experimental order of the conditions was randomized.

We used NuAmp and Quik-Cap (Neuroscan Systems) to record EEG activities; EEG activities were recorded using the extended 10-20 system, from 32 electrode sites. The analysis window extended for 600 ms (100ms before and 500ms after the onset of reaching movement). Averaging EEG waveform by setting onset of reaching movement as reference point, we calculated ERPs. The Onset time of reaching movement was confirmed by EMG measured at upper arm.

We compared ERPs in the condition that participants gave the answer that the object appeared an animate thing (4 or 5 in the 5-point scale) with those in the condition that they gave the answer that the object appeared an inanimate thing (1 or 2 in the 5-point scale) in order to investigate the brain activity for attributing animacy.

2.3 Result and Discussion

Results are shown in Fig. 1. Fig. 1 shows, at 250ms around in left infero-frontal region, that the amplitude of the averaged ERP of the condition that participants regarded the robot as inanimate thing (indicated by 1 in Fig. 1) is less that the ERP of the condition that participants regarded the robot as animate thing (indicated by 2 in Fig. 1) and the ERP of the condition that participants regarded the turtle as inanimate thing (indicated by 3 in Fig. 1). This indicated that the amplitude of ERP in the condition participants subjectively felt an object shown as animate is less than that in the condition that they subjectively felt the object as inanimate. One-way ANOVA revealed that the amplitude of ERP was significantly different between in the condition (F (2,11) = 4.67, p < .05). This result suggests that the activation in this region was elicited by the attribution of animacy to an object shown. Because MS is said to locate at infero-frontal region, the observed difference in amplitude in left infero-frontal region is considered to be originate in MS.

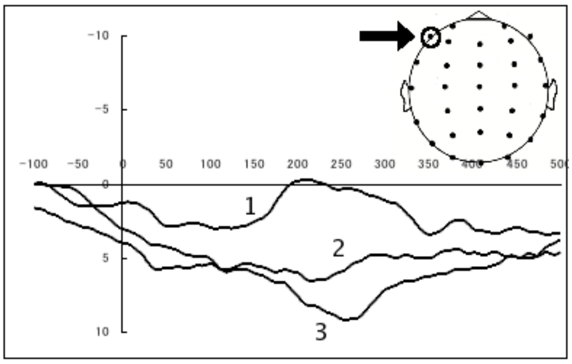

Fig.1 Averaged ERPs in left infero-frontal area are shown (F7 electorode in 10/20 system). Numbers given to the respective ERP waves indicate the corresponding experimental conditions: 1 means the condition that the object was a robot and was regarded as an inanimate thing; 2 means the condition that the object was actually a robot but was regarded as an animate thing; 3 means the condition that the object was a turtle and was regarded as an animate thing.

3 Experiment 2

3.1 Purpose

In Experiment 2, we compared ERPs among different robot's motion. We investigated how brain activity changed when the degree of similarity between robot's motion and turtle motion increased.

3.2 Method

The experimental setting except the robot's motion was the same as described in Experiment 1. To control the degree of similarity robot's motion and turtle's motion, either of the following four types of the robot's motion were implemented to the robot: The first motion (indicated by 1 in Fig. 2) was straight motion that was the same as turtle's motion in average speed; the second motion (indicated by 2 in Fig. 2) was motion that was the same as turtle's motion in average and validity of speed and average size of direction changes; The third motion (indicated by 3 in Fig. 2) was motion that was the same as turtle's motion in temporal property; the forth motion (indicated by 4 in Fig. 2) was motion that was the same as recorded turtle's motion. The similarity with turtle's motion is increasing in ascending order. Thus five conditions (robot's motions (1-4) and real turtle (5)) were settled in this experiment.

We compared the ERPs in these five conditions (a robot with either of the four types of motion or a real turtle) in order to investigate how brain activity changes when the degree of similarity of object's motion and animate motion increases. Each condition was performed 40 times by each participant (200 trials in sum). The experimental order of the conditions was randomized.

3.3 Result and Discussion

Results are shown in Fig. 2. Fig. 2 shows, at around 250ms in right occupito-temporal region, that the amplitude of the averaged ERP decrease as the condition numbers of ERPs increase. This indicates that the amplitudes of ERP in this region decrease as the object's motion resembled the turtle motion more. One-way ANOVA revealed that the amplitude of the ERP at 250ms. were significantly different among the conditions (F (4,11) = 3.547, p < .05). This suggests that the activation in this region is elicited by the similarity between the observed motion and the motion which an animate thing shows. Because rSTS locates at occupito-temporal region, the observed difference in occupito-temporal region is considered to originate in rSTS.

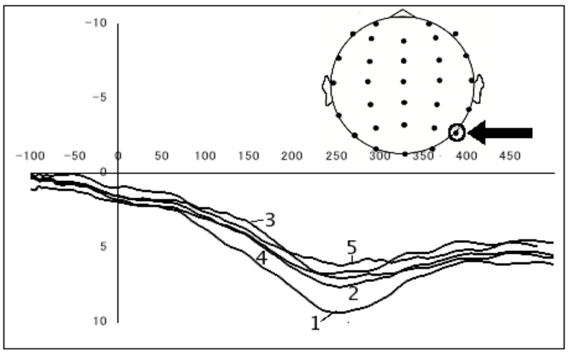

Fig. 2 Averaged ERPs in right occupito-temporal region (P8 electorode in 10/20 system) are shown. Numbers given to the respective ERP waves indicate the corresponding experimental conditions: In the condition 1-4, the object was a robot while, in the condition 5, the object was a turtle. The bigger the number is, the more animate the object's motion is.

4 General Discussion

We found that subjective animacy attribution was related with the activity in left infero-frontal region while analysis of animate motion was related with the activity in right occupito-temporal region. This result suggests that neural correlates of animacy perception at least contains of two subsystems, which involves left infero-frontal and right occupito-temporal regions. This means that animacy perception contains two independent neural mechanisms, i.e. MS and SNS, which undertake attribution of subjective animacy and analysis of animate motion, respectively.

Waytz, Gray and Wegner [19] state that the feeling of revulsion in “Uncanny Valley” occurs when the perception of mind (animacy) is disturbingly incomplete because the capacity of action is perceived though the capacity of sense or feeling is not perceived. This suggests that the feeling of revulsion in “Uncanny Valley” is caused by an observer’s analyzing animate motion without attributing animacy. We speculate that the balance of activations in these two mechanisms may contribute to our recognizing lifelikeness in a robot.

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