Imitation inhibition and facial expression recognition: imitation-inhibition training inhibits the impact of interference with facial mimicry

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Imitation-inhibition training, requiring the inhibition of automatic imitative tendencies, has been proposed to enhance self-other distinction. Previous studies have demonstrated the effect of imitation-inhibition training in improving one's ability of not only understanding others' visual perspectives, but also in empathizing with them. We investigated the relationship between training and empathy in the recognition of others' emotional states. All participants were trained on the first day and completed the self-reported empathy and facial expression recognition task the next day. The task consisted of a facial mimicry restricted block and an unrestricted block. The facial muscle activity and facial stimuli of participants were different in the restricted block, in that they had to hold chopsticks horizontally with their mouths, which interfered with facial mimicry. We found that imitation-inhibition training increased self-reported empathy. With respect to facial expression recognition, the performance of the control group declined due to interference with facial mimicry, while that of the imitation-inhibition training group did not. These results suggest that imitation-inhibition training increases self-reported empathy and allows for a similar level of recognition of others' emotional states, regardless of discrepancy between the condition of self and others.

Keywords: imitation inhibition, empathy, self-other distinction, facial expression recognition, facial mimicry

1. Introduction

Humans have an automatic tendency to imitate other people's actions (Brass et al., 2000). However, in their interactions with others, they have to inhibit this imitative tendency, given that they need to perform both the same and different actions as others depending on the requirements for maintenance of a smooth interaction. Performing actions incongruent to those of others requires inhibition of the representation of the other person's action and enforcement of one's own intended action. Thus, previous studies have discussed that actions require "self-other distinction", one of the social-cognitive processes (Cracco & Brass, 2019; Ramsey, 2018). Moreover, Santiesteban et al. (2012) showed that self-other distinction was improved by training that required participants to perform actions different from those presented, namely, imitation-inhibition training.

de Guzman et al. (2016) expanded the range of effects

of imitation-inhibition training. They showed that it increased the corticospinal empathic response to others' pain as well as self-reported empathy. The authors insisted that the trained participants could simulate others' mental states regardless of their own state, because of improved self-other distinction by training. A recent study also investigated the effect of training on empathy (Bukowski et al., 2021).

However, previous studies have not revealed whether imitation-inhibition training affects the ability to quickly and accurately recognize others' emotional states. Santiesteban et al. (2012), in the first study on imitation-inhibition training, ascertained whether the training affects the ability to quickly and accurately understand others' visual perspective using the director task. In contrast, de Guzman et al. (2016) and Bukowski et al. (2021) used a physiological response, questionnaire, and a rating task using a visual analogue scale to confirm the effect of

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training on empathy. Thus, previous studies investigated the effect of training on the degree or intensity of empathy rather than the ability to infer others' emotional states quickly and accurately, even though this ability is essential for empathy in daily life.

This study investigated whether imitation-inhibition training affects the recognition of others' emotional states. Accordingly, a facial expression recognition task (FER task) was used. This task requires participants to infer others' emotional states from the presented facial expression, and a simple experimental manipulation can create a situation where the states of self and others differ during this task. Facial mimicry is automatically caused by facial expression observations and contributes to facial expression recognition (Wood et al., 2016). Previous studies have showed that holding a pen or chopsticks horizontally with the mouth interferes with facial mimicry and leads to impairment of facial expression recognition (Borgomaneri et al., 2020; Oberman et al., 2007; Ponari et al., 2012; Wingenbach et al., 2018). In addition to blocking facial mimicry, this manipulation causes very different facial muscle activity from the observed facial expression. Under such conditions, participants need to ignore their facial muscle activity to recognize facial expressions, because the activity is incongruent with the facial stimulus. Therefore, the manipulation seems to require self-other distinction. We thought that the effect of imitation-inhibition training would be more pronounced when facial mimicry was interfered with, and then used the FER task.

We assessed self-reported empathy and performed an FER task 24 h after the training. If imitation-inhibition training indeed increases empathy as reported in previous studies, we anticipate that the training impacts the above empathy measurements.

2. Methods

2.1 Participants

Forty Japanese young adults (9 women and 31 men, mean age = 22.0 years, standard deviation [SD] = 2.8) participated in this study. The sample size was determined by a power analysis using the training effect size ($\eta^2 = 0.141$) reported by de Guzman et al. (2016). The analysis conducted with G*power 3.1 ($\alpha = 0.05$, two groups, two repeated measurements) indicated that 13 participants were needed per group when $1-\beta = 0.8$, and 21 when $1-\beta = 0.95$ (Faul et al., 2007). All participants were right-handed according to the Japanese version of the FLANDERS handedness questionnaire (Okubo et al., 2014) and were healthy volunteers, who had not been previously diagnosed with developmental or neurological disorders. This experiment was approved by the Ethics Committee of the Faculty of Education at Hokkaido University (approval

number: 20 - 20) and written informed consent was obtained from all participants.

2.2 Procedure

Participants completed the Interpersonal Reactivity Index (IRI) > 1 week before their first session on day 1 (Davis & Association, 1980); a Japanese version of the IRI was used in our study (Himichi et al., 2017). IRI is a self-reported questionnaire to assess empathy. Participants were assigned to either the imitation-inhibition training group (five women, 15 men) or the control training group (4 women, 16 men) so that IRI score was approximately the same between these groups (imitation-inhibition group: $M = 95.1$, $SD = 12.2$; control group: $M = 95.9$, $SD = 10.4$). Each participant attended on two consecutive days; on day 1, they received training, and on the next day (day 2, 24 h after the training), they completed the IRI again and the FER task in that order.

2.3 Day 1: Imitation-inhibition training or control training

Participants in both groups performed a finger-lifting task based on that developed in previous studies (Figure 1 A; Brass et al., 2000; Nobusako et al., 2017). In imitation-inhibition training, stimuli consisted of short videos showing a left hand lifting either its index or middle finger. Participants were asked to keep holding down the left and right mouse buttons using their right index and middle fingers while a resting hand was presented (800-2400 ms). Subsequently, they were required to lift their own index finger when the middle finger of the stimulus hand lifted and their middle finger when the index finger was lifted. Thus, they had to inhibit the automatic imitative tendency in imitation-inhibition training. In control training, instead of lifting movement, the number cue ('1' or '2') was presented. Participants were asked to lift their index or middle index finger according to the presented number cue '1' or '2', respectively. The stimuli hand was displayed orthogonally to the orientation of the participant's hand to allow imitation to be isolated from spatial compatibility. Participants in both groups completed six blocks of 72 trials each. Although de Guzman et al. (2016) compared imitation-inhibition training with imitation training, which requires lifting the same finger that the stimulus hand lifts, our study did not, because we thought imitation of others' actions might affect the recognition of others' emotional states. This study used control training to focus only on the effects of imitation-inhibition training.

[Insert Figure 1 here]

2.4 Day 2: FER task

The stimuli were faces of 16 Japanese actors displaying happy, surprised, disgusted, angry, and sad expressions, taken from the National Institute of Advanced Industrial

Science and Technology (AIST) facial expression database (four females, four males; Fujimura & Umemura, 2018) and the Japanese Female Facial Expression (JAFPE) database (eight females; Lyons et al., 1998). The images in the AIST database were converted to greyscale, and the contrast of the images was adjusted. A grey background was created based on the background of an image from the JAFPE database, and the same background was used for all stimuli (Figure 1 B). We performed a pilot experiment to select the actors who were chosen for the present experiment. In the pilot experiment, 12 participants (four women and eight men) were required to choose the expressed emotion among six labels (happiness, surprise, disgust, anger, sadness, fear) for each face stimulus expressing the emotions of 18 actors. We selected all actors in the AIST database and eight actors in the JAFPE database based on the accuracy rate. However, we did not include fear expressions in the stimuli of the present experiment. This is because in the pilot experiment, the mean accuracy rate for fear expression decreased by 50% only ($M = 40.1\%$), whereas we wanted to focus not only on the accuracy rate, but also the reaction time (RT) in the present experiment.

In the FER task, a fixation point was presented (800–1200 ms), followed by a facial stimulus, until the time of the participant's response. Five emotion labels (happiness, surprise, disgust, anger, and sadness) were always presented throughout the task. The FER task consisted of a facial mimicry restricted block and an unrestricted block. In the restricted block, participants held chopsticks horizontally between their teeth and lips during the task, while in the unrestricted block, they did not. They were required to choose the expressed emotion among the five labels for each face stimulus and press one of the five keys ("G, H, V, B, N") on a conventional keyboard corresponding to the label position with their right index finger. For example, if the labels are arranged as shown in Figure 1 B, "happiness," "喜び" in Japanese, corresponds to the "G" key. The placement of labels was the same throughout a block. Participants were instructed to place their index fingers on the "space bar" until they responded and to respond as fast and accurately as possible. In a block, the 40 facial stimuli (eight actors $\times$ five emotions) were presented in random order. The order of the two blocks, actors used per block (six females and two males in a block), and placement of labels were counterbalanced across participants.

Holding chopsticks between the teeth and lips blocks facial mimicry and causes facial muscle activity different from that corresponding to facial stimuli. Thus, in the restricted block, participants need to ignore their facial muscle activity to recognize facial expressions because

their facial muscle activity was incongruent with that required for the displayed facial expression.

2.5 Data analysis

For the FER task, the accuracy rate and mean RT of correct responses were calculated. Two participants in the imitation-inhibition group and one participant in the control group were not included in the analysis of the FER task for the following reasons. The data of one participant were lost due to technical failure (the program stopped during the task); one expressed strong discomfort with holding chopsticks in his mouth during the task, and the mean RT of one participant was an outlier in the Smirnov-Grubbs outlier test. Significance level was set at $\alpha = 0.05$.

3. Results

3.1 IRI

Analysis of variance (ANOVA) on the IRI score with group (imitation-inhibition training, control training) as the between-subject factor and the measurement point (pre-training, post-training) as the within-subject factor was performed. This analysis revealed a significant interaction between the group and measurement point ($F[1,38] = 4.214$, $p = 0.047$, $\eta^2 = 0.100$). However, the main effect of each factor was not significant (all $F[1,38] < 2.508$, $p > 0.121$, $\eta^2 < 0.062$). Post hoc tests showed that in the imitation-inhibition group, the IRI scores significantly increased between measurement points (Figure 2; imitation-inhibition group: $t[19] = 2.843$, $p = 0.010$, $d = 0.636$; control group: $t[19] = 0.305$, $p = 0.764$, $d = 0.068$). [Insert Figure 2 here]

3.2 FER task

ANOVA on the accuracy rate with group and block (facial mimicry restriction block, unrestricted block) as the within-subject factor was performed. This analysis revealed the main effect of the two factors, and the interaction was not significant (all $F[1,35] < 0.677$, $p > 0.416$, $\eta^2 < 0.019$). Regardless of the group and block, the accuracy rate was approximately 80% (unrestricted block, imitation-inhibition group: $M = 82.5$, $SD = 7.0$; control group: $M = 81.8$, $SD = 7.4$; restricted block, imitation-inhibition group: $M = 82.2$, $SD = 7.5$, control group: $M = 83.7$, $SD = 5.6$). This result indicates that interference with facial mimicry and training did not affect the accuracy of facial expression recognition.

Regarding RT, the ANOVA with group and block showed that the main effect of block ($F[1,35] = 5.167$, $p = 0.029$, $\eta^2 = 0.129$) and the interaction were significant ($F[1,35] = 5.027$, $p = 0.031$, $\eta^2 = 0.126$). Group did not have a significant main effect ($F[1,35] = 0.171$, $p = 0.682$, $\eta^2 = 0.005$). Post hoc tests revealed that RT in the unrestricted block was significantly slower than that in the

restricted block only in the control group ($t[18] = 3.452$, $p = 0.003$, $d = 0.792$), whereas there was no significant difference between the two blocks in the imitation-inhibition group (Figure 3; $t[17] = 0.020$, $p = 0.984$, $d = 0.001$).

[Insert Figure 3 here]

4. Discussion

This study investigated the effect of imitation-inhibition training on self-reported empathy and facial expression recognition. Consistent with a previous study, our study showed that the training increased self-reported empathy (de Guzman et al., 2016). However, we have two concerns regarding the impact of the training on IRI score. First, imitation-inhibition training increased the IRI score significantly, but less reliably. Indeed, a post hoc power analysis showed that the sample size ($n = 20$) was not enough to achieve a power of 80% at 5% alpha level ($1 - \beta = 0.769$). Second, we did not reveal the impact on each subscale. IRI is a multi-dimensional assessment of empathy, composed of four subscales: perspective-taking, fantasy, empathic concern, and personal distress. Because de Guzman et al. (2016) did not conduct analysis on subscales of the self-reported questionnaire, an *a priori* power analysis in our study was not designed for ANOVA on the subscales of IRI with group and measurement point; but when we performed the ANOVA as an explorative analysis, we did not find any significant effect on all the subscales. These results might be due to the insufficient sample size. A study with a larger sample size is needed to elucidate the impact of imitation-inhibition training on self-reported empathy in greater detail.

Regarding the FER task, in the control group, RT on the restricted block was significantly slower than that in the unrestricted block. Many previous studies have showed that interference with facial mimicry impairs the recognition of facial expressions (Borgomaneri et al., 2020; Oberman et al., 2007; Ponari et al., 2012; Stel & van Knippenberg, 2008; Wingenbach et al., 2018). Thus, the reduced performance in the control group reflects the decline in the ability to recognize facial expression due to the intervention for facial mimicry. For example, there may have been a conflict between self and other representations owing to the participants' facial muscle activity differing from the facial stimuli, resulting in slower facial recognition processing. On the other hand, in the imitation-inhibition group, RT in both blocks were comparable. These results indicate that imitation-inhibition training prevented the interference of facial mimicry from degrading performance on the FER task. This can be explained based on the hypothesis of de Guzman (2016), that imitation-inhibition training improved participants'

self-other distinction and enabled them to simulate others' mental state regardless of their own state. In the current study, we think that imitation-inhibition training improved participants' self-other distinction (Santesteban et al., 2012); as a result, they could recognize others' emotional states regardless of their own facial muscle activity. Our results suggest that when there is a discrepancy between the condition of self and the other, imitation-inhibition training affects the recognition of the other's emotional state.

We did not find an effect of imitation-inhibition training on the accuracy of facial expression recognition. However, our data cannot determine its ineffectiveness. Our data also showed that the intervention for facial mimicry did not have a significant effect on accuracy. We opined that if the intervention can decrease the accuracy of facial expression recognition, it is possible to confirm the effect of training, as in RT. Therefore, we need to reexamine the relationship between accuracy and imitation-inhibition training using an intervention method for facial mimicry and a task that can decrease the accuracy.

An increase in self-reported empathy could also explain why the group that received imitation-inhibition training showed reduced interference with facial mimicry in this study. A previous study reported that participants with higher scores on a subscale of the IRI had less performance impairment in the emotion discrimination task due to interference with facial mimicry (Borgomaneri et al., 2020). The study suggests that they can achieve the task by relying on facial mimicry to a lesser extent. Another study showed that participants with a high score on the empathy quotient questionnaire (EQ) displayed a greater impact of interference with facial mimicry with regards to neural activity, a well-known marker of visual working memory (Sessa et al., 2018). Thus, previous studies suggest that when facial mimicry is interfered with, individuals with high self-reported empathy tend to use alternative processes to compensate for the interference.

A recent study suggests that imitation-inhibition training modulates self-salience rather than self-other distinction (Bukowski et al., 2021). In other words, the study argues that training causes people to pay relatively more attention to self-related information and less attention to other people-related information. According to this idea, in our study, participants in the imitation-inhibition group might have had less facial mimicry because the training reduced sensitivity to other people-related information (Bukowski et al., 2021). Thus, they might use a strategy that did not rely on facial mimicry during the FER task, which was not affected by the interference with facial mimicry. Studies on individuals with Moebius syndrome suggest that such a strategy can also lead to accurate recognition of facial

expressions (Bogart & Matsumoto, 2010; Vannuscorps et al., 2020). As for self-reported empathy, our results do not contradict those of Bukowski et al. (2021). They showed that the intensity of one's own emotional ratings increased when one's own and others' perspectives were not in conflict. This result can explain why imitation-inhibition training affected the measurement of self-reported empathy when there was no conflict in the perspective of the self and others, as occurred in our study and in the one by de Guzman et al. (2016). More research is needed to understand the mechanism by which training increases empathy.

This study has two major differences from previous studies on interference with facial mimicry. First, we did not calculate the accuracy and RT for each type of emotion in the FER task. Previous studies reported that interference with facial mimicry selectively impairs recognition of emotion expressed by the face according to the facial muscles involved (Borgomaneri et al., 2020; Oberman et al., 2007; Ponari et al., 2012; Wingenbach et al., 2018). For example, holding a pen or chopsticks horizontally with the mouth, as in our study, impacts the activity of lower facial muscles (Oberman et al., 2007; Wingenbach et al., 2018) and impairs recognition of happy and disgusted expressions (Borgomaneri et al., 2020; Ponari et al., 2012). However, we decided to calculate the accuracy rate and RT regardless of the emotion type because we could not use only eight actors per block. As an explorative analysis, an ANOVA on RT with the group, block, and emotional type (happiness, surprise, disgust, anger, and sadness) was performed; and consistent with the main analysis, the interaction between the group and block was significant ($p = 0.018$), but a second-order interaction was not significant ($p = 0.619$). Second, the interference with facial mimicry impacted RT, not accuracy in this study. Although some studies reported the impact on RT (Jospe et al., 2018; Stel & van Knippenberg, 2008), previous studies often reported that interference reduces the accuracy of facial expression recognition (Borgomaneri et al., 2020; Oberman et al., 2007; Ponari et al., 2012; Wingenbach et al., 2018). We think this reflects the differences in the characteristics of tasks and instructions among studies.

Recently, it has been argued that imitation inhibition relies on executive function rather than social cognition such as self-other distinction (Cracco & Brass, 2019; Ramsey, 2018). Our study cannot rule out the possibility that empathy increases through improvements in executive functions such as response inhibition and interference inhibition by imitation-inhibition training. Santiesteban et al. (2012) and Bukowski et al. (2021) showed that inhibitory control training, which requires executive function, did not have similar effects as imitation-

inhibition training. More research is needed to reveal whether the effects of imitation-inhibition training on empathy are due to improvements in executive function. We have to compare the effects of both types of training on empathy in future studies.

5. Conclusion

This study investigated the relationship between imitation-inhibition training and empathy. Our data indicate that imitation-inhibition training enhances self-reported empathy and affects the recognition of others' emotions. Performing actions incongruent to those of others requires inhibiting the representation of others' actions and enforcing one's own intended actions. Our results suggest that imitation-inhibition training, which requires such actions, contributes to the ability to quickly and accurately recognize the other's emotional state even when the conditions of the self and other are different.

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Figures 1

A

Imitation-inhibition training

Control training

B

Figure 1. (A) Training on Day 1. Imitation-inhibition training required participants to perform a movement (lifting their index or middle finger), which was different from the action of the stimulus hand. The control training required them to perform the movement according to the number cue (1: index finger, 2: middle finger). (B) Facial expression recognition task on Day 2. This task required participants to identify the emotion conveyed by each face and press one of five keys (“G, H, V, B, N”) on a conventional keyboard corresponding to the label position, as fast and accurately as possible. For example, if the labels were arranged as shown in this figure, “happiness,” “喜び” in Japanese, corresponded to the “G” key. Although an emoji is presented here, human faces were presented in the experiment.

Figures 2

Figure 2. Effect of the training on self-reported empathy: Interpersonal Reactivity Index (IRI) score. Error bars represent the standard error of the mean; * $p < 0.05$.

1 Figures 3

2

3 Figure 3. Effect of the training on reaction time (RT) in the facial expression recognition task. Error bars represent the
4 standard error of the mean; ** $p < 0.01$.