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Observations while holding a tool activates the imitation of actions

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ABSTRACT

Human beings have lived by developing tools and using them. Imitation is an effective method of learning tool usage. Therefore, it is essential to elucidate the mechanisms of learning tool manipulation through imitation. Previous studies have examined the effects of different pictures of tools on manipulation, and methods of presenting different pictures of tools on Action Reaction Times before initiating imitation activities. However, the effects of holding a tool in hand on imitation have not been directly examined to date. Therefore, adult participants of an experiment（N=20）were requested to imitate the action of grasping a cup placed in front of them with their hand or imitate the action of grasping the cup with a tool held in their hand after watching an action picture. Four types of action pictures were presented; grasping a cup by the hand, grasping a cup using a tool, the points of the cup to be grasped indicated by two dots, or more complexly indicated by four dots. The results indicated that Action RT between presenting an action picture and performing an imitation was shorter when holding a tool in hand compared to when not holding a tool. There were no differences in Action RT when the effector was shown as a hand and when the effector was shown as a tool. These results suggest that watching action pictures while holding a tool in hand might activate nerve networks related to tool manipulation.

Key words: Imitation, Tool manipulation, Generalist theory, Specialist theory, Reaction time

The anatomy of human beings has not changed to be used as tools. Instead, human beings have invented tools, improved them over time, and lived by using them（Tomasello, 1999）. Moreover, tools extend physical functions（Clark, 2004; Gibson & Ingolt, 1993; Lockman, 2000）. Breaking hard objects by using a hammer or picking up small objects by using tweezers are examples of extended functions of the hand. Cars and bicycles extend the functions of legs, and computers extend the functions of the brain. Therefore, the invention of tools and using them are closely related to human survival.

Tools are typical products of a culture that characterizes human beings. Culture is acquired through three types of learning: imitative learning, instructed learning, and collaborative learning. Imitative learning starts from the youngest age, and it is regarded as the most effective method of learning a culture（Tomasello, Kruger & Ratner, 1993）. A number of studies have investigated tools and imitation from the perspectives of causal relationships in tool manipulation, such as understanding the causal relationship between tool use and the results of tool use. These studies are based on observations of tool manipulation（Gardiner, Greif & Bkorklund, 2011; Horner & Whiten, 2005; McGuigan, Whiten, Flynn & Honer, 2008; Vaesen, 2012; Want & Harris, 2001; Williamson & Meltzoff, 2011）, object affordance and visually dangerous information by imitation（Zhao & Sang,2019）, correlations with ideomotor actions, representations, and Body Schema（Arbib, Bonaiuto, Jacobs & Frey, 2009; Kellenbach, Brett & Patterson, 2003; Massen & Prinz, 2009）, characteristics of cultural inheritance（Amodio, Jelbert & Clayton, 2018; Caldwell & Millen, 2009; Jelbert, Hosking, Taylor & Gray, 2018）and its developmental changes（DiYanni & Kelemen, 2008; Lee & Rutherford, 2018; Sommerville, Hildebrand & Crane, 2008; van Leeuwen, Ad Smitsman & van Leeuwen, 1994）, and tool manipulation by human beings and other primates（Call, Carpenter & Tomasello, 2005; Fragaszy, Biro, Eschchar, Humle, Izar, Resende & Visalberghi, 2013; Myowa-Yamakoshi & Matuzawa, 1999; Nagell, Olguin & Tomasello, 1993; Russon & Galdikas, 1995; Whiten, 1998; Whiten, 2005）.

Ideomotor actions are specific changes to an observer's body resulting from observing another person's actions. One study compared imitation between chimpanzees and human children and identified the tool manipulation learning characteristics that are unique to human beings（Nagell, Olguin & Tomasello, 1993）. They showed chimpanzees and two-year-old human children the act of pulling an object that was out-of-reach, close to the demonstrator by using a rake. The results indicated that the chimpanzees did not accurately reproduce the use of the rake shown by the demonstrator. Moreover, the chimpanzees did not change their behavior and continued to behave the same, even when the demonstrator used the rake differently. On the other hand, children imitated the model, even when it was an inefficient method of pulling the object. This finding suggests that human beings could accurately imitate a presented tool manipulation by predicting an intention, which was not the case in chimpanzees.

Two opposing theories are used to explain the imitation of tool manipulation: These are the generalist and specialist theories of imitation. Generalist theories of imitation do not assume any special processing, or mechanisms, other than the visual input of tool manipulation（Bird, Brindley, Leighton & Heyes, 2007; Heyes, 2012; Leighton, Bird & Heyes,2010）. According to them, the effector that manipulates tools does not play a special role in imitation. In an experiment conducted with adults based on this theory, participants grasped and manipulated a pen（Bird, Brindley, Leighton & Heyes, 2007; Leighton, Bird & Heyes,2010）. The action series of their experimental task included three components:（1）grasping a pen using the right or left hand,（2）then, making a thumbs-up or thumbs-down sign,（3）and bringing the pen to either one of two cups placed in front of the demonstrator. The results indicated that when one of the components was colored in red or blue to make it stand out, imitation errors of the colored component decreased, whereas they increased in the uncolored components. The above result suggests that visual attention was directed towards the action components that were emphasized by colors, which were reproduced more accurately than the other components. This finding suggests that imitation responses are determined by the observed visual characteristics of manipulated objects. The highlighted component was accurately imitated because observers imitate by observing only the features that are emphasized in color.

On the other hand, specialist theories of imitation assume a processing system that is specialized for imitation（Anisfeld, 1991; Jones, 2009; Meltzoff & Moore, 1989; Meltzoff & Moore, 1997）. For example, Meltzoff and Moore suggested that goals or targets of action are identified in visually presented tool manipulations（Meltzoff & Moore, 1989）. Then, the others' effector, or hand or tool to be imitated, which is the object of observation）and the effector of the self（the hand or tool for imitating）, are correlated according to identified goals. Next, the equivalence between the two effectors are detected, and visual information about the object of observation is directly transformed into action by the self. This is considered a supramodal transformation that surpasses the sensory modality. In this case, the visually perceived action of the other person is directly transformed into a motor sensation of the self. According to Meltzoff and Moore, humans have an inherent internal representation system, and self-produced tool manipulation actions are compared with representations of observed actions, as proprioceptive feedback data（Meltzoff & Moore, 1989）. In other words, an effector plays a vital role in imitation, and equivalence between effectors of another person and the self is an essential factor in the imitation of tool manipulation.

Van Elk, van Schie and Bekkering（2011）experimentally investigated the role of effectors and factors related to congruency or incongruency. Participants imitated the action of grasping a cup using their hand or a tool（a robot arm）after pictures were shown of the object being grasped. Three types of pictures were shown: grasping a cup using the hand, grasping a cup using a tool, and the points that should be grasped indicated by symbols（two dots）. In the congruent condition, the presented picture and the imitating action were entirely congruent, whereas, in the incongruent condition, the picture and action were partially incongruent. For example, the congruent condition showed a picture of a hand being used, and participants performed an imitative action by using their hand, whereas the incongruent condition showed a picture of a tool being used, and participants performed an imitative action using their hand. The results indicated no differences in RT from the presentation of pictures to the execution of actions between hand and tool actions. Moreover, the types of presented pictures（effectors）did not affect the RT. However, RTs were longer when hand-grasping and tool-grasping pictures were presented, compared to when symbols were presented. The above results were interpreted as indicating that differences in visually presented effectors did not affect RT.

Based on the findings of van Elk et al.（2011）, this study first investigated differences between imitation by using a hand and imitation by using a tool. Tools extend physical functions: therefore, how the tool would be used would have been planned before grasping the tool by the hand. Van Elk et al. 's study might not have reported any differences between actions using hands and tools because of congruency and incongruency effects. Therefore, the present study directly examined the effects of effectors without conducting any congruent or incongruent tasks. Secondly, this study examined the effects of the types of presented images. The previous study used a hand, a tool, and symbols（two dots）as effectors. The symbols were black dots marked on the right and left sides of a cup that represented the points to be grasped, which might have been processed relatively easily, compared to hand or tool cues. In other words, symbols might have had shorter RTs in the previous study because the symbols（two dots）directly indicated the points to be grasped by the hand or the tool, and RTs for hand and tool cues did not differ as a result. Therefore, a more complicated situation consisting of four dots that did not directly indicate the points to be grasped was included in the present study, and the effects of the presented image type on RT were examined.

Methods

Participants

University students（N = 20, 7 men and 13 women）identified as right-handed according to the Edinburgh Handedness Inventory（Oldfield, 1971）participated in this study for a small remuneration（～ $5）. All the participants gave their written informed consent before participating. This experiment passed an ethics examination on the researches using human subjects conducted by my affiliations（Correspondence author）and was approved by the ethics committee of the Shinshu University（No. H28-8）.

Stimuli and apparatus

There were two switches on the table. One switch was a response switch（diameter = 7cm）that served as the starting position of the grasping actions, which was

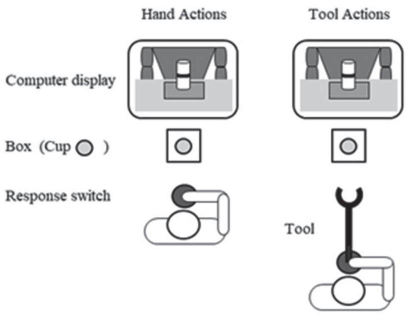

Figure 1. Hand actions and Tool actions

Note. The left picture shows hand actions and the right shows tool actions. A switch was set in the center of the box, and a cup was placed on the switch. Action RT was the time between observing the picture and releasing the response switch. Movement time was the time between releasing the response switch and grasping the cup, to which the switch on the box reacted. The jaws of the robot arm were shut when a participant pulled the trigger on the tool. In tool actions, the executor placed the hand on the response switch with a finger on the trigger in the same direction as in hand actions.

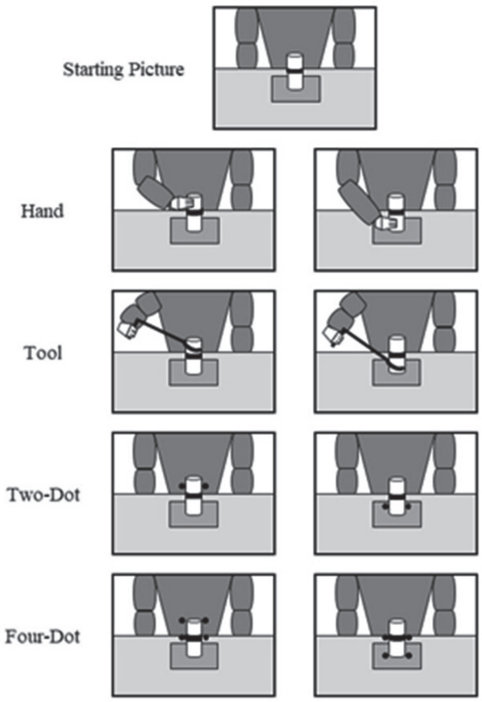

Figure 2. Four Type Pictures

Note. Black tape was pasted in the center of a white cylindrical cup so that both participants and experimenters could easily and clearly recognize which part of the cup (i.e., whether it is above the black tape or below it) was held by the demonstrator. "Hand" are pictures representing the demonstrator grasping the upper or the lower part of the cup by the hand. "Tool" are pictures representing the demonstrator grasping the upper or the lower part of the cup using the tool. "Two-Dot" and "Four Dot" picture uses dots to symbolically indicate the points to be grasped. The "Two-Dot" pictures directly indicated the points to be grasped, whereas the "Four-Dot" pictures did not directly indicate these points. Therefore, it was more difficult for participants to recognize the points to be grasped by observing the "Four-Dot" pictures, compared to "Two-Dot" pictures.

placed before each participant. The other switch was a small switch set in the center of a square box (12cm length x 18cm width x 4.5cm height) placed in front of a computer display (Figure 1). The response switch and the box were custom-made (Takei Scientific Instruments Co, LTD). In half of the experimental blocks, participants grasped a cup (11cm Height x 8cm diameter), lifted it, and moved it from the box using their right hand (hand block). In the other half of all blocks, they grasped the cup, lifted it and moved it from the box by using a handheld, mechanical tool, consisting of a robot arm (tool blocks), which was 75cm long, had a maximum distance of 11cm between open jaws and was designed to grasp cup-like objects.

Each Action RT and Movement time trial started with the participant keeping the right hand on the response switch. The participant's hand was kept resting on the response switch in tool blocks. The participant's hand grasped the robot arm with its jaws open. The robot arm has a finger trigger for closing the jaws. Then, the starting picture depicting the box and the actor was shown for 1000ms. Next, the target stimuli pictures were displayed until the computer detected a grasping response (Figure 2). The target stimulus consisted one of four types of pictures that depicted a hand cue (grasping the upper or lower part of the cup by the hand), a tool cue (grasping the upper or lower part of the cup by the robot arm), a two-dot cue, or a four-dot cue. The two- and four-dot cues were represented in the upper or lower part of the cup with no effector represented.

Procedure

(1) The participants were instructed to use either their right hand or the robot arm to hold the part of the cup shown in the picture and to lift or slide the cup. (2)

Participants were also instructed to initiate the action RT only when they were sure about the part of the object (cup) that they intended to grasp. Participants were also instructed to lift the cup and move it outside the box when executing the movement time. (3) The experimenters returned the cup to the starting position (on the box) at the end of each trial. Then, the next trial was initiated. Each participant performed 2 blocks of 80 trials in a 2 (action: hand and tool) x 4 (stimulus: hand cue, tool cue, two-dots cue, four-dots cue) design. The order of the blocks was counterbalanced between participants, and the stimuli were presented between participants in random order. The experiment took approximately 40 minutes to complete.

The participants started the experiment by pressing the switch with their hand, or, by using the tool held in their hand. Action was defined as the reaction time (RT) from presenting the picture to releasing the switch (Action RT). Movement was defined as the time from releasing the switch to grasping the cup (Movement time). The Movement time was measured after the Action RT. The Movement time consisted of the time for grasping the cup using the hand and the time for grasping the cup using the tool. Moreover, there were four cue presentation conditions. Therefore, eight types of action and cue combinations were prepared. Ten trials were conducted for each type of combination, which consisted of five pictures showing the cues in the upper part of the cup and five pictures showing the cues in the lower part of the cup. There were 20 participants. As a result, RTs were collected from 1600 Action RT and Movement time trials.

The response switch and the box were connected to a computer that controlled the experiment (Takei Scientific Instruments Co, LTD). This computer assessed the action RTs determined as the time between the onset of target stimuli and release of the response switch, and Movement times defined as the time between the release of the response switch and lifting the cup on the box. Two experimenters conducted the experiment: one controlled the experimental system using a desktop PC, and the other recorded the manipulated position (upper part or lower part) and returned the cup to the starting position at the end of each trial.

Results

We analyzed the data using a 2×4×2 repeated measures ANOVA with Action (hand/Tool) × Cue (hand/Tool/2-Dot/4-Dots) × Reaction time (Action RT/movement time) as within-subject factors. Action RTs and movement times are shown in Figure 3. The results indicated significant main effects of Action, $F(1, 19) = 23.5482$, $p = .0001$, $\eta^2 = 0.1136$; Cue, $F(3, 57) = 23.3358$, $p = .0001$, $\eta^2 = 0.0051$, and Reaction time, $F(1,19) = 7.6640$, $p = .0122$, $\eta^2 = 0.0490$. Moreover, the interaction between Action and Reaction time was significant, $F(1,19) = 135.0710$, $p = .0001$, $\eta^2 = 0.2270$. A test of simple main effects for Action RT indicated that RT for Tool was significantly shorter than RT for Hand, $F(1,79) = 14.521$, $p = .0003$, $\eta^2 = 0.1553$. However, a test of simple main effects for Movement time indicated that Movement time for Hand was significantly shorter than Movement time for Tool, $F(1,79) = 301.022$, $p = .0001$, $\eta^2 = 0.7921$. A test of simple main effect for Hand indicated that Movement time was significantly shorter than Action time, $F(1,79) = 54.095$, $p = .0001$, $\eta^2 = 0.4064$. However, a test of simple main effect for Tool indicated that Action time was significantly shorter than Movement time, $F(1,79) = 149.007$, $p = .0001$, $\eta^2 = 0.6533$.

The interaction between Cue and Reaction time was also significant, $F(3,57) = 3.7841$, $p = .0152$, $\eta^2=0.0020$. A test of simple main effect for Reaction time revealed that the Cue factor was significant, $F(3,117) = 13.8410$, $p = .0001$, $\eta^2 = 0.2619$. The results of multiple comparisons indicated that neither the RT between Hand and Tool ($p = .5629$) nor the RT between 2-Dot and 4-Dot conditions were significantly different ($p = .2819$). However, 2-Dot ($p = .0001$) and 4-Dot ($p = .0003$) were significantly shorter than Hand. Moreover, a test of simple main effect for Movement time revealed that the Cue factor was not significant, $F(3,117) = 2.5693$, $p = .0577$, $\eta^2 = 0.0618$. Also, a test of simple main effect for

Hand cue revealed that the difference between Action Reaction time and Movement time was not significant, $F(1,39) = 2.9312$, $p = .0948$, $\eta^2 = 0.070$. Moreover, a test of simple main effect of Tool cue revealed that the difference between Action Reaction time and Movement time was not significant, $F(1,39) = 3.1303$, $p=.0847$, $\eta^2=0.074$. However, a test of simple main effect for 2-Dot Cue revealed that Action RT were significantly shorter than Movement time, $F(1,39) = 8.0863$, $p = .0071$, $\eta^2 = 0.1717$. Furthermore, a test of simple main effect for 4-Dot Cue revealed that Action RT was also significantly shorter than Movement time, $F(1,39) = 5.9338$, $p = .0390$, $\eta^2 = 0.1321$. However, neither the interaction between Action and Cue ($F(3,57) = 1.0431$, $p = .3805$, $\eta^2=0.0003$), nor the interaction between Action, Cue and Reaction time were significant, $F(3,57) = 1.5270$, $p = .2173$, $\eta^2 = 0.0008$.

Discussion

We will first discuss the correlation between Action RTs and Action (hand or Tool) as well as Cue Types in Action. The previous study by van Elk, van Schie and Bekkering (2011) defined Action RT as the time between watching a picture and releasing a response switch that did not indicate Action RT differences between hand and tool actions. In the present study, Action RTs for tool actions were shorter than for hand actions. One difference between the two studies was cue pictures. The previous study's cues were a hand, a tool, and symbols (two-dots), whereas those in the present study were a hand, a tool, two dots, and four dots.

Although there was an effect of cue type in the current study, there was no interaction between cue types and hand or tool actions. Therefore, changes in cue types (hand, tool, two-dots, and four-dots) might not have affected the results of the current study. Another difference between the current and the previous study was that the current study did not include congruent or incongruent tasks. The difference between hand actions and tool actions might have been clearly demonstrated in the current study because of congruent and incongruent variables were excluded. Also, differences in equipment used in the experiment might have affected the results of the two studies differently. In the previous study, participants put their hands on a response box in which a small switch was placed in the center. In the present study, a relatively larger switch was used, on which the hand

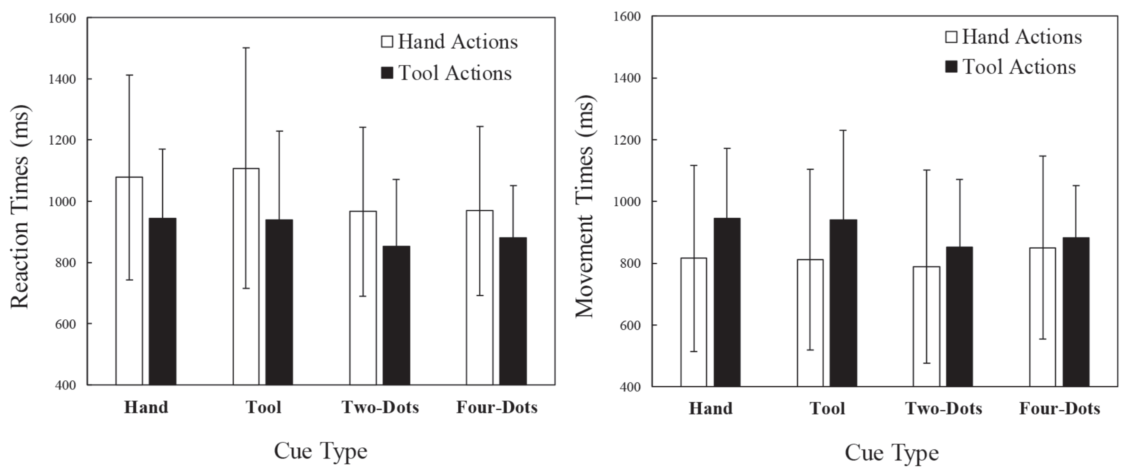

Figure 3. Action Reaction Times and Movement Times

Note. Figure on the left is the average of Action Reaction Times (the time between observing the picture and releasing the hand from the reaction switch) are shown. Error bars show the standard deviations in each condition. Figure on the light is the average Movement Times (the time between releasing the response switch and grasping the cup) are shown. Error bars show standard deviations in each condition.

or the hand holding a tool could be placed more easily, which might have enabled more accurate Action RTs measurement.

Action RTs was shorter when holding a tool, which suggested that an existing motor program, which is strongly associated with holding an object, might have been activated by holding the robot arm（which is similar an extension of the hand）while watching the picture. It is possible that the network of nerves related to processing the action of grasping a cup might have been activated by watching the picture while holding an object, such as a tool that has been designed to be handheld, which might have decreased the RT. Wohlschläger, Gattis and Bekkering（2004）indicated that the motor program in the brain that is most closely related to pictures or movements is activated when people watch pictures or movements. It can be assumed that the same type of activation might have occurred in the present study.

One of the theories related to the imitation of another person's action is the Goal-directed theory（GOADI）（Bekkering, Wohlschläger & Gattis, 2000; DiYanni, Nini & Rheel, 2011; Elsner & Pfeifer, 2012; Gleissner, Bekkering & Meltzoff, 2000; Ondobaka & Bekkering, 2012; Wild, Poliakoff, Jerrison & Gowen, 2012; Wohlschläger, Gattis & Bekkering, 2003）. According to GOADI, people do not imitate another person's actions by directly copying their body movements. Imitators find out the goals and the intentions of the action and imitate the action by using these goals and intentions as cues. Wohlschläger, Gattis, and Bekkering（2003）suggested the following principles of GOADI:（1）the perceived action is decomposed into separate aspects and then reconstructed. The goal that is extracted from the model action plays the leading role in the reconstruction. The elements that are related to the goal are correctly reproduced, whereas those that are not related to the goal tend to be reproduced incorrectly.（2）When many different goals are detected, the main goal is selected by competition caused by memory capacity limitations.（3）The switch that was pushed become a goal, rather than the means of pushing the switch, such as fingers, which was termed "imitation-specific goal selection" by Wohlschläger, Gattis and Bekkering（2003）.（4）The ideomotor principle states that the selected goals activate the motor program that is most strongly associated with the goals, which could explain the results of the present study. Holding a robot arm in one's hand might have clarified its goal to participants as being for grasping the cup placed in front of them, which might have activated the nerve network associated with this action. Based on the above, the results of the present study on Action RTs suggest that holding a tool such as a robot arm is linked to the motor program in the brain associated with the action goal. Moreover, using a tool might more easily activate the motor program associated with the action than using the hand, which is a new finding about the characteristics of devices that extends physical functions. This finding is significant for understanding the efficacy of a tool as a culturally representative product.

We want to discuss the types of cues shown in the pictures that were presented. The results indicated that Action RTs for dot（two-dots and four-dots）and no-dot conditions（Tool and Hand）were shorter than for the hand and tool condition. The previous study by van Elk, van Schie and Bekkering（2011）compared the Action RTs for the hand, tool, and dot conditions and reported that Action RTs in the dot condition were shorter than in hand or tool conditions. However, this result could be because the dot condition used in that study was rather simple and easy to process. Therefore, a more complicated four-dot condition was used in the present study. The two-Dot condition was a cue that directly indicated the position to be grasped by the hand or the tool, whereas the four-dot cue condition did not directly indicate the position to be grasped. Nevertheless, there was no difference in Action RTs between the two conditions, possibly because the participants in the four-dot condition could predict the position between upper and lower dots that had to be grasped and imitate identically to the two-dot condition. However, the results supported the previous study by showing there were no differences in Action RTs between hand and tool conditions. This result, consistently with the previous study, supports the idea that the types of pictures, which are visual stimuli, did not affect Action RTs. Unlike the results of the previous study, however, Action RTs when using a tool was shorter than the Action RTs when using the hand. The results indicated no differences in Action RTs even when the effector presented by the picture and the effector used in imitation were different. Concretely, Action RT did not differ when the hand cue was presented, and participants imitated using the tool and when the tool cue was presented, and participants imitated using the hand.

Next, we would like to discuss Movement time. Van Elk, van Schie & Bekkering（2011）indicated that movement time for the hand action was shorter than for the tool action, and it was not influenced by the cue types, which was consistent with the results of this study. The participants might have taken a relatively long time to use the tool compared to the hand because they were unaccustomed to using the robot arm tool.

This study identified the effects of using a tool. The pictures of the effectors shown to the participants, such as the hand and the robot arm tool, did not affect Movement time became shorter because of the nervous system's internal processing when holding a manipulation tool that was designed to extend the hand's physical functions. The Movement time indicated that a more extended time was required to move when manipulating a tool by using peripheral organs（effectors）, because of a lack of experience. One experiment using fMRI has indicated the Broca's area and parietal lobe were involved in imitation（Iacoboni, Woods, Brass, Bekkering, Mazziotta & Rizzolatti, 1999）. Moreover, the same study indicated that the Broca's area is involved in understanding the intentions of another person's actions, and the parietal lobe is involved in accurately reproducing movements identical to another person's movements. It has also been indicated that the Broca's area, which is involved in articulation and pronunciation, is indispensable to understanding another person's intentions（e.g., Brown & Yuan, 2018; Gatti et al, 2017; Maffei et al, 2020; Medeiros, 2019; Vicaria & Dickens, 2016; Zhang, Sun & Wang, 2018）. Furthermore, the results of recent studies using NIRS（Near-infrared spectroscopy）, which is a brain function imaging method using near-infrared light, suggest that the inferior parietal cortex is activated（Bhat, Hoffman, Trost, Culotta, Eilbott, Tsuzuki & Pelphrey, 2017）when adults watch another person manipulating an object. Furthermore, the study suggests that the inferior parietal cortex, a specific nerve network activated when executing an observed action, is involved in the integration of sensorimotor information needed for manipulating an object. Observing the pictures presented in the current study might have activated neuronal networks facilitated by holding a robot arm, which is a tool designed for grasping objects. However, this remains a hypothetical model because the current study did not use brain function imagery.

The following issues should be investigated in future studies. Firstly, the effects of different tools should be examined. This study used a robot arm, which is easily recognized as an extension of a body part. Other studies（Bird, Brindley, Leighton & Heyes, 2007; Leighton, Bird & Heyes, 2010）have used a pen as a tool, but unlike the use of the robot arm in this experiment, the pen was not used for its original purpose of writing. It is predicted that the degree of activation of related motor programs might differ depending on the type of tool（Wohlschläger, Gattis & Bekkering, 2003）. Also, these studies（Bird, Brindley, Leighton & Heyes, 2007; Leighton, Bird & Heyes, 2010）examined the error rates without measuring Action RT. Therefore, it is suggested that Action RTs be compared between using a tool that is easily recognized as an extension of a body part and using a tool that is not such an obvious extension of a body part. Secondly, the effects of visual cues on imitation should be investigated. Generalist theories of imitation advocate that the accuracy of imitation is determined by observing tool manipulation（Bird, Brindley, Leighton & Heyes, 2007; Heyes, 2012; Leighton, Bird & Heyes,2010）. According to the Generalist theories, the process of visual processing after presenting the input would not affect imitation. Previous study has indicated that not only the input of observing a model but also visual cues that are presented when imitating the action have a decisive effect on the imitation （Mizuguchi, Sugimura, Shimada & Hasegawa, 2017）. In other words, imitation is facilitated by cues that are presented when observing a model and by presenting the same cues when performing the imitation. However, the current study only assessed Action RT between the presentation of a picture and the execution of the imitation. As a result, the current study did not investigate whether only visual inputs influence imitation, or whether subsequent processing also has an effect on imitation, which remains an essential issue for establishing the validity of Generalist theories of imitation. It is suggested that future investigations should examine this question by modifying the experimental procedure of this study. Thirdly, Heyes and her colleges have recently compared the imitation of meaningful and meaningless actions（Catmur & Heyes, 2019）and reported that RT between presenting a picture and imitating meaningful pictures was faster than for meaningless pictures. The meaning of an action is related to predicting the goal of an action. Heyes and her colleagues suggested that visual processing might not be the only method of conducting imitation. This is another issue for future investigations.

Notes

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3. The authors declare no conflict of interest.

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