



**HAL**  
open science

## Observation and action priming in anticipative tasks implying biological movements.

Christel Bidet-Ildes, Yoshiyuki Tamamiya, Kazuo Hiraki

► **To cite this version:**

Christel Bidet-Ildes, Yoshiyuki Tamamiya, Kazuo Hiraki. Observation and action priming in anticipative tasks implying biological movements.. Canadian Journal of Experimental Psychology, 2013, 67 (4), pp.253 - 259. 10.1037/a0034333 . hal-01662981

**HAL Id: hal-01662981**

**<https://hal.science/hal-01662981>**

Submitted on 17 Sep 2019

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Observation and action priming in anticipative tasks implying biological movements

Christel Bidet-Ildei<sup>1,2</sup>, Yoshiyuki Tamamiya<sup>1</sup>, Kazuo Hiraki<sup>1</sup>.

<sup>1</sup> Graduate School of Arts and Sciences, The University of Tokyo, Japan

<sup>2</sup> CERCA Laboratory (Centre de Recherche sur la Cognition et l'Apprentissage, UMR-CNRS 7235), University of Poitiers, France

Corresponding author: Christel Bidet-Ildei

Mailing Address:

Christel Bidet-Ildei (PhD)

CeRCA/MSHS, Bâtiment A5

5, rue Théodore Lefebvre

86000 POITIERS

Tel.: 33 (0)5 49 45 46 97

Fax: 33 (0)5 49 45 46 16

Email: [christel.bidet@univ-poitiers.fr](mailto:christel.bidet@univ-poitiers.fr)

Short title: priming in perceptual anticipation

## ABSTRACT

The purpose of this study was to assess the effect of short-term priming in perceptual anticipation tasks involving point-light biological motions. After the production or the observation of a relevant or an irrelevant movement (action vs. observation priming), eleven right-handed volunteers were asked to anticipate, as quickly and accurately as possible, the end-point of a pointing movement after the stimulus vanished upon completion of 60 % of the total movement. Our results indicate that perceptual accuracy is significantly affected only with relevant observation priming. This suggests that perceptual anticipation tasks' involving point-light biological motions implies specific perceptual competencies.

**Keywords:** anticipation, biological motion, action priming, observation priming

## INTRODUCTION

Decades of research have demonstrated the remarkable capacity of humans to detect and recognize biological motions. Reduced depiction, based only on dots of lights placed on the limbs of an actor (i.e., a point-light display paradigm), is sufficient to identify the produced action (Johansson, 1973) and to resolve both the gender (Kozlowski & Cutting, 1977) and identity of a person (Beardsworth & Buckner, 1981; Loula, Prasad, Harber, & Shiffrar, 2005). One of the most remarkable abilities is that humans are able to anticipate subsequent components of a human motion sequence. For instance, in a two-forced choice handwriting task, Kandel, Orliaguet and Boë (2000) show that adults are able to predict the second letter of a digram (“l” or “n”) after observing the first letter (“l”). This capacity for perceptual anticipation also manifests itself when observers are asked to point with a mouse the final position of a simple arm movement in which the last segment of the trajectory is hidden (Martel, Bidet-Ildei, & Coello, 2011; Pozzo, Papaxanthis, Petit, Schweighofer, & Stucchi, 2006). In this case, participants are able to estimate the terminal location of the reaching movement after the stimulus vanished, even though only 60 % of the total movement duration was observed (Martel et al., 2011).

The most common theoretical explanation for this visual anticipation capacity is based on the motor theory of perception, which suggests that an individual's motor competencies are connected to their perceptions of movements of other humans (Hommel, Musseler, Aschersleben, & Prinz, 2001; Jeannerod, 2001; Prinz, 1997; Rizzolatti & Craighero, 2004; Schütz-Bosbach & Prinz, 2007). This point of view is illustrated in various neurophysiological, behavioral and neuropsychological works that demonstrate that the motor system is significantly involved in the anticipation of perceptual events. In this context, brain-imaging studies have shown that the anticipation of sequential patterns activates specific brain areas involved in the production of motor sequences. For instance, Chaminade, Meary, Orliaguet and Decety (2001) show that the left premotor cortex and the right intraparietal sulcus are activated during anticipation of pointing movements while the left frontal operculum and the superior parietal lobule are activated during the anticipation of writing movements. Moreover, increased premotor activation is revealed when observers have to anticipate the final state of an occluded human action (Stadler et al., 2011). Additionally, Graf et al. (2007) show that the capacity to judge whether a static image corresponding to a well continuation of a motor sequence previously observed improves when the timing of the visual presentation of the static image matches the timing of the execution of the motor

sequence. This suggests that predictive competencies are based on real-time, covert motor activation. Recently, Springer et al. (2011) have shown that the efficiency of this real-time process increases when the perceptual anticipation task is associated with the simultaneous execution of an action. Finally, recent experiments show that anticipation of a human's movement goal improves when predictions are made on biological point-light motions (Elsner, Falck-Ytter, & Gredeback, 2012; Martel et al., 2011). This suggests that anticipation competencies could be based on kinematics information which is known to be a marker of human action production (e.g., Viviani & Stucchi, 1989).

Although several experiments demonstrate the intervention of the motor system during visual anticipation of human movements, the specific mechanism implied in this intervention stays an open issue. Two possibilities can be envisaged. First, in agreement with a recent study of Jantzen et al. (2012), we could consider that the intervention of motor system in visual anticipation task implying human movements is based on sensorimotor integration. In this case, sensory feedback of compatible actions would be integrated to improve the anticipation processing. Alternatively, the intervention of motor system could be based on the activation of specific motor representation. This hypothesis is consistent with the idea proposed by Pozzo et al. (2006) that perceptual

anticipation is sustained by an “internal representation of potential action related to the stimulus”. To distinguish these two hypotheses, the present study aimed to directly compare the facilitation of perceptual anticipation after visual and action priming. It is known that production and observation of biological movements are connected in a lot of characteristics in particular concerning the activation of a specific motor representation. For instance, several studies have documented equivalent levels of cerebral activation when humans produce or observe a human action (Decety et al., 1997; Filimon, Nelson, Hagler, & Sereno, 2007; Rizzolatti et al., 1996). However, some researchers argue that the equivalence between production and observation is not systematic (Bidet-Ildei, Chauvin, & Coello, 2010; Bidet-Ildei, Meary, & Orliaguet, 2008; Bidet-Ildei & Orliaguet, 2008; Bidet-Ildei, Orliaguet, & Coello, 2011; Pavlova, Staudt, Sokolov, Birbaumer, & Krageloh-Mann, 2003). For example, the detection of point-light walking movements embedded in a mask is independent of the walking capacity of adolescents with periventricular lesions (Pavlova et al., 2003). In the same manner, Bidet-Ildei and Orliaguet (2008) have shown in children that specific kinematic parameters as movement speed are independent of motor-perceptual coupling (see Meary, Kitromilides, Mazens, Graff, & Gentaz, 2007 for similar evidence in human newborns). Overall, these findings show that action representation is not strictly related

with motor competencies and suggest that action representation could be more pregnant during the observation than the execution of actions. In this theoretical context we asked participants, after a brief period of visual or action priming, to anticipate the final position of a point-light pointing movement that vanished before the final position was reached. If perceptual anticipation capacity is based on sensorimotor integration we should observe better performance after action relevant priming. On the contrary, if perceptual anticipation capacity is based more on action representation, we should observe a higher influence of visual relevant priming than equivalent action priming.

## METHOD

### *Participants*

Eleven right-handed healthy adults (6 male and 5 female) aged between 18 and 27 years (mean age= 24.3 years, standard deviation= 2.6 years) participated in this experiment.

These participants were recruited as volunteers from the University of Tokyo. All participants provided written informed consent for the protocol, which was in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Tokyo. None of the participants reported any sensory or motor deficits, and none had previous experience with this stimulus condition. All participants had



normal or corrected-to-normal vision.

### *Apparatus and stimuli*

Each participant sat in an unlit room in front of a 17" CRT computer screen (EIZO FlexScan F520, spatial resolution: 1024 \* 768 pixels, sampling rate: 60 Hz) at a viewing distance of 69 cm. The visual angle subtended by the screen to eye-level was 17.4 ° vertical (V) \* 25.9 ° horizontal (H). Body movements were limited by establishing contact between the participant's chest and a table placed between the participant and the screen (see figure 1B).

The stimuli were created in the same manner as in our previous work (Martel et al., 2011). They consisted of animations showing a point-light display sequence depicting a pointing movement of either 20 or 30 cm of distance. This target movement was represented by 4 dots placed on the shoulder, elbow, wrist and forefinger of an actor. In a pre-experimental session, an actor (who did not participate as a subject in the present experiment) produced a number of pointing motions in a horizontal plane with the right hand. His performance was filmed from above using the 3D ultrasound Zebris system (Zebris, <http://www.zebris.de/>) by using markers placed on his articulation points (shoulder, elbow, wrist and forefinger). This system allows for the recording of spatial and temporal parameters of movement (spatial resolution, 0.2 mm; temporal resolution,

200 Hz). The actor was instructed to produce as fast and accurately as possible ten pointing movements toward a circular target ( $\varnothing = 1$  cm) placed at a distance of 20 or 30 cm in front of him. For each distance, a point-light reaching movement was generated with Matlab software by using the mean coordinates recorded by the Zebris system.

The point-light stimuli consisted of white dots ( $97 \text{ cd/m}^2$ ,  $\varnothing$ :  $0.65^\circ$  visual angle) on a dark background ( $0.14 \text{ cd/m}^2$ ). According to our previous work on anticipation (Martel et al., 2011), the animation included 60 % of the total duration of the pointing movement because that is the minimum duration required to observe significant anticipative competencies (Kandel et al., 2000). Therefore, for the 20 and 30 cm distances, we included 23 and 36 frames (25 ms/frame), resulting in total durations of 575 ms and 900 ms, respectively. Each sequence was transformed into an avi movie with a resolution of  $512 * 640$  pixels and a frame rate of 40 frames/s. The target stimuli were presented at the center of the screen in a window constituting 60 % of the screen ( $10.5^\circ$  (V) \*  $15.6^\circ$  (H) visual angle), with sustained visual angles of  $3.3^\circ$  (V) \*  $3.3^\circ$  (H) and  $4.9^\circ$  (V) \*  $3.3^\circ$  (H) for the 20 and 30 cm distances, respectively. Therefore, the distance on the screen is divided by three with respect to the true distance (4 cm and 6 cm for 20 cm and 30 cm respectively). The visual presentation was in the center of the screen in vertical plane and the direction of motions was from the bottom to the top of

the screen (see videos <sup>1</sup>).

Each experimental trial was preceded by a prime. Three types of priming were proposed.

The observation priming consisted of the visual presentation of 1) an actual pointing movement or 2) an actual applauding movement, which were presented as color movies.

The movements were previously recorded with a video camera (spatial resolution: 760 \* 576 pixels, sampling rate: 30 frames/s) placed above the device (see videos <sup>1</sup>) and showed an actor either making a pointing (relevant observation priming condition), or making an applauding movement (2 times) (irrelevant observation priming condition).

For the relevant observation priming condition, the actor had to produce as fast and accurately as possible several pointing movements directed to a target placed in front of him in a horizontal plane. To avoid perceptual similarities between the relevant observation priming and the stimuli, the actor who produced the observation priming movements was a woman (whereas stimuli have been created from the production of a man), the distance of pointing was 40 cm (instead of 20 or 30 cm used in the experimental task) and the pointing was directed toward a light toy (instead of a circular target). The light toy was a figurine representing “Pikachu”, a manga character well-known in Japan.

However, visual relevant priming movements as point-light stimuli were presented

---

<sup>1</sup> Videos of stimuli and observation priming are visible on <https://bv.univ-poitiers.fr/access/content/user/cildei/stimuli%20tokyo/>

vertically on the screen with a displacement from the bottom to the top of the screen.

Movement duration was 1.5 s for both pointing and applauding movements.

In contrast, the action priming consisted of each participant making either a pointing movement (relevant action priming condition) or an applauding movement (irrelevant action priming condition) under the same conditions as those used in the observation priming. For pointing movement, the participants had to reach with his/her right hand the figurine placed in front of him/her as fast and accurately as possible. During the entire movement, the forefinger was in contact with the table. The starting position was marked on the table. For applauding movement, participants had to applaud 2 times. For both applauding and pointing movements, participants had 2.5 s to execute the motions and come back in the starting position. This time duration was previously tested on 20 participants and it was sufficient to make the task. During the training's phase, the experimenter checked that this time was convenient for each participant. The experimental box was unlit during the experiment; therefore, visual feedback was not available. An additional control condition consisted of the participant observing a fixation cross for 2.5 s (neutral priming condition).

### *Experimental procedure*

The presentation of stimuli and the registration of manual responses were controlled by E-prime software (version 2.0, <http://www.pstnet.com/>). Before beginning the experiment, participants were allowed to become familiarized with the point-light display. For this familiarization, participants showed 4-5 point-light movements representing human actions and had to recognize the action perceived. Next, the experimenter explained the task procedure, and participants were given time to practice producing the applauding and pointing priming movements that were required during the experimental phase. After practicing, participants were required to perform nine training trials with the same instructions and the same priming as those used in the experimental phase but with different point-light pointing stimuli. To make the experimental task clear to the participants, comments about these examples and about the experimental tasks were provided by the experimenter during the training phase. If anything was unclear, the participant was allowed repeat the training phase.

The participant's task was to identify, as quickly and accurately as possible, the end-point of the point-light pointing movement after it vanished upon completing 60 % of the total movement duration. Participants indicated the location corresponding to the judged end-point of the movement by moving a mouse cursor and clicking the left

button of the mouse. The mouse was positioned on the table near the participants so that the participants could easily give their responses by moving the mouse and clicking one of the buttons. The starting position of the mouse was given by contact with a block placed near the participants. To make the experimental task less monotonous and increase the variability of the required response, two different point-light stimuli (20 and 30 cm) were used.

Each trial started with a visual, action or neutral priming for 2.5 s. To clarify the task before priming, instructions appeared for 1 s before each test (i.e., “please look at the pointing movement”, “please look at the applauding movement”, “please look at the fixation cross”, “please point at Pikachu” and “please applaud”). Each instruction appeared in Japanese and was clarified during the training phase. The instructions appeared in different colors (white, blue and yellow) to distinguish between neutral, visual and action priming (see figure 1A). The color selected for each priming condition varied between participants. As soon as the priming phase was finished, participants had to place their hand on the mouse and then a fixation cross appeared for 500 ms followed by the presentation of the point-light stimulus. Participants performed 200 trials (20 trials \* 5 primings \* 2 distances) in a random order, resulting in a total duration of approximately 30 min for the entire experimental session.

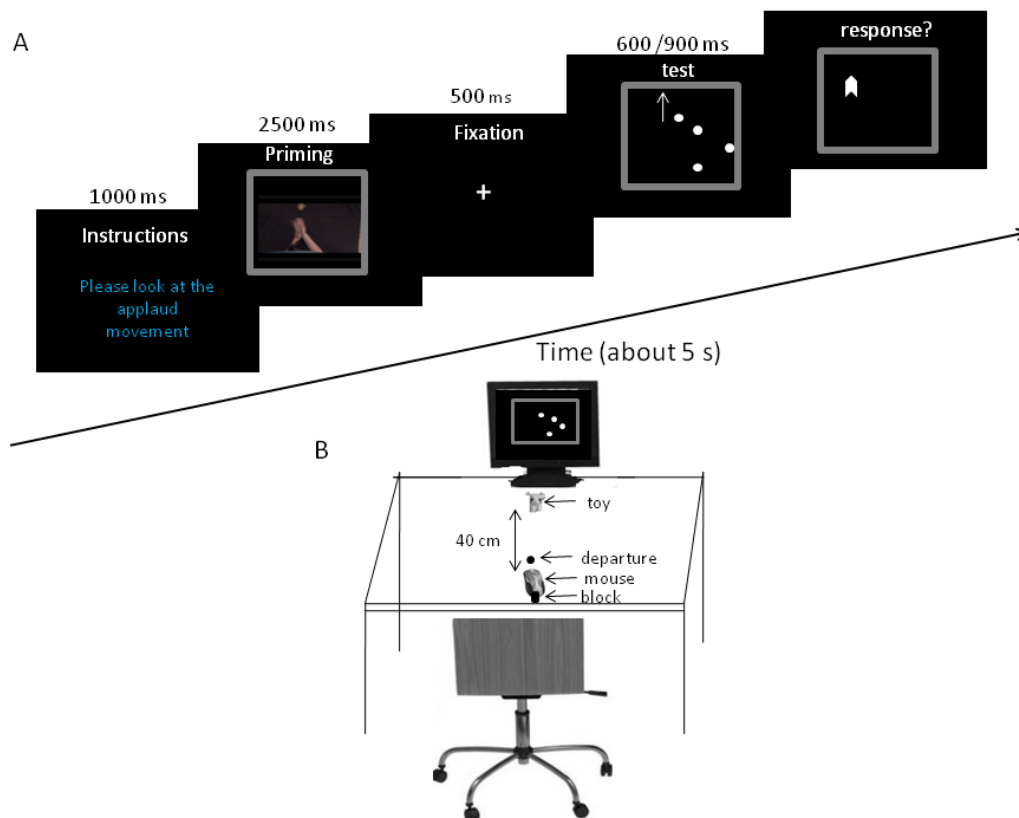


Figure 1: A) Example of the procedure used in the experiment for the “Irrelevant observation priming condition”. The stimulus was a point-light arm-pointing movement in a view from above with four points represented (shoulder, elbow, wrist and forefinger). The arrow represents the time course of one trial. B) Experimental setting. The point-light display stimuli are presented in a window occupying 60 % of the screen. The starting position of the mouse was given by contact with the block. “Departure” indicates the starting position of the participants in all priming conditions. After the priming, participants had to place their hand on the mouse to give their response.

### *Data analysis*

Response accuracy and response variability were assessed for each participant. Response accuracy corresponded to the absolute constant errors (i.e., the difference in cm between the participant's end-point mouse position and the position of the end of the movement registered by Zébris) and response variability to the standard deviation (SD) of the 20 replications. For both response accuracy and response variability, a three-way analysis of variance (ANOVA) was performed according to the priming condition (action, observation), the congruency (relevant vs irrelevant movements) and the stimulus condition (20 cm or 30 cm). Local comparisons were performed using post-hoc Newman-keuls' comparisons. Effect sizes were computed using eta-square estimates. Performances after observation and action priming conditions were compared with performance after neutral priming by using Student t-test. Bonferroni corrections were applied for multiple comparisons.

## RESULTS

With respect to response accuracy, we observed two interesting interactions. First, we had an interaction between the congruency and the stimulus condition ( $F(1,10)=7.14$ ;  $p<0.05$ ;  $\eta^2=0.41$ ). In both 20 cm and 30 cm stimuli conditions, relevant priming



conditions affected more the performance in anticipation than irrelevant priming conditions but relevant conditions interfered with the performance in the 20 cm stimulus condition while they facilitated the performance in the 30 cm stimulus condition.

The other most important interaction appeared in Figure 2 between the priming condition, the congruency and the stimulus condition ( $F(1,10)=13.57$ ;  $p<0.01$ ;  $\eta^2=0.58$ ).

To clarify the last interaction we made separate 2 (type of priming: visual vs action) \* 2 (congruency: relevant vs irrelevant movements) ANOVA for each stimulus condition.

For the 20 cm stimuli, we observed in figure 2A better performance after the action (mean=1.20 cm, SD=0.52 cm) than the observation (mean=1.33 cm, SD=0.55 cm) priming conditions ( $F(1,10) = 54.43$ ;  $p<0.01$ ;  $\eta^2= 0.84$ ) and better performance for the irrelevant (mean=1.17 cm, SD=0.57 cm) than the relevant (mean=1.36 cm, SD=0.50 cm) priming conditions ( $F(1,10)=8.13$ ;  $p<0.05$ ;  $\eta^2= 0.44$ ). Further inspection of Figure 2A revealed also a significant interaction with a higher decrease of performance in the relevant observation priming condition than the relevant action priming condition ( $p<0.01$ ). Finally, only the relevant observation priming condition (mean=1.46 cm; SD=0.52 cm) caused poorer anticipation performance than the neutral priming condition (mean= 1.16 cm; SD=0.54 cm,  $t_{10}= 3.92$ ;  $p<0.05$ ).

For the 30 cm stimuli, Figure 2B showed better anticipation performance after relevant

(mean=1.48 cm, SD=0.35 cm) than irrelevant (mean=1.67 cm, SD=0.50 cm) priming conditions ( $F(1,10)=4.75$ ;  $p=0.05$ ;  $\eta^2=0.32$ ). Moreover, a significant interaction appeared in figure 2B with a higher increase of performance in the relevant observation priming condition than the relevant action priming condition ( $p<0.05$ ). Finally, further analysis revealed that only the relevant observation priming condition improved significantly the performance of participants (mean=1.41; SD=0.34) in comparison with the performance observed after the neutral priming condition (mean= 1.67; SD=0.44,  $t_{10}=3.20$ ;  $p<0.05$ ).

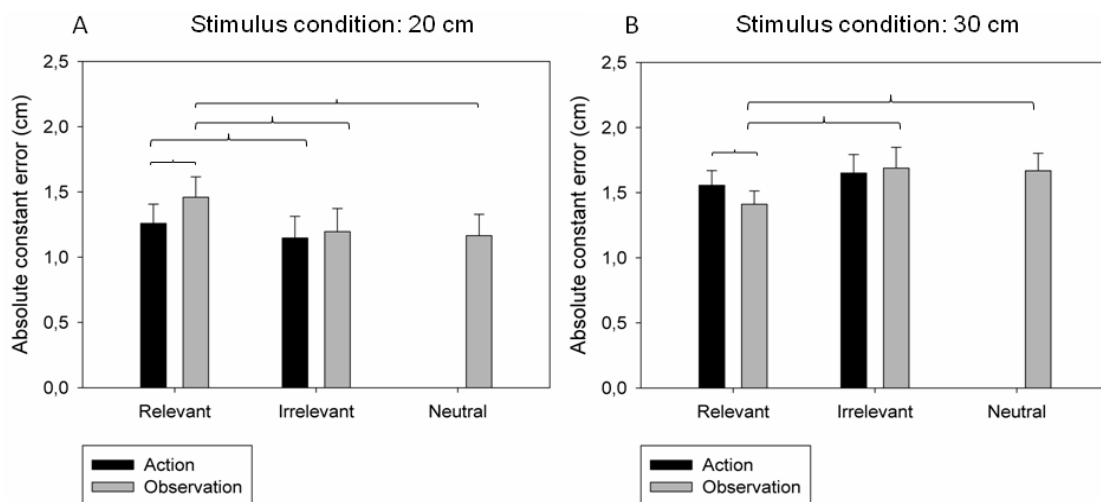


Figure 2: Mean and standard error of the absolute constant errors according to the priming condition and the congruency for the 20 cm stimulus condition (A) and the 30 cm stimulus condition (B). Brackets indicate significant differences at the  $p < 0.05$  level.

With respect to the response variability, we observed no main effect of the priming condition ( $F(1,10)<1$ ), the congruency ( $F(1,10)<1$ ) or the stimulus condition ( $F(1,10)=2.14$ ;  $p=0.16$ ) and no interaction between these factors (all  $p>0.20$ ). In all conditions, we had a mean response variability of 0.47 cm (SD= 0.12 cm) which was not significantly different of the variability observed after the neutral priming condition (mean= 0.43 cm; SD=0.15 cm,  $t_{10}=1.75$ ;  $p=0.11$ ).

## DISCUSSION

This study compared the effect of action and observation priming on the anticipation capacity after observation of incomplete point-light pointing movements. The main finding is that relevant observation priming is more efficient than equivalent relevant action priming in anticipating the final state of a biological stimulus. In the specific context of the motor theory of biological motion perception, the superiority of the visual relevant priming over the other conditions is an intriguing finding and suggests that not only motor competencies but also specific perceptual competencies can be used to resolve perceptual anticipation tasks. This finding agrees with some experiments that show that humans can have better perceptive competencies regarding biological movements than motor competencies (e.g., Pavlova et al., 2003). Moreover, it argues in

the favor of the hypothesis of the use of internal action representation in anticipation task (Pozzo et al., 2006). It is also in accordance with a recent work which showed that inferring another's goal implies more reasoning regarding action and context than pure motor simulation (Liepelt, Von Cramon, & Brass, 2008). One interesting similarity between observation priming and the actual stimulus is that both involved another person making a pointing movement. Some experiments have shown that perspective (self vs. other) can influence the activation of motor systems (Fourkas, Avenanti, Urgesi, & Aglioti, 2006). Moreover, it is well known that the analysis of our own motions is processed differently than the analysis of the motions generated by others (e.g., Loula et al., 2005) and that this difference is manifested in behavior and in brain activity (Chaminade & Decety, 2002; Farrer & Frith, 2002; Shmuelof & Zohary, 2006). Consequently, we can hypothesize that action priming that involves our own motor competencies is processed differently by the brain than equivalent observation priming that involves motions generated by others. In that case, judgment of the observation priming and the visual stimuli might involve a similar mechanism, which could account for the superior efficiency of observation priming. This common mechanism could be supported on a neurophysiological level by the activation of the superior temporal sulcus (STS) when participants observe actual (during the priming) or point-light

(during the task) biological motions. Indeed, it is well known that the observation of biological movements (but not their production) specifically activates the STS (see Pavlova, 2012 for a review). Consequently, we propose that the initial activation of the STS in observation priming could affect the subsequent anticipative visual competencies. However, further investigations are necessary to examine this neurophysiological hypothesis, which will be conducted in a future study.

One alternative explanation for our results could be that observation priming had a higher spatio-temporal proximity with respect to the point-light display stimulus than the pointing movement performed by the participant. Indeed, observed prime and stimulus were presented in vertical plane whereas action priming had been executed in horizontal plane. However, it is important to note that observation priming had been built from a production in the horizontal plane. Accordingly, when we asked to participants whether the observation priming showed someone who produced a pointing movement in horizontal or vertical plane, 10 out of 11 people answered that the movement had been executed in a horizontal plane. Consequently, it is few unlikely that the vertical presentation of observation priming can explain the difference obtained between action and observation priming conditions. One other possibility is that kinematics used in the observation priming condition was nearer kinematics of the

stimuli than kinematics associated with action priming condition. Without kinematics analysis of primes, we cannot completely reject this assumption. However, the person used for the observation priming and the person used for the creation of the point-light stimulus were different, and individual analysis indicates that the difference between observation and action relevant priming is present in more than 80 % of the participants (100% for the 20 cm stimuli and 73% for the 30 cm stimuli). In a random sampling, it is unlikely that more than 80% of participants would produce a greater difference between their own action and the point-light stimulus than the difference between the observed prime and the point-light stimulus. Moreover, both the distance and the target, which are two major components known to influence the spatio-temporal properties of a pointing movement (Fitts, 1954), were different in the observation priming and the stimulus displays. Finally, previous experiments implying biological human movements have shown that there are differences between males and females in their production of movements and that observers are sensitive to these sex differences when they judge human movements (Alaerts, Nackaerts, Meyns, Swinnen, & Wenderoth, 2011; Bidet-Ildei et al., 2010; Kozlowski & Cutting, 1977). In the present study, the observation priming involved movements produced by a woman, whereas the stimuli involved movements produced by a man, which suggests that our findings are not due to

similarities between the observation priming and the stimulus.

One other important finding is that the priming effect demonstrated in the present experiment is specific; we show an effect only with relevant priming conditions on the anticipation accuracy regarding biological stimuli. This specific effect is consistent with the idea of Wohlschläger (2000) which suggests that “priming only occurred if the goal of the action and the motion display shared a common cognitive dimension”.

Most importantly, we obtain an interaction between the effect of relevant priming condition and the stimulus implicated in the anticipation task. While relevant movements facilitate the performance in anticipation for the 30 cm stimuli, they interfere with the performance in anticipation for the 20 cm stimuli. Given that this difference is significant in both cases at least for observation priming condition, it excludes a pure context effect where observation priming of 40 cm would have been more efficient for the 30 cm stimuli than for the 20 cm stimuli. It is more likely that this interaction results of a difficulty to disengage attentional resources in 20 cm stimuli. Actually, there is 300 ms of difference between the 20 cm (500 ms) and 30 cm (900 ms) stimuli and therefore it may be possible that treatment of visual congruent priming is not finished when participants had to give their answer about the 20 cm stimuli. In contrast, with the 30 cm stimuli, participants would have the time to finish the treatment

of priming condition before to give their answer. This explanation should be assessed in future experiments but it is coherent with the idea that both observation priming and anticipation task involve a similar treatment of action's goal.

## REFERENCES

- Alaerts, K., Nackaerts, E., Meyns, P., Swinnen, S. P., & Wenderoth, N. (2011). Action and emotion recognition from point light displays: an investigation of gender differences. *PloS ONE*, *6*(6), e20989. doi: 10.1371/journal.pone.0020989
- Beardsworth, T., & Buckner, T. (1981). The ability to recognize oneself from a video recording of one's movements without seeing one's body. *Bulletin of the Psychonomic Society*, *8*, 19-22.
- Bidet-Ildei, C., Chauvin, A., & Coello, Y. (2010). Observing or producing a motor action improves later perception of biological motion: Evidence for a gender effect. *Acta Psychologica (Amst)*, *134*(2), 215-224. doi: 10.1016/j.actpsy.2010.02.002
- Bidet-Ildei, C., Meary, D., & Orliaguet, J. P. (2008). Visual preference for isochronic movement does not necessarily emerge from movement kinematics: a challenge for the motor simulation theory. *Neuroscience Letters*, *430*(3), 236-240. doi: 10.1016/j.neulet.2007.10.040
- Bidet-Ildei, C., & Orliaguet, J. P. (2008). Developmental study of visual perception of handwriting movement: influence of motor competencies? *Neuroscience Letters*, *440*(1), 76-80. doi: 10.1016/j.neulet.2008.05.041
- Bidet-Ildei, C., Orliaguet, J. P., & Coello, Y. (2011). Rôle des représentations motrices dans la perception visuelle des mouvements humains. *L'Année psychologique*, *111*(2), 409-445. doi: 10.4074/S0003503311002065
- Chaminade, T., & Decety, J. (2002). Leader or follower? Involvement of the inferior parietal lobule in agency. *Neuroreport*, *13*(15), 1975-1978.
- Chaminade, T., Meary, D., Orliaguet, J. P., & Decety, J. (2001). Is perceptual anticipation a motor simulation? A PET study. *Neuroreport*, *12*(17), 3669-3674. doi: 10.1097/00001756-200112040-00013
- Decety, J., Grezes, J., Costes, N., Perani, D., Jeannerod, M., Procyk, E., & Fazio, F. (1997). Brain activity during observation of actions. Influence of action content



- and subject's strategy. *Brain*, *120* (Pt 10), 1763-1777. doi: 10.1093/brain/120.10.1763
- Elsner, C., Falck-Ytter, T., & Gredeback, G. (2012). Humans Anticipate the Goal of other People's Point-Light Actions. *Frontiers in Psychology*, *3*, 120. doi: 10.3389/fpsyg.2012.00120
- Farrer, C., & Frith, C. D. (2002). Experiencing oneself vs another person as being the cause of an action: the neural correlates of the experience of agency. *Neuroimage*, *15*(3), 596-603. doi: 10.1006/nimg.2001.1009
- Filimon, F., Nelson, J. D., Hagler, D. J., & Sereno, M. I. (2007). Human cortical representations for reaching: mirror neurons for execution, observation, and imagery. *Neuroimage*, *37*(4), 1315-1328. doi: 10.1016/j.neuroimage.2007.06.008
- Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, *47*(6), 381-391. doi: 10.1037/h0055392
- Fourkas, A. D., Avenanti, A., Urgesi, C., & Aglioti, S. M. (2006). Corticospinal facilitation during first and third person imagery. *Experimental Brain Research*, *168*(1-2), 143-151. doi: 10.1007/s00221-005-0076-0
- Graf, M., Reitzner, B., Corves, C., Casile, A., Giese, M., & Prinz, W. (2007). Predicting point-light actions in real-time. *Neuroimage*, *36 Suppl 2*, T22-32. doi: 10.1016/j.neuroimage.2007.03.017
- Hommel, B., Musseler, J., Aschersleben, G., & Prinz, W. (2001). The Theory of Event Coding (TEC): a framework for perception and action planning. *Behavioral Brain Science*, *24*(5), 849-937.
- Jantzen, K. J., Seifert, M., Richardson, B., Behmer, L. P., Odell, C., Tripp, A., & Symons, L. A. (2012). Dorsal stream activity and connectivity associated with action priming of ambiguous apparent motion. *Neuroimage*, *63*(2), 687-697. doi: 10.1016/j.neuroimage.2012.07.010
- Jeannerod, M. (2001). Neural simulation of action: a unifying mechanism for motor cognition. *Neuroimage*, *14*(1 Pt 2), S103-109. doi: 10.1006/nimg.2001.0832
- Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics*, *14*, 201-211. doi: 10.3758/BF03212378
- Kandel, S., Orliaguet, J. P., & Boe, L. J. (2000). Detecting anticipatory events in handwriting movements. *Perception*, *29*(8), 953-964. doi: 10.1068/p2864
- Kozlowski, L., & Cutting, J. E. (1977). Recognizing the sex of a walker from dynamic point-light displays. *Perception & Psychophysics*, *21*, 575-580. doi:

10.3758/BF03198740

- Liepelt, R., Von Cramon, D. Y., & Brass, M. (2008). How do we infer others' goals from non-stereotypic actions? The outcome of context-sensitive inferential processing in right inferior parietal and posterior temporal cortex. *Neuroimage*, *43*(4), 784-792. doi: 10.1016/j.neuroimage.2008.08.007
- Loula, F., Prasad, S., Harber, K., & Shiffrar, M. (2005). Recognizing people from their movement. *Journal of Experimental Psychology Human Perception and Performance*, *31*(1), 210-220.
- Martel, L., Bidet-Ildei, C., & Coello, Y. (2011). Anticipating the terminal position of an observed action: Effect of kinematic, structural, and identity information. *Visual Cognition*, *19*(6), 785-798. doi: 10.1080/13506285.2011.587847
- Meary, D., Kitromilides, E., Mazens, K., Graff, C., & Gentaz, E. (2007). Four-day-old human neonates look longer at non-biological motions of a single point-of-light. *PloS ONE*, *2*(1), e186. doi: 10.1371/journal.pone.0000186
- Pavlova, M. (2012). Biological motion processing as a hallmark of social cognition. *Cerebral Cortex*, *22*(5), 981-995. doi: 10.1093/cercor/bhr156
- Pavlova, M., Staudt, M., Sokolov, A., Birbaumer, N., & Krageloh-Mann, I. (2003). Perception and production of biological movement in patients with early periventricular brain lesions. *Brain*, *126*(Pt 3), 692-701.
- Pozzo, T., Papaxanthis, C., Petit, J. L., Schweighofer, N., & Stucchi, N. (2006). Kinematic features of movement tunes perception and action coupling. *Behavioral Brain Research*, *169*(1), 75-82. doi: 10.1016/j.bbr.2005.12.005
- Prinz, W. (1997). Perception and action planning. *European Journal of Cognitive Psychology*, *9*(2), 129-154. doi: 10.1080/713752551
- Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, *27*, 169-192. doi: 10.1146/annurev.neuro.27.070203.144230
- Rizzolatti, G., Fadiga, L., Matelli, M., Bettinardi, V., Paulesu, E., Perani, D., & Fazio, F. (1996). Localization of grasp representations in humans by PET: 1. Observation versus execution. *Experimental Brain Research*, *111*(2), 246-252. doi: 10.1007/BF00227301
- Schütz-Bosbach, S., & Prinz, W. (2007). Perceptual resonance: action-induced modulation of perception. *Trends in Cognitive Sciences*, *11*(8), 349-355. doi: 10.1016/j.tics.2007.06.005
- Shmuelof, L., & Zohary, E. (2006). A mirror representation of others' actions in the human anterior parietal cortex. *Journal of Neuroscience*, *26*(38), 9736-9742. doi: 10.1038/nn.2196

- Springer, A., Brandstadter, S., Liepelt, R., Birngruber, T., Giese, M., Mechsner, F., & Prinz, W. (2011). Motor execution affects action prediction. *Brain Cognition*, 76(1), 26-36. doi: 10.1016/j.bandc.2011.03.007
- Stadler, W., Schubotz, R. I., von Cramon, D. Y., Springer, A., Graf, M., & Prinz, W. (2011). Predicting and memorizing observed action: differential premotor cortex involvement. *Human Brain Mapping*, 32(5), 677-687. doi: 10.1002/hbm.20949
- Viviani, P., & Stucchi, N. (1989). The effect of movement velocity on form perception: geometric illusions in dynamic displays. *Perception & Psychophysics*, 46(3), 266-274. doi: 10.3758/BF03208089
- Wohlschläger, A. (2000). Visual motion priming by invisible actions. *Vision Research*, 40(8), 925-930. doi: 10.1016/s0042-6989(99)00239-4

#### Acknowledgements

Christel Bidet-Ildei was a visiting post-doctoral student in Kazuo Hiraki's laboratory.

This work was supported by the short-term program of the Japanese Society for Promotion of Sciences (JSPS). We thank all members of Hiraki's lab for their participation, particularly Goh Matsuda and Shun Itagaki for their help in the experimental design. We thank also Arnaud Badets, Lucette Toussaint, Tim Welsh and the two anonymous reviewers for their helpful comments that are contributed to improve our paper.