Evaluation of Impressions Given by Life-like Agents' Ambiguous Nonverbal Expressions

Jun-ichi Imai*, Takahiro Ohkubo*, and Yu Yamada*

** Chiba Institute of Technology, imai@cs.it-chiba.ac.jp*

Abstract: Nonverbal expressions such as facial expressions and gestures are often used in interpersonal communication. It is considered that expressing information ambiguously is effective to avoid the risk latent in the interpersonal communication. Humans tend to interpret such ambiguous expressions for their own convenience, and they even positively utilize this tendency in their communication. In recent years, life-like agents which can interact with humans have been increasingly studied. In order to achieve smooth communication with humans, such agents are also required to use the ambiguous expressions as efficiently as humans. In this paper, as the first step to realize such agents, we investigate impressions given by the life-like agents' ambiguous nonverbal expressions. First, we investigate differences among impressions given by the agents' "ambiguous," "clear" and "expressionless" expressions in facial expressions and gestures. Second, we investigate effects of the context in communication between humans and the agents on interpretation of the agents' ambiguous facial expressions. Based on the experimental results, we discuss the effectiveness of the agents' ambiguous nonverbal expressions.

Key words: Life-like agents, Nonverbal expressions, Ambiguity, Impressions

1. Introduction

Nonverbal expressions such as facial expressions and gestures are often used in interpersonal communication. From the viewpoint of the traditional information theory [2], such expressions are not appropriate means of communication because some of them are often interpreted ambiguously. On the other hand, Takahashi et al. [3] have pointed out that such "ambiguity" works effectively to avoid a risk latent in the interpersonal communication. Expressing information clearly but inappropriately for the circumstances can discomfort a recipient of that information. However, it is sometimes difficult to estimate the circumstances accurately and to choose the appropriate expression. In such a case, it is effective to express information ambiguously on purpose to avoid the risk mentioned above. Humans tend to interpret such ambiguous expressions for their own convenience [4], and they even positively utilize this tendency in their communication.

In recent years, life-like agents which can interact with humans have been increasingly studied. It is expected that humans get more opportunities to interact with the agents even in their daily living spaces as the agent technologies develop more. In order to achieve smooth communication with humans, the agents are also required to use the ambiguous expressions mentioned above as efficiently as humans.

In this paper, as the first step to realize such agents, we investigate impressions given by the life-like agents' ambiguous nonverbal expressions. First, we investigate differences among impressions given by the agents' "am-

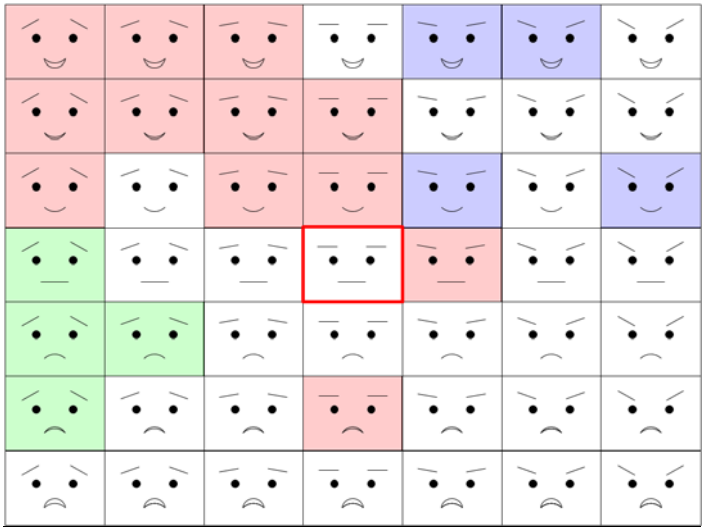


Figure 1. Definition of Ambiguous and Clear Facial Expressions

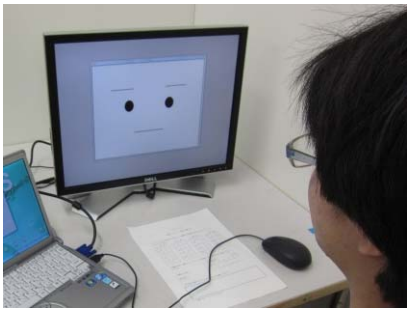
biguous," "clear" and "expressionless" expressions in facial expressions and gestures. It is considered that the "expressionlessness" is another possible way to induce humans to interpret the agents for their own convenience. We aim to make clear the difference between the ambiguity and the expressionlessness through some experiments. Second, we investigate effects of the context in communication between humans and the agents on interpretation of the agents' ambiguous facial expressions. We carry out two experiments. In the first experiment, we investigate the effects of the context of the agent, which shows ambiguous facial expressions, on the participant's interpretation. In the second experiment, we then investigate the effects of the context of the participant, who is a recipient of the agent's expressions, on his or her interpretation. Based on the results of these experiments, we discuss the effectiveness of the agents' ambiguous nonverbal expressions.

2. Preliminary Experiment

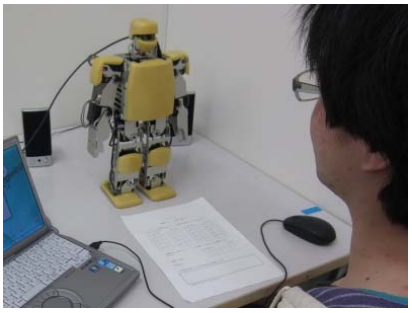
First of all, we carry out a preliminary experiment to define which nonverbal expressions are "ambiguous" and "clear."

In advance of the experiment, we prepare candidate expressions; forty-nine candidates for facial expressions (as combinations of seven shapes of eyebrows and seven shapes of mouth, as shown in Figure 1) and forty-two candidates for gestures (as combinations of seven motions of arms, three motions of a head, and two speeds of them). The facial expressions are shown on an LCD and the gestures are shown by a small humanoid robot as shown in Figure 2. Participants in the experiment are requested to estimate the emotions expressed by these expressions subjectively and to classify them into the Ekman's six basic emotions: "anger," "disgust," "fear," "happiness," "sadness" and "surprise" [1]. They are also requested to evaluate how confident they are of their classification in seven grades for each expression.

After the classification, we calculate the entropy of the probability distribution of the participants' classification for each expression. Then we define the expressions which have the high entropy and the low confidence as "ambiguous," and those which have the low entropy and the high confidence as "clear" for both of facial expressions and gestures. Furthermore, we also define the expression in the center of Figure 1 (for the facial expressions) and the agent's initial pose of standing straight as shown in Figure 2 (b) (for the gestures) as "expressionless." Figure 1



(a) Facial Expression



(b) Gesture

Figure 2. Presentation of Expressions

shows the definition for the facial expressions as an example. The faces colored by red, blue and green correspond to “ambiguous,” “clearly happy” and “clearly sad” expressions. The center one with the bold red frame corresponds to “expressionless.”

We use the expressions defined here for the following experiments.

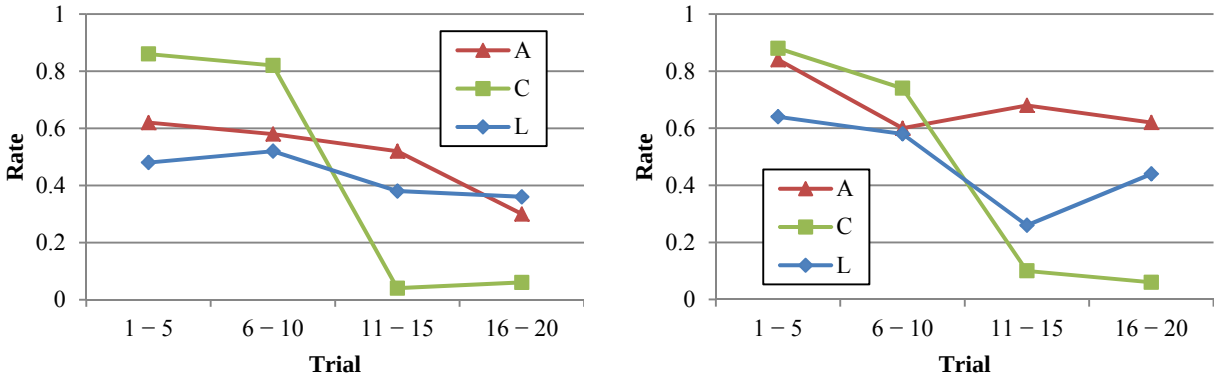
3. Effectiveness of Ambiguous Nonverbal Expressions

In this section, we carry out two experiments to investigate differences among impressions given by agents’ “ambiguous,” “clear” and “expressionless” expressions in facial expressions and gestures.

3.1 Methods

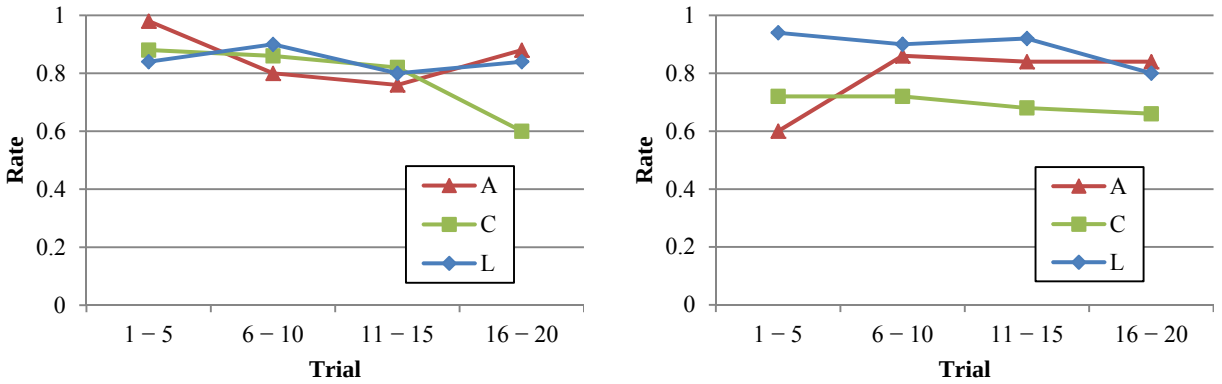
We carry out two experiments, for facial expressions and for gestures. Thirty college students participate in each experiment. In both experiments, the participant plays the “treasure hunting game” with the agent. The participant is requested to get the treasure by choosing the correct box from two boxes. The agent gives advice to the participant on which box to choose. The participant does not necessarily have to follow agent’s advice. The participant is required to repeat this procedure (trial) twenty times for each experiment.

In each trial, after the participant chooses the box, the agent shows a facial expression or a gesture to the participant according to the result. We set three conditions A, C and L of the agent’s expression: the agent shows the “ambiguous” (A), “clear” (C) and “expressionless” (L) expression. In Condition L, the agent always shows the expression defined as “expressionless” in the preliminary experiment regardless of the results. In Condition A, it randomly shows one of the “ambiguous” facial expressions or gestures defined in the preliminary experiment, which can be interpreted as either “happiness” or “sadness.” In Condition C, it shows one of the “clearly happy” expressions when the participant chooses the correct box and one of the “clearly sad” expressions otherwise in the first ten trials. However, in the last ten trials, it shows the “clearly sad” expression when the participant chooses the correct box and the “clearly happy” expression otherwise. Furthermore, in all three conditions, we set the probability that the agent’s advice is right as eighty percent in the first ten trials and fifty percent in the last ten trials respectively. These settings of the expressions and the probability imply that the agent behaves friendly to the participant in the first ten trials while it behaves negatively in the last ten trials. At the end of every trial, the participant is requested to evaluate whether the agent in the trial behaves friendly or negatively to him/herself. The facial expressions are shown on the LCD and the gestures are shown by the small humanoid robot as similar to the preliminary experiment.



(a) Facial Expressions (b) Gestures

Figure 3. Rates of Participants who Evaluate Agent as Friendly



(a) Facial Expressions (b) Gestures

Figure 4. Rates of Participants who Follow Agent's Advice

3.2 Experimental Results

Figure 3 (a) and (b) show the rates of participants who evaluate the agent as friendly at intervals of five trials for facial expressions and for gestures, respectively. Furthermore, Figure 4 (a) and (b) show the rates of participants who follow the agent's advice at intervals of five trials for facial expressions and for gestures, respectively.

We can see from Figure 3 that, for both of facial expressions and gestures, the rate of participants who evaluate the agent as friendly tends to be high in the first half but to fall in the latter half in Condition C. On the other hand, in Condition A, the rate tends not to fall even in the latter half when the agent behaves negatively to the participant. Furthermore, the rate in Condition A generally tends to be higher than that in Condition L.

We can see from Figure 4 that, for both of facial expressions and gestures, the rate of participants who follow the agent's advice tends to be low especially in the latter half in Condition C. On the other hand, in Condition A, the rate tends to be relatively high. The rate for Condition L shows similar tendency to that in Condition A.

3.3 Discussion

The experimental results show that, if the agent shows "clear" expressions, the participants evaluate the agent's attitude toward them as friendly in the first half but as negatively in the latter half of the experiment. Since it is a fact that the agent behaves so, these results are reasonable. On the other hand, they interpret the agent's "ambiguous" expressions as friendly even if it behaves negatively to them. These results show that the ambiguous expres-

sions are effective for inducing humans to interpret the agents for their own convenience and for avoiding the risk in the case that the agent necessarily cannot behaves appropriately for the circumstances.

Furthermore, the results for “expressionless” has similar tendency to that for the “ambiguous” expressions. This fact indicates that the expressionlessness is another possible way to induce humans to interpret the agents for their own convenience. However, the experimental results also show that the participants evaluate the agent’s “ambiguous” expressions as relatively friendlier than its “expressionlessness.” It is considered that the participants evaluate the agents which intend to try to convey some meaning to them higher than those which do not show such intention. These results show that the agent’s “ambiguous” expressions can show the “communicative intention” to the user while avoiding the unwanted risk in the communication.

4. Context Effects on Emotion Estimation from Ambiguous Facial Expressions

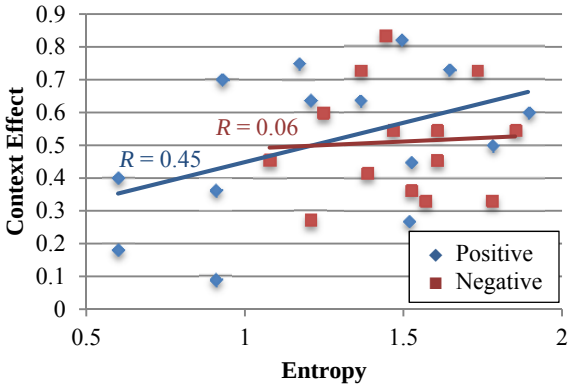
In this section, we carry out two experiments to investigate effects of the context in communication between humans and the agents on interpretation of the agents’ ambiguous facial expressions.

4.1 Methods

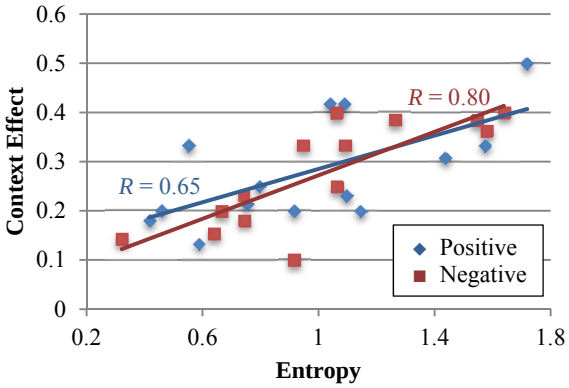
In the first experiment, we investigate the effects of the context of the agent, which shows ambiguous facial expressions, on the participant’s interpretation. Twenty-three college students participate in this experiment. First, the participant is requested to classify the “ambiguous” facial expressions defined in the preliminary experiment into the Ekman’s six basic emotions and to answer the degree of confidence of the classification in seven grades. The facial expressions are shown on the LCD as similar to the preliminary experiment. Then, a passage of explanation that either the positive context or the negative context is given to the agent, which showed the expressions, is shown on the LCD to the participant. The positive context and the negative one in this experiment are defined that a happy event and an unhappy event happens to the agent respectively. After that, the participant is again requested to classify the same facial expression and to answer the degree of confidence. The participant is requested to do this procedure for all the “ambiguous” facial expressions.

In the second experiment, we then investigate the effects of the context of the participant, who is a recipient of the agent’s expressions, on his or her interpretation. Twenty-five college students participate in this experiment. First, the participant is requested to classify the “ambiguous” facial expressions defined in the preliminary experiment into the Ekman’s six basic emotions and to answer the degree of confidence of the classification in seven grades as similar to the first experiment. Next, the participant is requested to play a simple game (rock-paper-scissors). We define that the positive context is given to the participant if he or she wins, and the negative context is given if he or she loses. After that, the participant is again requested to classify the same facial expression and to answer the degree of confidence. The participant is requested to do this procedure for all the “ambiguous” facial expressions.

We can investigate the context effect by comparing two evaluations before and after the context is given. In this paper, we define the degree of the context effect for an expression as the rate of the participants who change their classification after the context is given.

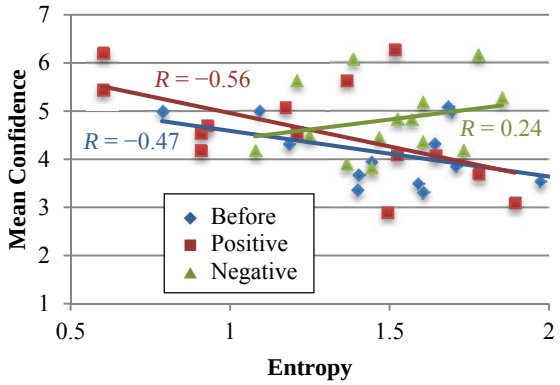


(a) First Experiment

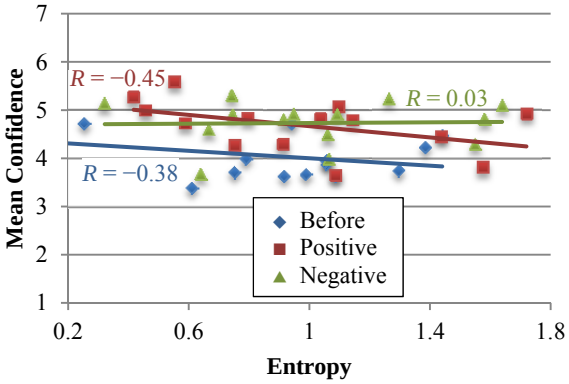


(b) Second Experiment

Figure 5. Relationship between Context Effect and Entropy



(a) First Experiment



(b) Second Experiment

Figure 6. Relationship between Entropy and Degree of Confidence

4.2 Experimental Results

Figure 5 (a) and (b) show the relationship between the context effect and the entropy of the probability distribution of the participants' classification in the first and second experiments, respectively. In the first experiment, there is a weak positive correlation ($R = 0.45$) between them for the positive context. On the other hand, there is almost no correlation for the negative context ($R = 0.06$). In the second experiment, there are relatively strong positive correlations between them for both of the positive and negative contexts ($R = 0.65$ and $R = 0.80$ respectively).

Figure 6 (a) and (b) show the relationship between the entropy and the mean degree of confidence of the participants' classification in the first and second experiments, respectively. In the first experiment, there are negative correlations between them before and after the positive context is given ($R = -0.47$ and $R = -0.56$ respectively). Furthermore, there is a weak positive correlation after the negative context is given ($R = 0.24$). In the second experiment, there are negative correlations between them before and after the positive context is given ($R = -0.38$ and $R = -0.45$ respectively).

Furthermore, in the first experiment, the entropy for each expression tends to decrease after the context is given while the mean confidence of the classification for each expression tends to increase. On the contrary, in the second experiment, both of the entropy and the mean confidence for each expression tend to increase after the context is given.

4.3 Discussion

The experimental results show that, in both the experiments, the interpretation of the agent's ambiguous facial expressions changes according to the context, and its degree tends to have a positive correlation with the entropy of the classification, that is, the degree of ambiguity of the facial expressions. In the first experiment, the effect of the negative context is larger than the positive. On the other hand, in the second experiment, the effects of the positive and negative contexts are both large. This result implies that the context of the recipient of the expressions will affects the interpretation more strongly.

In the first experiment, the entropy for each expression tends to decrease after the context is given while the confidence of the classification for each expression tends to increase. These results indicate that the participants confidently interpret the facial expressions similarly to others by obtaining detail information on the agent's situation. On the contrary, in the second experiment, both of the entropy and the confidence of the classification for each expression tend to increase after the context is given. These results indicate that, after the context is given, the participants interpret the expressions confidently, but their interpretations tend not to agree but to vary more widely than before the context is given. That is, the ambiguous facial expressions tend to be interpreted for the recipients' own convenience more conspicuously.

5. Conclusions

In this paper, we investigate impressions given by the life-like agents' ambiguous nonverbal expressions.

First, we carry out experiments to investigate differences among impressions given by the agents' "ambiguous," "clear" and "expressionless" expressions in facial expressions and gestures. Experimental results show that the participants in the experiment interpret the agent's "ambiguous" expressions as friendly even if it behaves negatively to them. These results show that the ambiguous expressions are effective for inducing humans to interpret the agents for their own convenience and for avoiding the risk in the case that the agent cannot necessarily behaves appropriately for the circumstances. Furthermore, the results also show that the participants relatively evaluate the agent's "ambiguous" expressions as friendlier than its "expressionlessness." It is considered that the participants evaluate the agents which intend to try to convey some meaning to them higher than those which do not show such intention.

Second, we investigate effects of the context in communication between humans and the agents on interpretation of the agents' ambiguous facial expressions. We carry out two experiments. In the first experiment, we investigate the effects of the context of the agent, which shows ambiguous facial expressions, on the participant's interpretation. In the second experiment, we then investigate the effects of the context of the participant, who is a recipient of the agent's expressions, on his or her interpretation. Experimental results show that the interpretation of the agent's ambiguous facial expressions changes according to the context, and its degree tends to have a positive correlation with the degree of ambiguity of the facial expressions. Furthermore, the results also show that the ambiguous facial expressions tend to be interpreted for the recipients' own convenience more conspicuously.

As a future task, based on these results, we should study a strategy to switch the ambiguous and clear expressions according to the circumstances appropriately.

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