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Effects of the mere presence of conspecifics on the motor performance of rats: Higher speed and lower accuracy

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ABSTRACT

Many studies on humans and animals have shown that the mere presence of another individual or individuals accelerates the motor performance speed of the subject individual. However, it has not been well investigated whether the mere presence of another individual affects the accuracy of motor performance in animals. In this study, we developed a novel task (run-and-pull task) to simultaneously investigate both the speed and accuracy of motor performance in rats and examined the effect of the mere presence of another rat on the task performance of the subject rat. Rats were first trained in isolation to run a runway and then pull a lever on the terminal end of the runway. After training, the subject rats were required to perform the task in isolation (Single) or in front of a non-competitive confederate rat without direct interaction (Pair). The results showed that the latency to start running and to pull the lever were shorter and the accuracy of the lever-pull movement was lower in the Pair condition than in the Single condition. These findings suggest that the mere presence of another individual increased the speed and decreased the accuracy of the motor performance of rats.

1. Introduction

It is well known that the presence of others affects the performance of several tasks in humans and animals. In earlier studies, 'an increase in response merely from the sight or sound of others making the same movement' was referred to as 'social facilitation' (Allport, 1924). This definition, however, did not distinguish the 'mere presence' of others from 'co-action', in which the subject and the other individual(s) perform the same action. Since Zajonc (1965) proposed that the mere presence of others was enough to facilitate well-learned behaviours or to retard new learning or complex behaviours via the increase in drive or arousal, a number of studies have been conducted on the effect of the mere presence of others on the performance of a task (Guerin, 1993, for a review). The mere presence of another individual is the simplest form of social condition and an essential component of other social conditions in humans and other animals. For example, co-action and competition involve the presence of another consequently. Thus, it is indispensable to dissociate the effect of mere presence from the effect of co-action, competition or any other social condition.

Previous studies have confirmed that the mere presence of another increased the speed of performance (e.g., Markus, 1978; Schmitt et al., 1986) or decreased the accuracy of the performance (e.g., Innes and Gordon, 1985) in humans. In non-human animals, it has been shown that the mere presence of another individual results in an increase in response rate and response speed of instrumental behaviour in rats (e.g., Gipson et al., 2011; Levine and Zentall, 1974) and rhesus monkeys (Reynaud et al., 2015). Takano and Ukezono (2014) recently investigated the performance of rats with a motor task in the presence of another non-competitive observer rat. These authors required a subject rat to perform a skilled reaching task (Metz and Whishaw, 2000) in front of a cage-mate which could not interfere with the subject. In the original task, rats were trained to reach and grasp a pellet placed on the shelf inside of the wall slit. Takano and Ukezono (2014) partly modified the original task, i.e., rats were trained to spin in front of the wall slit before the reach-to-grasp movement. Results showed that rats spun faster in the presence of the cage-mate, in comparison to when they performed the task solitarily. Thus, the mere presence of conspecifics has been shown to commonly accelerate motor behaviours in human and non-human animals.

In humans, the aspects of a behaviour that are affected by the mere presence of another are not only quantitative, such as speed, but also qualitative, such as accuracy. Strauss (2002) reviewed studies on social facilitation (including both co-action and the mere presence effect) in humans with a focus on motor performance. Based on the conservation

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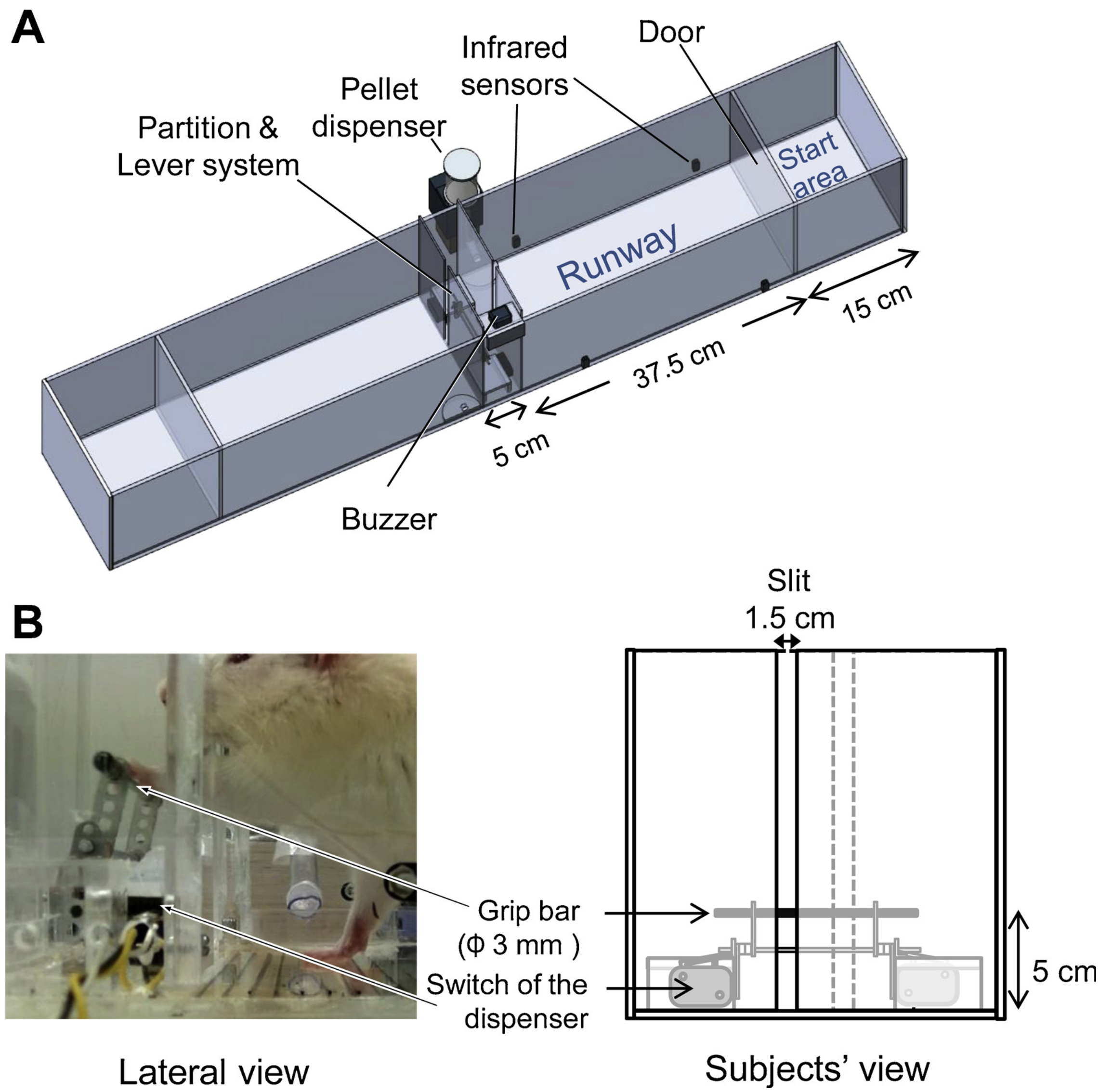

Fig. 1. Apparatus used in the experiment. **A**: Overall view of the apparatus. Two clear acrylic boxes were separated by a partition in the centre. Each box consisted of a start area and a runway. **B**: The partition and a lever system. Subject rats could grasp a bar and pull down the lever to get a reward pellet.

in Bond and Titus (1983), Strauss (2002) then argued that the presence of another individual would cause (a) improvement in the performance of a task; placing high demands on 'conditioning ability' (speed, stamina, power, movement etc.), and which tends to be scored by its quantitative aspects (e.g., reaction time) and (b) decrement in the performance of a task; placing high demands on 'coordination ability' (precise control of the body, some extent of speed) which tends to be scored by its qualitative aspects (e.g., the accuracy of the performance).

In contrast to human studies, many studies of non-human animals have overlooked the effect of the mere presence of another individual on the response accuracy of the acting individual. For example, Takano and Ukezono (2014) examined the effect of mere presence on a quantitative aspect of performance (i.e., spinning time) but did not assess the qualitative aspect (i.e., the accuracy of the reaching movement) in test sessions. However, Ogura and Matsushima (2011) did assess the effect of co-action on both qualitative and quantitative aspects of behaviour by determining the changes in accuracy of pecking action as well as running speed in co-acting domestic chicks. These authors manipulated the difficulty of pecking by systematically altering the arrangement of a reward to be picked up. The study showed that when the difficulty of pecking was high, the number of pecking to pick up a reward was higher in co-acting chicks than in solitary chicks. However, this previous study was focused on the effect of co-action, not mere presence. To the best of our knowledge, the present study is the first to focus on the effect of mere presence of others on the accuracy of the motor performance in non-human animals.

The purpose of the present study was to examine the effect of the mere presence of another rat on both the speed and accuracy of motor performance in subject rats and to compare the results with that of human studies. Specifically, the present study aimed to establish a more informed animal behavioural model of the mere presence effect on motor performance in rats; considering its future use in studies on the neural mechanisms that underpin the mere presence effect. Then, to establish a better animal model of the mere presence effect, it is essential to show that this effect appears in an analogous manner in both the qualitative and quantitative aspects of the motor performance of the animal model, e.g., rats, as it does in humans. We modified the task and the apparatus used in Takano and Ukezono (2014) to prepare two task components: running and lever-pull action by a forelimb. Running was scored by its quantitative aspect (i.e., the time taken to perform the task) and lever-pull action was scored by its qualitative aspect (i.e., the success of the lever-pull action). If the mere presence effect is common across species, the changes in motor performance in rats are expected to be similar to those seen in humans, i.e., in the presence of others, running speed is expected to increase and the accuracy of the lever-pull movement is expected to decrease. The aim of the present study was therefore to determine if the mere presence effect in rats is comparable with that in humans in both qualitative and quantitative aspects of motor performance, and to present a more appropriate animal behavioural model for investigating neural mechanisms that underpin the mere presence effect in mammals.

2. Materials and methods

2.1. Subjects

Experimentally-naïve male albino Wistar rats (*Rattus norvegicus,* n = 15, age: 14 weeks old, weight: 291–313 g at the start of the experiment) were used. Rats were individually housed in cages which were kept in a controlled environment (breeding) room with constant temperature (23 ± 2 °C) and humidity (60%). The photoperiod cycle was maintained at 12:12 h (light:dark) and the light period began at 8:00 AM. All experimental sessions were conducted during the light period. The weights of the subjects were maintained at 85–90% of their free-feeding weight throughout the experimental period by mild food deprivation. Animals were fed daily after the experimental session of the day and were given ad libitum access to water in their housing cages. Some of the rats were assigned as subjects (n = 10), and the remainder were assigned as confederates (n = 5) (see 2.3.1.4). This experiment was approved by the Doshisha Committee of Animal Experiment.

2.2. Apparatus

We prepared a modified version of the apparatus used in previous studies (Metz and Whishaw, 2000; Takano and Ukezono, 2014) (Fig. 1A, B). The apparatus consisted of two boxes made of clear acrylic plates (19.0 × 67.5 × 20.0 cm each) separated by a partition component (5.0 cm wide) between the boxes. A clear sliding door (15 cm from each end of the box) separated the box into a runway (37.5 cm in length) and a start area (15 cm in length). The partition component had a metal lever (grip bar: φ3 mm, 5 cm in height) located on a shelf (Fig. 1B). The lever stood upright held by Neodymium magnets under the lever. Rats could grasp the grip bar and pull the lever down with their preferred forelimb(s) from either side of the box through the vertical slits of the partition (1.5 cm in width). The shortest distance from the wall of the partition to the lever was 2.5 cm. When the lever was pulled down to one side, a switch on a pellet dispenser (LE100 × 50, Panlab s.l.u., Spain) on the same side closed one reward pellet (45 mg, F0021-J, Bio Serv, US) into the receptacle. The lever returned to the standing position after its release. A buzzer was set at the top of the partition. Infrared sensors (separated photo interrupters; PIE310 and PID310 L, Kodenshi, Japan) were set at 5 cm away from the door and 5 cm away from the wall of the partition to detect the passage of the rats. Arduino Mega 2560 (Arduino S.r.l., Italy) was used to control the pellet dispenser and the buzzer, and to read the data from the sensors. A video camera (GZ-R300, JVC, Japan) was set up on the outside of the apparatus to record performance of the rats from a lateral view (60 fps).

2.3. Procedure

A flowchart of the experiment is shown in Fig. 2A. Before starting training phases, all rats received handling for 10 min per day for 3 days and habituation to the apparatus for 20 min on the other days leading up to the training phase.

2.3.1. Training phases

During the training phases, only the subject rats were trained in isolation. The experimenter was present at the side of the box during the phases. The training phases consisted of a lever-pull shaping phase, a lever-pull training phase, and a run-and-pull training phase. One reward pellet was placed in the food receptacle on the opposite box in all trials of the training phases. This consideration was to exclude the effect of the olfactory property of the reward (which the confederate would eat in the experimental phase) (see 2.3.1.4).

2.3.1.1. Lever-pull shaping phase. In the first session of the lever-pull phase (one session/day), we trained rats to obtain a pellet from a food receptacle 60 times with variable time (VT) 20 s schedule (magazine training). Rats were then trained, using the successive approximation method, to insert their preferred forelimb into the slit, grasp the grip bar, and pull down the lever to obtain a reward pellet, i.e., basically the same as the usual lever-press behaviour in operant chambers. Rats were trained until they pulled the lever and earned the 40 rewards by themselves within a 20 min session with a continuous reinforcement (CRF) schedule. A session was complete when the subject rat obtained 60 rewards. These shaping sessions took 3 to 4 days.

2.3.1.2. Lever-pull training phase. After the lever-pull shaping phase, six sessions of the lever-pull training phase were conducted. At the start of each trial, a subject was placed in the start area. After 25 s, the buzzer tone (400 Hz, 75 dB) was presented for 5 s. The door was then opened and the rat was able to run along the runway to the partition and pull the lever. The lever-pull behaviour was reinforced using a CRF schedule. When the subject pulled the lever for a fixed number of times (ten times during the first half of the six sessions, and six times during the last half), the subject was returned (by hand) to the start area to begin another trial after a 25 s inter-trial interval (ITI). A session was completed when the subject rat earned 60 rewards.

2.3.1.3. Run-and-pull training phase. Finally, training sessions for the ‘run-and-pull task’ were conducted. These sessions were similar to those in the lever-pull training except that a trial consisted of opening the door, running along the runway, and pulling the lever to get one reward. When rats had finished pulling the lever and consumed the reward pellet, the experimenter moved them to the start area for a 25 s ITI before the next trial. Daily training sessions consisted of 30 trials and continued for 8 days.

2.3.1.4. Treatment of confederate rats. As was conducted for the subject rats, the confederate rats underwent handling, habituation for the apparatus, and a magazine training session, however, they did not receive any lever-pull shaping or training sessions. Confederate rats were habituated for the confederate side of the boxes for 20 min the day before the commencement of the test phases. To encourage the confederate rats to remain close to the central partition, they were given pellets in the food receptacle on a VT 30 s schedule.

2.3.2. Test conditions

Test phases consisted of two types of phases: Single or Pair. Each phase contained two consecutive sessions and appeared in the order of Pair-Single-Pair-Single (see Fig. 2A). A session was comprised of 30 trials. In the Single-phase sessions, rats performed the run-and-pull task solitarily, i.e., the trials in these sessions were same as those in the training sessions (Fig. 2B). In the Pair-phase sessions, subject rats performed the task in the presence of another weight-matched confederate rat in the opposite box. Because of a clear wall in front of the partition, the confederate could not pull or touch the lever, thus they did not coact or interfere with subjects. As with the habituation the day prior to the experiments, the confederate rat was given one pellet during each ITI.

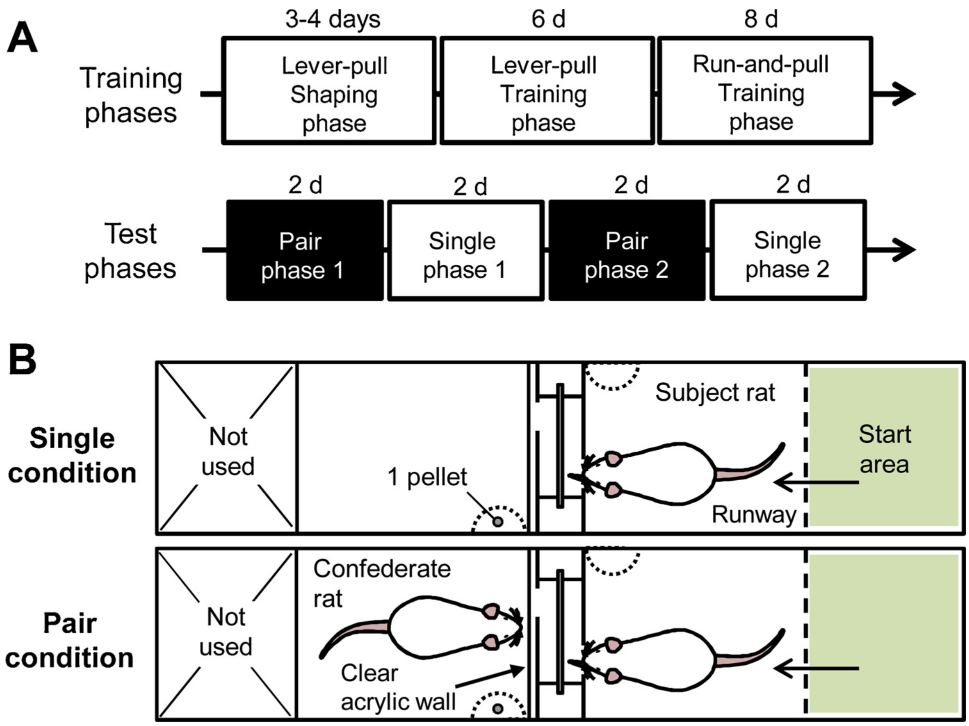

Fig. 2. A: An overall flowchart of the experiment. Rats had been handled and habituated before the training phases. **B**: Description of each test condition. In Single phases, the subject rat performed the task without a confederate rat. In Pair phases, the confederate rat was placed in the runway on the opposite side to the subject rat.

2.4. Dependent variables

2.4.1. Index of performance accuracy

The reaching accuracy was scored based on the method used in Metz and Whishaw (2000). If rats could reach, grasp, and pull the lever on their first attempt in a trial, the trial was regarded as a first-hit trial. If the subject failed to catch or released the lever during pulling, the trial was not included in the first-hit trials. The scoring was conducted by visual observation of the experimenter during the experiment and was confirmed by frame-by-frame analysis of the video recordings after all experimental sessions were concluded. First hit rates were calculated for each subject as the proportion of first-hit trials to all trials in each session (for run-and-pull training phase) or in each phase (for test phases), and averaged rates were used in the analyses.

2.4.2. Indices of the performance speed

The time needed to complete the trials was used as an index of performance speed and was recorded using two infrared sensors and the switch of the dispenser. We divided the time needed for the rat subject to complete a trial into three sections (see Fig. 3): (a) Start latency: the duration from the door opening to the arrival of the rat at the first sensor, (b) Running time: the duration from the arrival at the first sensor to the arrival at the second sensor, and (c) Lever-pull latency: the duration from the arrival at the second sensor to the completion of pulling the lever. Only the data from first-hit trials were used as indices of speed. We calculated the median speeds of each subject for each session (in training sessions) and each phase (in test phases), and averaged values were used in the analyses.

2.5. Statistical analysis

We conducted one-way repeated measures ANOVAs with the number of sessions as the factor for each index in the run-and-pull training phase, and with the phase (Phase 1/2) and condition (Pair/Single) as the factors for each index in the test phases. Statistical significance was set at α = 0.05. Additionally, we examined the relationship between the differences in performance accuracy and performance speed between Pair and Single phases. We calculated the differences between Pair and Single phases for each index of each rat, i.e., start latency, running time, lever-pull latency, and first hit rate. The Spearman's correlation coefficients between the difference score of the first hit rates and each of the indices of performance speed were then computed.

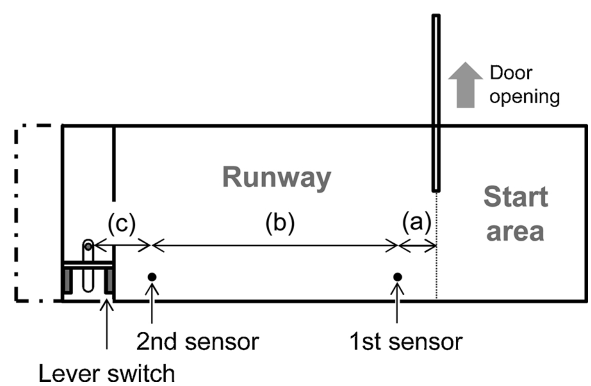

Fig. 3. The side view of the runway and the start area. Time needed for the rat to complete a trial was divided into three sections: (a) Start latency: the duration from the door opening to the arrival of the rat at the first sensor. (b) Running time: the duration from the arrival at the first sensor to the arrival at second sensor. (c) Lever-pull latency: the duration from the arrival at the second sensor to the completion of a lever-pull response.

3. Results

3.1. Run-and-pull training phase

The mean ± standard error of the mean (SEM) scores from the run-and-pull training sessions are shown in Fig. 4. The index of performance accuracy, i.e., the mean first hit rate (Fig. 4A), increased from 70% to 85% until the 5th training session. Results of the repeated-measures ANOVA revealed that the main effect of the number of sessions was significant (F (763) = 3.74, p = 0.002, $\eta^2_G = 0.211$). Multiple comparisons showed that differences among the later four sessions were not

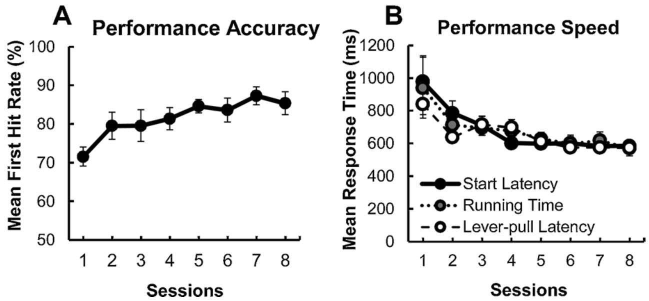

Fig. 4. Dependent variables in the run-and-pull training phase. **A**: Index of performance accuracy. The mean first hit rate increased over the first four sessions and then no more changes were observed. **B**: Indices of performance speed. Mean ± SEM of start latency, running time, and lever-pull latency decreased over the first four sessions, but did not decrease during last four sessions.

significant (all p-values > 0.60).

Similarly, the indices of performance speed (start latency, running time, and lever-pull latency) (Fig. 4B) decreased each day for the first 4 days, but no subsequent changes were seen in the remaining four sessions, and all values stabilized at ~600 ms. The ANOVA for each index revealed a significant main effect of the number of sessions (i.e., start latency: F (763) = 6.21, $p < 0.001$, $\eta^2_G = 0.279$; running time: F (763) = 3.98, p = 0.001, $\eta^2_G = 0.170$; lever-pull latency: F (763) = 11.85, $p < 0.001$, $\eta^2_G = 0.350$). Multiple comparisons (Shaffer's method) in each measure by sessions showed that there was no significant difference in any of the Pair conditions among the later four sessions (all p-values > 0.12).

3.2. Test phases

Scores in test phases are shown in Fig. 5.

3.2.1. Index of performance accuracy

The first hit rate (Fig. 5A) was lower in the Pair phases than in Single phases in both phases and higher in the second phase than in the first phase in both conditions. The main effects of condition (F (1,9) = 6.25, p = 0.034, $\eta^2_G = 0.114$) and phases (F (1,9) = 14.1, p = 0.005, $\eta^2_G = 0.147$) were significant, while the interaction was not (F (1,9) = 0.15, p = 0.703, $\eta^2_G = 0.002$).

3.2.2. Index of performance speed

Start latency (Fig. 5B) was ~50 ms shorter in the Pair phases than in Single phases. The main effect of condition was significant in the start latency (F (1,9) = 23.1, p = 0.001, $\eta^2_G = 0.065$). The main effect of phases (F (1,9) = 0.03, p = 0.878, $\eta^2_G < 0.001$) and their interaction (F (1,9) = 0.002, p = 0.970, $\eta^2_G < 0.001$) were not significant. A similar difference was seen between conditions in the lever-pull latency (Fig. 5D) and the main effect of condition was also significant (F (1,9) = 23.3, p = 0.001, $\eta^2_G = 0.183$). The main effect of phases (F (1,9) = 2.72, p = 0.133, $\eta^2_G = 0.028$) and their interaction (F (1,9) = 1.07, p = 0.327, $\eta^2_G = 0.002$) were not significant. significant effect was seen in running time (Fig. 5C, i.e., condition: F (1,9) = 3.03, p = 0.116, $\eta^2_G = 0.004$; phases: F (1,9) = 4.46, p = 0.063, $\eta^2_G = 0.010$; interaction: F (1,9) = 0.29, p = 0.602, $\eta^2_G < 0.001$).

3.2.3. The correlation between performance accuracy and performance speed

Fig. 6 presents scatter plots that show the correlations between the differences in the first hit rate and that of each index of the performance speed (start latency, running time and lever-pull latency) of the Pair and Single phases. The correlation coefficient of the differences between performance accuracy and the lever-pull latency (Fig. 6C) was relatively high, although it was not statistically significant (Spearman's ρ = 0.624, p = 0.054). The order correlation coefficients between the differences in start latency versus the first hit rate (Fig. 6A, ρ = -0.030, p = 0.934), and the running time versus the first hit rate (Fig. 6B, ρ = -0.127, p = 0.726) were very small and non-significant.

3.2.4. Confederates

The confederate rats spent almost the entire duration of the test sessions nearby the central partition.

4. Discussion

We aimed to investigate the effect of the mere presence of another individual on the speed and accuracy of motor performance in rats. We found that the presence of a confederate rat affected the performance of

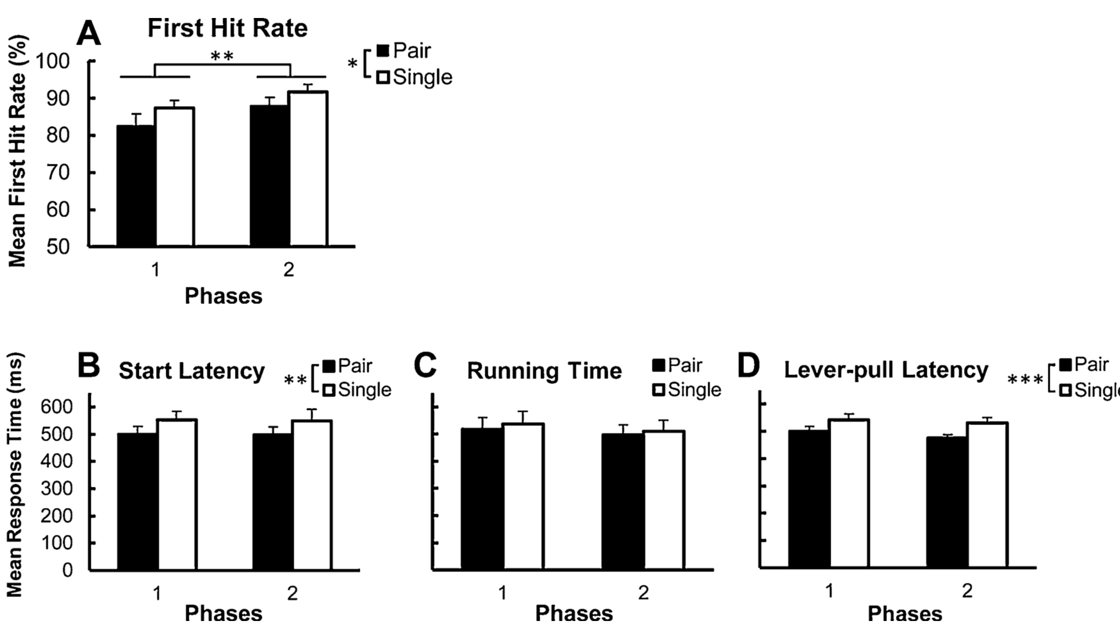

Fig. 5. Mean ± SEM values of performance accuracy (**A**: First hit rate) and performance speed (**B**: Start latency. **C**: Running time. **D**: Lever-pull latency) in test phases. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

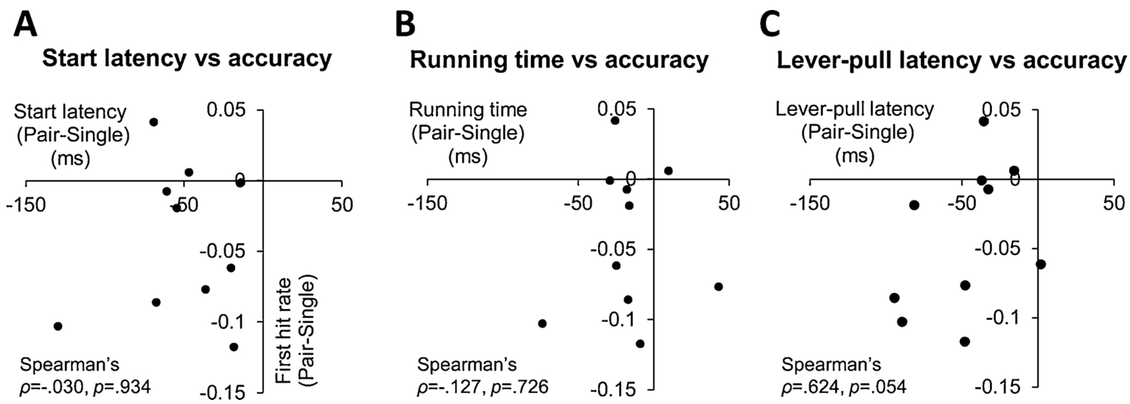

Fig. 6. Correlation between the inter-phases (Pair-Single) difference of the first hit rate (y-axis) and those of start latency (A), running time (B), and (C) lever-pull latency (x-axis). Each dot represents the data of individual rat. When the first fit rate of Pair phases was lower than that of Single phases, the difference score is negative value, and *vice versa*. Similarly, when the indices of performance speed were smaller (faster) in Pair phases, the difference score is negative value.

the subject rat in a similar manner as has been reported in humans, and, therefore, it is suggested that the effect of the mere presence of another individual is common across these species.

4.1. The effect on the performance accuracy

For the first time, the present study showed that the accuracy of a motor performance (i.e., first hit rate) of rats was lower when in the presence of another conspecific. Previous studies of animals on the mere presence effect have only measured quantitative aspects of performance, such as the response rate or the response speed, but not the effect of the qualitative aspect, such as performance accuracy. In contrast, we assessed both the qualitative and quantitative aspects. As is shown in Fig. 5A, the first hit rate was lower in the Pair condition than in the Single condition. These results suggested that the mere presence of another conspecific impaired the accuracy of motor performance, which are consistent with the results from such human studies (Bond and Titus, 1983; Strauss, 2002), i.e., that the accuracy of motor performance was lower in the presence of another individual. Although Ogura and Matsushima (2011) have previously shown that co-action leads to less accurate pecking in domestic chicks, the present study showed that the mere presence of another individual can cause such changes in animals.

In our analyses, we assumed that distraction by novel exposure to another rat did not affect the lower accuracy in Pair phases. It is possible that the unexpected appearance of another rat in the Pair phase did distract the performance of lever-pull action. However, we present motivations for why distraction was not responsible for the results observed in the present study. Firstly, if the lower accuracy was due to distraction, the largest decrease in accuracy would be expected to occur between the last day of the training phase and the first session of the Pair phase, because subject rats first encountered the confederate rat in the first session of Pair phase; but such a tendency was not found in this study. Secondly, if subject rats were distracted by another rat, the distraction would be expected to deteriorate not only the performance accuracy but also the performance speed. However, lever-pull latency was shorter in Pair sessions. Thirdly, according to Levine and Zentall (1974), distraction would not have had an effect in this study, even though this logic is inductive. Using individually housed and well-trained rats and naïve confederate rats, Levine and Zentall (1974) investigated if the lever-press performance of rats would be facilitated or distracted by the presence of another naïve rat in an adjacent box separated by Plexiglas wall. These authors found that even in individually housed rats, distraction was not confirmed by the performance and number of lever-presses. They concluded that when physical contact was restricted, the effect of the mere presence of the other enhanced rather than distracted the performance. The condition almost consistent with those in our study; i.e., subjects and confederates were separated using acrylic walls, and trained rats were used as the subjects and naïve rats were used as the confederates.

The gradual increase in the first hit rate during the test phases (Fig. 5A) might potentially be a result of practice, i.e., the performance of rats in the test phase further improved in spite of presumably sufficient training during the run-and-pull training sessions. Despite the mean first hit rate in the run-and-pull training phase having reached an asymptote prior to the commencement of the test phase (Fig. 4A), the continuous increase implied there may have been room for improvement regarding the first hit rate. To rule out the possibility of the effect of practice, a replication study is needed which incorporates the test phases in the order of Pair-Single-Single-Pair or Single-Single-Single-Single.

An ‘after-effect’ of the presence of the confederate rat cannot explain the gradual increase in the first hit rate. Ukezono et al. (2015) reported an increment in the performance speed of a simple calculation task (Uchida-Kraepelin test) when the confederate had left the testing room, just prior to the commencement of the test session. However, we could not find any previous studies that reported the after-effect lasting for such a long period, i.e., one day, including Ukezono et al. (2015). We were unable to explain the observed increase in the first hit rate by repetition of phases. Further studies are needed to clarify the details of the effect of experiencing sessions in the presence of another on the afterward performance of well-trained behaviour.

4.2. The effect on the performance speed

Our findings provide support for the phenomenon that the presence of another conspecific accelerates the speed of motor performance. We found that the start latency and the lever-pull latency in the Pair condition were shorter than those in the Single condition (Figs. 5B, D). Many previous studies have also reported that the presence of another conspecific increased the performance speed in humans (Bond and Titus, 1983; Strauss, 2002) and animals (Gipson et al., 2011; Levine and Zentall, 1974; Reynaud et al., 2015; Takano and Ukezono, 2014). The higher performance speed in the presence of a confederate in this study is consistent with the findings of these previous studies, which demonstrates the robustness of the mere presence effect. The higher performance speed in the presence of conspecifics in this study, which is thought to be more dependent on the conditioning ability, is also consistent with the results in rhesus macaques (Reynaud et al., 2015), rats (Gipson et al., 2011; Levine and Zentall, 1974; Takano and Ukezono, 2014), and humans (Innes and Gordon, 1985). Therefore, our study offers further evidence that the mere presence of another individual affects the quantitative aspects of behaviour, e.g., acceleration of performance speed, and that this a general phenomenon across species.

It is assumed that the lack of difference in running time was due to the floor effect. Running time did not differ between conditions, but a similar tendency with the start latency and the lever-pull latency was observed. Although it was not quantified, an observation by the experimenter confirmed that the subject rats rapidly ran through the runway toward the central partition and scarcely stopped in the runway regardless of the conditions. It is possible that the running time could not be shortened because it did not contain stopping time, unlike that which occurred in the start latency or the lever-pull latency sessions.

The higher performance speed could not be explained by the tendency of subject rats to affiliate with another isolated rat. Indeed, the start latency in Pair sessions was shorter than that in Single sessions. This shorter start latency may have been induced by the tendency to affiliate with another rat. However, the shorter lever-pull latency could not be explained by such affiliation because the lever-pull action was not associated with the action of approaching the confederate. The action did not allow rats to approach the confederate rat. Therefore, at least the shorter lever-pull latency in Pair phases could not be explained by affiliation behaviour.

4.3. The correlation between differences in performance accuracy and performance speed

We found that the differences between phases in the first hit rate and the lever-pull latency (Fig. 6C) were positively and moderately correlated, i.e., rats performed the lever-pull action faster but with less accuracy in Pair phases. This correlation indicated that there was a speed-accuracy trade-off in the lever-pull action. This speed-accuracy trade-off is a feature which has commonly been seen in goal-directed movements in humans (Plamondon and Alimi, 1997, for review). Thus, the task used in the present study was successful in replicating a feature of goal-directed motor task as has been used in previous studies involving humans and rats (Metz and Whishaw, 2000; Takano and Ukezono, 2014).

4.4. The mere presence effect

Our findings suggest that the mere presence of a conspecific is sufficient to decrease the accuracy and increase the speed of performance in rats. Prior studies on the social facilitation in animals confounded the effects of direct contact (cf. aggressive behaviour in rats, Deni and Jorgensen, 1976), co-action between animals (Ogura and Matsushima, 2011; Reynaud et al., 2015), or cueing (cf. observational learning, Zentall and Levine, 1972) with the effect of the mere presence of the conspecific. However, in this study, a transparent acrylic wall permitted only visual contact and prevented direct contact between the confederate and the subject. Additionally, because confederates did not receive any training of the lever-pull behaviour, they would not co-act with the subjects and their behaviour would not provide a cue for the subjects. Possible confounding effects were, therefore, eliminated in this study, and it is thus suggested that direct contact, co-action, and cueing are not necessary to cause qualitative and quantitative changes in performance. This interpretation is consistent with the findings of Takano and Ukezono (2014), which showed that the mere presence of a confederate accelerated the speed of motor performance of the subject rat. Thus, the phenomenon that the mere presence of a conspecific accelerates the speed of motor performance was found to be replicable.

Moreover, the present results extend the knowledge of the previous study by Takano and Ukezono (2014) by at least three points. Firstly, we showed, for the first time, that the mere presence of a conspecific was sufficient to decrease the accuracy and increase the speed of motor performance. Secondly, our study excluded the possibility of an alternate interpretation of the findings stemming from a difference in environments, i.e., housing or training, and the test phases. In the study by Takano and Ukezono (2014), rats were housed and trained in pairs, and tested in pairs or singly, depending on the conditions. This means that rats in the single condition did not have a companion in the test phase (Guerin, 1993), which could induce ‘solitary inhibition’, i.e., deceleration of the speed of motor performance in a solitary situation (Clayton, 1978; Stamm, 1961). Hence, it may be possible that the shorter spinning time in the pair condition was caused by solitary inhibition (i.e., an extension of spinning time) in the single condition, not by the social facilitation, i.e., a reduction of spinning time in the pair condition. In contrast, we housed and trained rats solitarily and then conducted the tests in this same condition, i.e., by adding a companion or not. Nevertheless, the findings of this study revealed that a lower performance accuracy and higher performance speed occurred in the pair condition despite the differences in the housing or training environment. Therefore, results of our study could be explained by social facilitation, not by solitary inhibition. Thirdly, the comparison between the present results and those of Takano and Ukezono (2014) implies that the extent of familiarity with another individual is not critical for the occurrence of social facilitation. As mentioned above, we used singly housed, trained rats and, therefore, the possibility of familiarity with confederate rats would be relatively low in this study. In contrast, familiarity is presumed to have been relatively high in the rats of the Takano and Ukezono (2014) study because they were housed and trained in pairs. The familiarity of other individuals is thought to be a factor which influences social facilitation by raising the arousal level of the individuals (Guerin and Innes, 1982; Zajonc, 1965). However, considering that the same results were obtained in our study and in that of Takano and Ukezono (2014), it is suggested that familiarity is not a key factor for the occurrence of the mere presence effect in rats when direct contact is prevented.

Overall, the experimental procedure used in this study serves as an effective animal model of the mere presence effect in humans, which enables us to examine its effect on both qualitative and quantitative aspects in a single experiment. The procedure, for example, can be used to investigate the neural underpinnings of the effect of mere presence, which have previously been studied using fMRI. In rhesus monkeys, Monfardini et al. (2015) reported that the activity of frontoparietal areas was increased when they perform a task in front of another conspecific. Recently, in humans, the activity of neurons in the medial prefrontal cortex have also be shown to increase when participants performed a simple task in the presence of another (Chib et al., 2018). Causal studies using our proposed behavioural model with rats may lead to a better understanding of the neural basis of the mere presence effect in other mammals, including humans.

5. Conclusions

Our data suggested that the mere presence of another individual results in lower performance accuracy and higher performance speed in rats, as has been seen in humans, thus the mere presence effect on qualitative and quantitative aspects of performance appears to be common among rats and humans. The experimental procedure outlined in the present study may be used in studies regarding the neural mechanisms that underpin the effect of mere presence in mammals.

Author contributions

Y.S. and T.H. designed the study and wrote the paper. Y.S. developed the apparatus, conducted the experiment, and analysed the data.

Declaration of interest

None.

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References

Allport, F.H., 1924. Social Psychology. Houghton Mifflin, New York, NY.
Bond, C.F., Titus, L.J., 1983. Social facilitation: a meta-analysis of 241 studies. Psychol. Bull. 94 (2), 265–292. https://doi.org/10.1037/0033-2909.94.2.265.
Chib, V.S., Adachi, R., O'doherty, J.P., 2018. Neural substrates of social facilitation effects on incentive-based performance. Soc. Cogn. Affect. Neurosci. 13 (4), 391–403. https://doi.org/10.1093/scan/nsy024.
Clayton, D.A., 1978. Socially facilitated behavior. Quart. Rev. Biol. 53 (4), 373–392. https://doi.org/10.1086/410789.
Deni, R., Jorgensen, B.W., 1976. Inhibition of fixed interval bar-pressing in rats during exposure to a trained companion. Psychol. Rep. 39 (1), 243–246. https://doi.org/10.2466/pr0.1976.39.1.243.
Gipson, C.D., Yates, J.R., Beckmann, J.S., Marusich, J.A., Zentall, T.R., Bardo, M.T., 2011. Social facilitation of d-amphetamine self-administration in rats. Exp. Clin. Psychopharmacol. 19 (6), 409–419. https://doi.org/10.1037/a0024682.
Guerin, B., 1993. Social Facilitation. Cambridge University Press, Cambridge, UK.
Guerin, B., Innes, J.M., 1982. Social facilitation and social monitoring: a new look at Zajonc's mere presence hypothesis. Brit. J. Soc. Psychol. 21 (1), 7–18. https://doi.org/10.1111/j.2044-8309.1982.tb00506.x.
Innes, J.M., Gordon, M.I., 1985. The effects of mere presence and a mirror on performance of a motor task. J. Soc. Psychol. 125 (4), 479–484. https://doi.org/10.1080/00224545.1985.9713527.
Levine, J.M., Zentall, T.R., 1974. Effect of a conspecific's presence on deprived rats' performance: social facilitation vs distraction/imitation. Anim. Learn. Behav. 2 (2), 119–122. https://doi.org/10.3758/BF03199135.
Markus, H., 1978. The effect of mere presence on social facilitation: an unobtrusive test. J. Soc. Psychol. 14 (4), 389–397. https://doi.org/10.1016/0022-1031(78)90034-3.
Metz, G.A., Whishaw, I.Q., 2000. Skilled reaching an action pattern: stability in rat (*Rattus norvegicus*) grasping movements as a function of changing food pellet size. Behav. Brain Res. 116 (2), 111–122. https://doi.org/10.1016/S0166-4328(00)00245-X.
Monfardini, E., Redouté, J., Hadj-Bouziane, F., Hynaux, C., Fradin, J., Huguet, P., Costes, N., Meunier, M., 2015. Others' sheer presence boosts brain activity in the attention (but not the motivation) network. Cereb. Cortex 26 (6), 2427–2439. https://doi.org/10.1093/cercor/bhv067.
Ogura, Y., Matsushima, T., 2011. Social facilitation revisited: increase in foraging efforts and synchronization of running in domestic chicks. Front. Neurosci. 5, 91. https://doi.org/10.3389/fnins.2011.00091.
Plamondon, R., Alimi, A.M., 1997. Speed/accuracy trade-offs in target-directed movements. Behav. Brain Sci. 20 (2), 279–303.
Reynaud, A.J., Guedj, C., Hadj-Bouziane, F., Meunier, M., Monfardini, E., 2015. Social facilitation of cognition in Rhesus monkeys: audience vs. coaction. Front. Behav. Neurosci. 9, 328. https://doi.org/10.3389/fnbeh.2015.00328.
Schmitt, B.H., Gilovich, T., Goore, N., Joseph, L., 1986. Mere presence and social facilitation: one more time. J. Exp. Soc. Psychol. 22 (3), 242–248. https://doi.org/10.1016/0022-1031(86)90027-2.
Stamm, J.S., 1961. Social facilitation in monkeys. Psychol. Rep. 8 (3), 479–484. https://doi.org/10.2466/pr0.1961.8.3.479.
Strauss, B., 2002. Social facilitation in motor tasks: a review of research and theory. Psychol. Sport Exerc. 3 (3), 237–256. https://doi.org/10.1016/S1469-0292(01)00019-X.
Takano, Y., Ukezono, M., 2014. An experimental task to examine the mirror system in rats. Sci. Rep. 4, 6652. https://doi.org/10.1038/srep06652.
Ukezono, M., Nakashima, S.F., Sudo, R., Yamazaki, A., Takano, Y., 2015. The combination of perception of other individuals and exogenous manipulation of arousal enhances social facilitation as an aftereffect: re-examination of Zajonc's drive theory. Front. Psychol. 6, 601. https://doi.org/10.3389/fpsyg.2015.00601.
Zajonc, R.B., 1965. Social facilitation. Science 149, 269–274. https://doi.org/10.1126/science.149.3681.269.
Zentall, T.R., Levine, J.M., 1972. Observational learning and social facilitation in the rat. Science 178 (4066), 1220–1221. https://doi.org/10.1126/science.178.4066.1220.