# Explanation for Human Sensitive Response to a Humanlike Agent Focusing on Amygdalar Function

TAWATSUJI Yoshimasa[1] MURAMATSU Keiichi[2]
KOJIMA Kazuaki[3] MATSUI Tatsunori[2]

[1] Graduate School of Human Sciences, Waseda University
[2] Faculty of Human Sciences, Waseda University
[3] Learning Technology Laboratory, Teikyo University

**Abstract:** *The uncanny valley* is a critical issue in the research field of Human-Computer Interaction. While interacting with an agent highly similar to a real human, people perceive it as a human and subsequently as a non-human. The dual-pathway of emotion can provide an explanation for these two kinds of human perception to the agent, and the inconsistency of processed information, *human* and *non-human*, can cause the occurrence of the uncanny valley. We propose a model of how the inconsistency can occur based on the dual-pathway of emotion and the function of the amygdala. According to the model, the inconsistency can the most likely occur when an agent looks almost human.

## 1 Introduction

In the research of Human-Computer Interaction, the uncanny valley [1] is a critical issue in designing an appropriate appearance of a humanlike agent. Although human familiarity toward an agent increases as the agent gets more similar to human, it drastically decreases to the bottom of a valley when the agent is considerably similar to a real human (Fig.1).

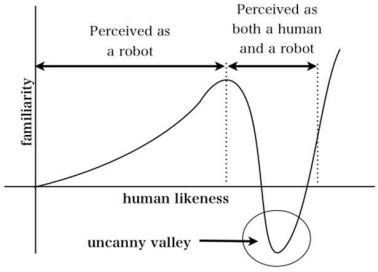


Figure 1: The concept of the uncanny valley

According to MacDorman *et al.* [2], humanlike agents are not human but shares some human qualities, located on *category boundaries*, where they are percieved as both a human and a non-human. In addition, Tawatsuji *et al.* [3] investigated a human response during watching faces of CG-modeled agents and a person, focusing on fixation time of eyes on the faces. The results led to an assumption that human perceives a humanlike agent in two processes whose first output is a human and whose second a non-human. The inconsistency of these human responses to humanlike agents can be a critical factor of the human uncanny response toward them.

Some studies have indicated that the uncanny responses occur in infants [4] and macaque monkeys [5]. These results suggest that the uncanny valley is a system which is not only innate but also common to the primates. Mori [1] regarded the uncanny responses as a human self-preservation. Thus, it is valid to focus on functions of the brain which are common beyond spieces, especially those on the phylogenetically old region. In this paper, we propose a model to give an explanation for the human peculiar responses to a humanlike agent, focusing on the amygdalar function, based on dual-pathway of emotion [6].

## 2 Dual-pathway of emotion and the function of the amygdala

From the standpoints of anatomy and neurophysiology, LeDoux [6] supposed that a dual-pathway and the amygdala play an important role in human instinctive appraisal to threating objects. Information from an external stimulus reaches the amygdala in two different ways; by a rapid but imprecise road directly from the thalamus (low road), and by a slow but precise road via the cortex (high road). The roughness of information transmission of the low road depends on the features of the thalamus. On the other hand, information transmitted to the amygdala via the cortex is processed in detail. Therefore, the amygdala is responsible more widely to information by the low road. The inconsistency of an amygdalar response can be a trigger of the occurrence of the uncanny valley (Fig.2).

## 3 Model for amygdalar response

In this section, we propose a model of the probability of occurrence of the inconsistency between two pieces

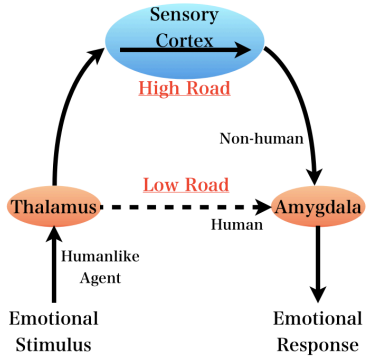


Figure 2: Dual-pathway of emotion[6]

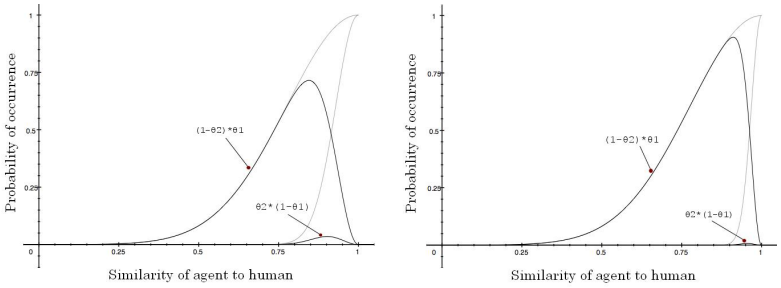


Figure 3: Probability of occurrernce of the inconsisitency according to the range of an amygdalar response on high road (Left: $\sigma_2^2 = \frac{1}{100}$, Right: $\sigma_2^2 = \frac{1}{500}$)

of information transmitted to the amygdala. In human information processing, the amygdala makes a senstive response to human faces. Therefore, this sensitivity of an amygdalar response to the agents increases as an agent gets more humanlike. We define this sensitivity as the probability of occurrence of a certain amygdalar response. Let $s \in [0,1]$ be similarity of an agent to human and $p(s)$ be the sensitivity of an amygdalar response, respectively. In particular, we define $\theta_1 \in [0,1]$ as the sensitivity of an amygdalar response to information from the low road, and $\theta_2 \in [0,1]$ as that from the high road, where $\theta_i (i = 1, 2)$ is defined as a function of $s$,

$$\theta_i(s) = \exp\left(-\frac{(s - s_{\max})^2}{2\sigma_i^2}\right) \quad (1)$$

Here, $s$, a similarity of a humanlike agent to human, is equal to 1 when the agent is completely human ($s_{\max} = 1$) and in this case, the sensitivity of an amygdalar response is expected to be the highest. $\sigma_i^2$ refers to the width of ranges in which the amygdala responds to information on each road, and it can be set $\sigma_1 \gg \sigma_2$.

The inconsistency of information on the amygdala can be two types. Case (A) indicates that the amygdala responds to the information on the low road whereas it does not on the high road. Case (B) indicates that the amygdala does not respond to the information on the low road whereas it does on the high road. The possibility of occurrence of these cases are denoted as following equations:

$$p^* = \begin{cases} (1-\theta_2)\theta_1 & \text{case(A)} \\ \theta_2(1-\theta_1) & \text{case(B)} \end{cases} \quad (2)$$

Figure 3 shows graphs which illustrate the equations (2), where $\sigma_1^2$ is fixed ($\sigma_1^2 = \frac{1}{10}$) and $\sigma_2^2$ is varied ($\sigma_2^2 = \frac{1}{100}, \frac{1}{500}$). It is indicated in Case (A), the lower $\sigma_2^2 (= \frac{1}{500})$ provides the higher value of $p^*$. On the other hand, in Case (B), the overall value of $p^*$ is much smaller than that in Case (A). The maximum value of $p^*$ is given at the point of the highest similarities in the both cases.

# 4 Discussion and Conclusion

In this study, we hypothesized that the dual-pathway of emotion and the amygdalar function play an essential role in the occurrence of the uncanny valley, and we calculated the possibility of the occurrence of the inconsistency, focusing on the sensitivity of an amygdalar response to perceived information. This inconsistency is enhanced by the increase of differences between the sensitivities of two amygdalar responses, and it gets maximized at the highest similarity of an agent. One important future work is to clarify relationships between the amygdala and other brain parts, such as the hippocampus and how the uncanny valley dynamically occurs.

# References

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