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3 Deferred imitation and declarative memory in domestic dogs

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9
10 Abstract

11 This study demonstrates for the first time deferred imitation of novel actions in dogs (*Canis*
12 *familiaris*) with retention intervals of 1.5 minutes and memory of familiar actions with
13 intervals ranging from 0.40 to 10 minutes.

14 Eight dogs were trained using the ‘Do as I do’ method to match their own behaviour to
15 actions displayed by a human demonstrator. They were then trained to wait for a short
16 interval to elapse before they were allowed to show the previously demonstrated action. The
17 dogs were then tested for memory of the demonstrated behaviour in various conditions, also
18 with the so-called ‘two-action procedure’ and in a control condition without demonstration.

19 Dogs were typically able to reproduce familiar actions after intervals as long as 10 minutes,
20 also if distracted by different activities during the retention interval and were able to match
21 their behaviour to the demonstration of a novel action after a delay of 1 minute. In the two-
22 action procedure, dogs were typically able to imitate the novel demonstrated behaviour after
23 retention intervals of 1.5 minutes.

24 The ability to encode and recall an action after a delay implies that facilitative processes
25 cannot exhaustively explain the observed behavioural similarity and that dogs’ imitative
26 abilities are rather based on an enduring mental representation of the demonstration.
27 Furthermore the ability to imitate a novel action after a delay without previous practice
28 suggests presence of declarative memory in dogs.

29
30 Keywords: deferred imitation; dog; declarative memory; social learning

31
32 Introduction

Deferred imitation is the ability to encode, retain and retrieve a memory of an action and then to use it as the basis to reproduce the demonstrated action after a delay (Klein & Meltzoff 1999). Since Piagetian theories (Piaget 1952), deferred imitation has been considered a hallmark of mental representation as it indicates the emergence of the infant's ability to form a mental representation of the model's behaviour at the time of demonstration and recall of that image after a retention interval (Barr et al. 1996).

From a cognitive perspective, evidence for deferred imitation excludes alternative explanations of behavioural similarity between demonstrator and observer where the demonstration triggers a similar behaviour in the observer at the same time or shortly after it, such as contagion and response facilitation (Bandura 1969). Researchers generally agree that one minute is a sufficiently long delay to exclude the kind of reflexive response thought to be responsible for immediate imitation (e.g. Zentall 2006). Accordingly, imitative behaviour after such a delay is considered as deferred imitation.

While imitation is usually studied between individuals of the same species, there is strong evidence that dogs can learn socially both from con- and heterospecifics demonstrators. Dogs represent a particularly interesting species for the study of hetero-specific social learning abilities (Kubinyi *et al.* 2009) as they have undergone selection for living in human groups through domestication and these changes helped to form a species with surprisingly complex social skills (Miklósi *et al.* 2007; Hare & Tomasello 2005, Miklósi and Topál 2013). Dogs are particularly keen on relying on human communicative cues (Hare *et al.* 2002; Miklósi *et al.* 2003; Miklósi & Soproni 2006), they are able to learn by observing humans in detour tests and manipulative tasks (Pongrácz *et al.* 2001, 2003, 2012; Kubinyi *et al.* 2003) and are easily influenced by humans in observational learning situations (Kupán *et al.* 2010). The selection for living in human social groups might therefore have favoured their general ability to learn from humans.

Two independent studies (Topál *et al.* 2006; Huber *et al.* 2009), using the 'Do as I do' procedure (Hayes & Hayes 1952), showed that dogs are able to match functionally their behaviour to an action demonstrated by a human experimenter. In one of these studies the authors (Huber *et al.* 2009) found that the dog's matching degree decreased with the increased delay interposed before the 'Do it!' command: she could perform correctly with delays shorter than 5 seconds and only once she could match a familiar action after 35 seconds. Thus dogs may lack the ability of (true) deferred imitation, but this negative result

could be explained by problems with the procedure used. It is likely that through the ‘Do as I do’ procedure as applied by Topál et al. (2006) and Huber et al. (2009), the dog learns that it should copy the action that has been demonstrated immediately before the ‘Do it!’ command. Thus dogs trained this way would not have learned that they were required to copy the action that was demonstrated before an interval.

The aim of the present study is to assess if dogs possess the cognitive ability of deferred imitation. For this purpose dogs were first trained by their owners with the ‘Do as I do’ method and then before testing they were trained to wait for short intervals (from 5 to 30 seconds) before they were allowed to display a copy of the observed action. By using this procedure we taught our subjects that the ‘Do it!’ command referred to what had been demonstrated before an interval. In the following testing phase the dogs participated in a series of test looking at (1) generalisation ability, (2) deferred imitation, (3) emulative learning.

First we investigated the dogs’ ability to reproduce human demonstrated actions after delays ranging from 0.40 to 10 minutes that also included distractions during the retention interval. The use of distractions engages dogs in a different activity, thus preventing them from keeping their mind active on the demonstration, so that the ability to encode and recall the demonstrated action after an interval can be tested.

In studies on children, their deferred imitation after long retention intervals is affected by changes in context between demonstration and retrieval and it is supposed that context might serve as a retrieval cue that helps recalling the demonstration (e.g. Barnat et al. 1996). Thus, in the second part of the testing dogs were given the ‘Do it!’ command in a different location from that of the demonstration.

Two-action or multi-action experiments (Dawson & Foss 1965) have become recognised methods (e.g. Akins & Zentall 1996; van de Waal et al. 2012) to test imitative abilities because they control for other non imitative processes that may increase the probability of a similar response by the observer, such as local enhancement (Thorpe 1963) and stimulus enhancement (Galef 1988). In the case of emulation the observer learns about the outcome of the demonstrator’s action, but not about the action itself (Wood 1989; Tomasello 1990). Importantly, Horner and Whiten (2005) found that chimpanzee’s tendency to use emulation or imitation to solve a tool-using task depended on the availability of causal information during demonstration and they seem to be able to flexibly use the process that is more

efficient, given the environmental constraints of the situation.

Accordingly, we included two tests that control for emulation learning using the two-action procedure because earlier studies on imitation in dogs (Topál et al. 2006, Huber et al. 2009) did not explicitly test for such alternative explanations. We designed our two two-action tests to be different in the kind of information shown to the dogs: in the first two-action test the two actions did not lead to different outcomes while in the second two-action test two different outcomes were achieved by the demonstrators. If dogs were only able to engage in deferred emulation but not in deferred imitation, we would expect them to perform correctly only when two different outcomes were presented, but not to succeed when different actions without different outcomes were shown.

Finally, a test to control for Clever Hans effect and a control test in absence of demonstration were carried out.

Material and methods

Subjects

The subjects in our study consisted of 8 adult pet dogs ranging from 2 to 10 years old and their owners who volunteered to participate in this experiment. The dogs were females of various breeds (4 Border Collies, 1 Shetland Sheepdog, 1 Yorkshire Terrier, 1 Czechoslovakian Wolfdog, and 1 mixed breed).

Before the study began, all the subjects had previously been trained by their owners with the ‘Do as I do’ method to match their behaviour to demonstrated actions (based on Topál et al. 2006, see below).

Training phase

Preliminary ‘Do as I do’ training (based on Topál et al. 2006):

The training protocol had been previously explained to all the owners by the experimenter (C.F.) before the study began and consisted of two phases:

Phase 1. The dogs learned to match their behaviour to 3 demonstrated familiar (i.e. already trained) actions using the ‘Do it!’ command through operant conditioning techniques. Each owner could decide what actions to use for the training. Once the dogs reached approximately 80% of correct performance in at least two sessions in a row, they began the

129 second training phase.

130 Phase 2. The dogs learned to match their behaviour to 6 demonstrated familiar actions using
131 the ‘Do it!’ command (in the training sessions 3 other familiar actions were added to the 3
132 used in phase 1). Both in phase 1 and 2 owners could decide what actions to use for the
133 training, the only requisite being that they had to be already trained actions. The owners
134 typically used both object related actions and body movements.

135 The owners were allowed to train the dogs at home and were instructed to reward the dog
136 using food or access to favourite toys only if their behaviour after the ‘Do it!’ command
137 corresponded to the action that had been demonstrated. The definition of correspondence
138 was based on Topál et al. 2006: the action that the dog performed immediately after the ‘Do
139 it!’ command was considered as functionally matching the demonstration if it entailed the
140 same goal and, given the species-specific differences in the behaviour repertoire of the two
141 species, was executed in a similar way.

142 The owners were instructed to train their dogs two to three times per week in a single
143 training session lasting no more than 5 minutes. A single training session typically included
144 six to ten trials but owners were not given restrictions about the number of trials.

145 The training of the dogs lasted on average approximately one month, but the duration varied
146 from two to seven weeks according to the time devoted by owners to the training.

147 Once the dogs reached 80% of correct performance with the 6 familiar actions, owners were
148 allowed to train their dogs to perform novel actions using this training technique.

149

150 *Preliminary training for deferred imitation:*

151 Before the testing began, all subjects went through a training phase aimed at teaching dogs
152 that the ‘Do it!’ command now referred to the action that had been demonstrated after the
153 ‘Stay’ command, even if: 1) an interval elapsed between the demonstration and the ‘Do it!’
154 command and 2) the demonstrator performed other actions during the interval (i.e. walked in
155 another direction). The procedure was as follows:

156 Owners made their dog stay in place while facing them and made them pay attention using
157 cues known by the dog. Next the owners demonstrated a familiar object-related action. Then
158 they returned to the starting position in front of their dog and waited for 5 seconds while
159 looking straight ahead, before giving the ‘Do it!’ command. Dogs were rewarded using food
160 or access to favourite toys only if their behaviour after the ‘Do it!’ command corresponded

161 to the action that had been demonstrated. In case of failure the procedure was repeated.
162 When the dogs were successful with this short delay in at least two trials in a row, owners
163 increased the delay up to 10 seconds, repeating the same procedure. When dogs were
164 successful with this delay in at least two trials in a row, owners were instructed to perform
165 the demonstration and then walk with their dogs during increasingly longer delays, before
166 returning to the starting position and giving the ‘Do it!’ command. The delay was gradually
167 increased to approximately 30 seconds to allow owners to walk with their dog behind a
168 curtain positioned at 14 m from the objects, before returning to the starting position and
169 giving the ‘Do it!’ command (Fig. 1).
170 Owners trained the dogs in two different dog schools. They admitted the dog to the
171 following testing procedure once they or the trainer who controlled the training procedure
172 reported that the dogs could functionally match their behaviour to the demonstration of
173 familiar actions in two trials in a row with a delay of 30 seconds.

174

175 *Testing phase*

176 The testing took place at the same two dog schools where the dogs were trained, in outdoor
177 fenced areas. Before the testing, owners completed a list of all the actions that were already
178 familiar to their dogs (i.e. the dogs were already trained to perform those actions either with
179 traditional training methods or with the Do as I do method). For each subject we randomly
180 picked five object-related actions from this list to use those in those testing conditions where
181 familiar actions were demonstrated. Thus in the Familiar action conditions dogs were
182 randomly shown actions that, either were part of their training repertoire but had never been
183 used in the Do as I do framework, or were used for the Do as I do training.

184 In each test and for each dog, three object-related actions were randomly chosen out of those
185 five for the Familiar action condition, Distracting condition’ and Changed context condition
186 and three completely novel object-related actions were presented in the Novel action
187 condition and in the Two-action tests (Table 1). The relative position of the objects on which
188 the demonstration was performed (centre, right, left) was also randomized, their distance
189 being 3.5 m from each other. The curtain used to prevent dogs from looking at the target
190 object during the retention interval was placed at a distance of 14 m from the objects (Fig. 1).
191 The owners taking part in the tests helped to prepare the setting (i.e. they carried all the
192 objects to the predetermined position). This was done to exclude that dogs could rely on

olfactory cues for their performances, as all the objects were previously manipulated by the owners.

At the beginning of each trial, the owner made the dog stay at the same place (using verbal commands and hand gestures known by the dog) and demonstrated a randomly chosen object-related action. After the demonstration, dog and owner walked behind the curtain in order to prevent the dog from looking at the target object. When the predetermined retention interval elapsed, the experimenter told the owner to go back to the starting position and, once reached this position, the owner gave the ‘Do it!’ command to the dog while looking straight ahead. For the analysis, the length of the delay in each condition was calculated from the demonstration to the ‘Do it!’ command and could slightly vary (± 30 seconds) according to the walking speed of each owner and dog when they went back from behind the curtain to the starting position.

Dogs were tested in different periods, according to their owners’ availability for the testing. For each subject an interval of at least 30 minutes passed between two consecutive tests and the maximum number of tests per day was 4. The maximum interval between two consecutive tests for one dog was 53 days.

Each dog went through the same testing protocol (Table 2) consisting of 19 tests in eight different conditions (one trial per delay) in the following detailed order:

Familiar action: Eight tests on familiar actions with different retention intervals (durations of retention intervals: 0.40 min; 1 min; 1.5 min; 2 min; 3 min; 4 min; 6 min; 10 min).

Novel action: Three novel objects were placed in randomized positions and the dogs were tested on a novel action (enter a wooden box) with a retention interval of 1 min.

Distracting action: In five tests the dogs observed the demonstration of a familiar action and were then distracted during the retention interval, before the ‘Do it!’ command was given (in 3 tests owners distracted them by giving a different command ‘lay down’, with retention intervals of 0.50 min; 3 min; 4 min; and in two tests owners distracted the dogs by throwing a ball and encouraging them to fetch it, with retention intervals of 1 min and 4 min).

Changed context: Owners demonstrated a familiar action at one location, then walked with their dog to another location where 3 identical objects were placed in similar respective positions and gave the ‘Do it!’ command (retention interval: 1 min).

‘Clever Hans’ control: A single test with the same procedure as the Familiar action condition, however after the demonstration by the owner, he and the dog walked behind the

225 curtain, where a familiar person who was not aware of what action was demonstrated was
226 hiding. After a retention interval of 1.15 minutes, this naive person went with the dog to the
227 predetermined starting position and gave the 'Do it!' command in absence of the owner who
228 stayed behind the curtain.

229 *No demonstration control:* Two novel objects (a tube placed in vertical position and an
230 umbrella stand) and the wooden box (already used in the Novel action condition) were
231 placed at randomized positions. The owner commanded the dog to stay in the usual starting
232 position and to pay attention as was done in the other tests. The owner remained still for 5
233 seconds and then gave the 'Do it!' command to the dog. After the command the owner was
234 instructed to keep looking straight ahead for the duration of the test. The behaviour of the
235 dog was video recorded for 30 seconds after the 'Do it!' command.

236 *Two-action on box:* The setting was the same as in the No demonstration control test. Three
237 dogs were shown an action on the box and the other 5 dogs were shown a different action on
238 the box. The demonstrations were 'Look inside the box' and 'Touch the box with hand'
239 respectively. The two actions lead to the same outcome (i.e. the box did not move). The dogs
240 that were already familiar with the action of 'Muzzle in the bucket' were shown 'Touch the
241 box with hand' because we suspected that 'Look inside the box' would have been similar to
242 the already familiar action. The retention interval was 1.30 minutes.

243 *Two-action on tube:* The setting was the same as in the No demonstration control condition.
244 Half of the dogs were shown an action on the tube and the other half of the dogs were shown
245 a different action on the tube. The actions were 'Walk around the tube from the left side to
246 the right' and 'Knock over the tube' (retention interval: 1.30 min). In this case the two
247 demonstrations lead to different outcomes (the tube stayed in his vertical position when the
248 experimenter walked around or the tube fell to a horizontal position when it was knocked
249 over and was then repositioned by the experimenter while the dog and the owner were
250 behind the curtain). For this test the assignment of the subjects to the groups was
251 randomized.

252 The testing sessions were recorded by two video cameras placed in two different positions in
253 order to always have a view of the dog and the owner.

254

255 Data collection and analysis

256 The actions of the dogs after the 'Do it!' command were coded by the experimenter as

257 'match' (the dog performs an action that is functionally similar to the demonstrated task) or
258 'no match' (the dog performs any other action). In the conditions where novel actions were
259 demonstrated (Novel action, Two-action on box and Two-action on tube) the behaviour of
260 the dog was scored as matching only if there was a correspondence in both the goal (if a goal
261 was present) and the body movement, taken into account the differences in the body schema
262 of dogs and humans (i.e. a human's hand touch was considered corresponding to a dog's
263 front paw touch). In the conditions where familiar actions were demonstrated, a mere
264 functional correspondence was used as criterion because the expected response of the dog
265 was already known since these were trained actions.

266 In addition to the main coder (C.F.) an independent observer coded 30% of the videos in
267 order to assess inter-observer reliability. The calculation of the Kappa coefficient yielded the
268 following value: $k=1$.

269 The results were analysed by comparing performances between the different conditions and
270 the No demonstration control test using Fisher's exact test with α level at 0.05. However,
271 since each testing condition was planned to answer a specific theoretical question, the above
272 value was corrected by the method suggested by Bonferroni taking into account the number
273 of 'Do as I do' tests performed within a specific condition.

274 For the statistical analysis we used GraphPad software.

275

276 Results

277

278 In the No demonstration control condition no dog performed any action on the objects
279 present in the testing area, all dogs but one did not perform any action at all for at least 5
280 seconds after the 'Do it!' command, which is matching with the demonstration (the owner
281 did not perform any action for 5 seconds). One dog remained in a sitting position for the
282 duration of the video recording (30 seconds) but slightly raised a paw 2 seconds after the
283 'Do it!' command was given. Three dogs did not move for the whole duration of the test,
284 one dog did not move for 20 seconds and then stood up, one dog remained in place but
285 barked, one dog moved a little backward while remaining in a sitting position and one dog
286 remained in a sitting position for 5 seconds and then ran away to play and then sniffed the
287 ground.

288 We compared performances between the different conditions and the No demonstration

control using Fisher's exact test. In the Familiar action condition the subjects were tested with eight different retention intervals and the Bonferroni corrected α level is 0.00625. Comparing the number of correct performances of the demonstrated action after the different delays with the No demonstration condition, we found a statistically significant difference for the tests with delays of 0.40, 1, 1.5, 2, 4 and 10 minutes (Fisher's exact test, respectively: $P=0.0014$, $P=0.0002$, $P=0.0014$, $P=0.0002$, $P=0.0014$ and $P=0.0002$, respectively), while for the tests with 3 and 6 minutes delays the difference was not significant after the Bonferroni correction ($P=0.007$).

The subjects have been tested two times on their memory of novel actions on the box (i.e. all dogs were tested on 'Enter the box' and then some of them were tested on 'Touch the box with hand/front paw' and some of them on 'Look inside the box' in the subsequent Two-action test on box in which all dogs performed the demonstrated action). In this case the Bonferroni corrected α level is 0.025 and there is a significant difference between all the performances and the No demonstration condition ('Enter the box': $P=0.0014$; 'Touch the box with paw' and 'Look inside the box': $P=0.0002$). The dogs' performances was also significantly different from the No demonstration condition in the Two-action test on tube ($P=0.0014$) in which only one dog performed a different action (entered the box) before performing the action that had been demonstrated ('Knock over the tube') and was scored as 'no match'.

In the Distracting action condition dogs were tested with two different distractions in overall five tests with different delays and the Bonferroni corrected α level is 0.01. All the performances showed a significant difference from the No demonstration condition (Distraction: 'Lay down' with 1 minute delay: $P=0.0002$; with 3 and 4 minutes delay: $P=0.0014$; Distraction: 'Play with ball' with 1 minute delay: $P=0.0002$ and with 4 minutes delay: $P=0.007$, respectively).

In the Changed context and Clever Hans conditions the dogs were only tested with one delay, so we did not use the Bonferroni correction for the statistical analysis. We found a significant difference between the dogs' performance and the No demonstration condition (Changed context: $P=0.0014$ and Clever Hans: $P=0.0002$).

Fisher's exact test was used to compare each different condition to the Familiar action condition to assess if the matching performance changes with the increased delays, with the introduction of distractions, when changing the context of retrieval or when demonstrating

novel actions. First, in order to assess if the increased delay affects the performance, we compared with each other the results obtained after different delay durations in the Familiar action condition (E.g. comparing the performance of dogs with 1 minute delay with their performance with 10 minutes delay) and no comparison reached the level of significance ($P=0.4667$ for the comparison of the performance after delays of 3 and 6 minutes compared to the performance after delays of 1, 2 and 10 minutes and $P=1.000$ for the comparisons with all the other delay durations) (Fig. 2a). Second, we compared the performance of the dogs in the Familiar action condition with their performance in the Distracting condition with respectively similar delays and no comparison reached the level of significance ($P=1.000$ for all the comparisons). Then we also compared the performance in the Familiar action condition after one minute delay with that in the Novel action condition and Changed context condition, in which the ‘Do it!’ command was also given after 1 minute delay and not even in this case we found significant differences ($P=1.000$ for both comparisons). The matching performance of the dogs did not even change when they were tested for emulation and imitation in the two Two-action tests, compared to the test in the Familiar action condition with a similar delay ($P=1.000$ in both comparisons). Throughout the testing procedure of 18 trials, 6 dogs made only one error, one dog made two errors and one dog made 6 errors (for the details see Table 2). Overall 130 (90.28%) trials have been scored as ‘match’ and 14 as ‘no match’.

Discussion

The robust performance of the dogs in the present study convincingly supports deferred imitation. Dogs were typically able to reproduce familiar and novel actions after different delays, in different conditions and also if distracted by their owners who engaged them in different types of activities before recalling the demonstrated action. Their performance in the tests where familiar actions were demonstrated are compatible with response facilitation (or ‘deferred response facilitation’), defined as the ability to detect and encode a perceived action and to select and control an already known motor response, so that there is similarity between the observed action and the motor response (Byrne 1994). As we used object related actions, in the tests where familiar actions were shown, also ‘deferred stimulus enhancement’ (Galef 1988) could explain the dogs’ performance. However, the results of the

Two-action tests reveal that subjects not only acted on the same object that was manipulated by the demonstrator, but also copied the different novel actions that were performed on that object. In particular, dogs were able to match their body movement to the demonstration not only when the two demonstrated actions lead to different outcomes, which could be explained by goal emulation, but also when the different body movements on the same object did not lead to different outcomes.

Given the anatomic differences between man and dog, we cannot be sure how human actions are encoded by a dog and the coding of the performance as ‘match’ or ‘no match’ has been adjusted to the differences in the behaviour repertoire of the two species, using the definition of ‘functional imitation’ (see Topál et al. 2006). The novel actions were considered as ‘match’ only if the body part used by the dog for performing the particular action was corresponding (e.g. the human’s hand touch was considered corresponding to the dog’s front paw touch) which is also a more stringent criterion for imitation than the one used by Miller et al. (2009) where a human demonstrator pulled a screen with hand and the dog’s performance was considered imitation if the dog used his muzzle.

In the Clever Hans control condition, all dogs were able to reproduce the demonstrated action when the ‘Do it!’ command was given by an unknowledgeable (‘naïve’) experimenter after a delay of 1.15 minutes. Thus we can exclude any effect of involuntary cues given by the demonstrator or the owner on the dog’s performance.

In the No demonstration control condition dogs tended to stay still, without performing any action, which replicates the finding from Topál et al. (2006) and also excludes that the mere presence of the objects could elicit the target behaviours.

Imitation after some delay has been claimed to indicate representational abilities in human infants (e.g. Carpenter et al. 1998b; Meltzoff 1995). The ability to recall and reproduce actions after such delays as those used in the present study reveals that reflexive behaviour cannot exhaustively explain the observed behavioural similarity and we can exclude that facilitative processes played a role in triggering similar actions in the observer after attending the demonstrator (Bjorklund & Bering 2003).

Evidence for deferred imitation of a novel action without previous practice has been used to provide a direct measure of declarative (non-verbal) memory in infants (Barnat et al. 1996; Klein & Meltzoff 1999). Klein and Meltzoff (1999) assessed deferred imitation in 12-month-old infants using a procedure that did not allow subjects to motor practice on the

385 tasks before the delay was imposed, therefore excluding that memory could be based on re-
386 accessing a motor habit. The ability shown by children to recall the behaviour has been
387 claimed by the authors to demonstrate declarative (non-procedural) memory. In the present
388 study we used a similar procedure: dogs were not allowed to interact with the object before
389 the ‘Do it!’ command was given (so called ‘observation-only procedure’ Klein & Meltzoff
390 1999). In the Novel action condition and in both Two-action conditions, subjects imitated
391 the novel behaviours after a delay without any previous practice of these particular actions,
392 so that their memory and recall could not have been based on re-accessing a motor habit,
393 because none was formed. Furthermore, they had to recall the action in absence of any direct
394 or indirect cue that, during the retention interval, could have functioned as a perceptual
395 trigger, because the curtain obstructed the view of the objects. Therefore dogs did not simply
396 recognize and choose after a delay the object that was used during the demonstration, but
397 also retrieved and reproduced an action they had not performed on this object before,
398 without the possibility to base their recall on the aid of previous motor practice. Taken
399 together, these results suggest the presence of some form of declarative (non-procedural)
400 memory for imitative actions in dogs.

401 In the Novel action condition all dogs were scored as matching the demonstrated action,
402 with the exception of one. However, the dog that was scored as ‘no match’ approximated her
403 behaviour to the demonstration: she entered the box only using her front paws, leaving the
404 hind legs outside. We can therefore argue that she was able to at least partially encode and
405 recall the demonstration. Novelty is a relative concept (Whiten & Custance 1996) as it can
406 refer to various aspects of the behaviour (e.g. the object involved, the body movement, the
407 context etc.). In the current study the behaviour was considered new if it had never been
408 trained (Heyes & Sagerson 2002). We cannot state that our subjects had never performed
409 these actions spontaneously during their lifetime, but this was not likely to have happened.
410 In the Novel action condition the behaviour was new regarding the body movement and the
411 object for all dogs, with the exception of one dog who had been previously trained to enter a
412 box, although this box was different from that used during testing (different in shape, size,
413 material and colour). Thus for this dog, that behaviour was new only with regard to the
414 target object.

415 The Two-action test, in which two other different actions were shown on the same box,
416 demonstrates that at least three different actions were conceivable for a dog on that object:

417 'Enter the box', 'Look in the box' and 'Touch the box with paw', thus we can exclude that
 418 'Enter the box' was the only achievable or probable action for a dog who could just match
 419 the object after a delay (delayed matching), or that the increased attention toward the
 420 stimulus alone can explain the observed behavioural similarity (stimulus enhancement).
 421 In the Two-action condition on the tube it may not be possible to distinguish between goal
 422 emulation and imitation, because the dogs both reached the same goal (i.e. caused the same
 423 movement of the object) and also used the same body action. In particular, for those dogs
 424 that witnessed a knock over action, the affordance of the object – the tube passed from a
 425 vertical to a horizontal position - might have helped to retrieve the goal to be reached.
 426 However, in the Two-action test on the box (or Multi-action test, if also the 'Enter the box'
 427 action is considered) neither affordance nor goal was available, as no modification in the
 428 object was possible. Thus, in the latter case, only deferred imitation can be considered as an
 429 explanation of the observed behavioural similarity.
 430 In the present study all dogs were exposed to the demonstration of 'Enter the box' in the
 431 Novel action condition and seven dogs out of eight could match this action. In the first Two-
 432 action condition two other different actions on the box were demonstrated ('Touch the box'
 433 was demonstrated to five subjects and 'Look in the box' to the other three) and all dogs
 434 imitated the particular action that was shown to them after a delay of 1.30 minutes. While
 435 the classical two-action procedure usually involves two different groups of subjects that are
 436 tested on two different actions (E.g. Akins et al. 1996; Dorrance & Zentall 2001; Van de
 437 Waal et al. 2012), the present results also reveal that dogs may be able to change their
 438 behaviour according to what they have observed in two different tests where two different
 439 actions without different outcomes are demonstrated to the same subject on the same object.
 440 In our study, the dogs' performance was not affected by context change (Barnat et al. 1996;
 441 Klein & Meltzoff 1999) with retention intervals of 1 minute, which further supports the
 442 deferred nature of dogs' imitative abilities. More importantly, this result provides
 443 compelling evidence that local enhancement (i.e. increased attention toward the location of
 444 the demonstration) cannot exhaustively explain the observed behavioural similarity.
 445 However, this does not imply that, during memory retrieval, context may not serve as a cue
 446 that might help recall under different conditions, such as with longer retention intervals that
 447 stretch to the end of the forgetting function.
 448 Studies on human infants (E.g. Klein & Meltzoff 1999; Óturai et al. 2012) show that the

length of the delay affects performance. Very long retention intervals, such as one week or four weeks, affect imitative behaviours and it has been hypothesized that this forgetting pattern might be due to the transfer of the acquired information to ‘very-long-term memory’ (Klein & Meltzoff 1999).

Fiset et al. (2003) explored the duration of dog’s working memory in an object permanence task and found that, although the performance decreased with increased delay, dog’s accuracy remained higher than chance level with retention intervals up to 4 minutes. In the present study dogs did not decrease their performances with increased delay up to 10 minutes and further experimental work should investigate the forgetting pattern in dogs and their memory of actions after longer delays.

In conclusion, previous studies and the present results strongly suggest that dogs possess a rudimentary form of deferred imitation that may also play a role in acquiring information from both conspecifics and heterospecifics (humans). It is likely that this ability is not restricted to dogs and other canids may also possess it. Further investigation could reveal what functional role this skill might have in wild living canids.

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571 FIGURE CAPTIONS

573 **Table 1** Behaviours used for the testing, description of the human demonstration and
 574 description of the expected dog’s behaviour

576 **Table 2** Subjects (dog’s name and breed) and actions chosen for each subject in the different

577 testing conditions. Wrong performances of the dogs are marked by *. Actions and conditions
578 are listed in the actual order of testing.

579

580 **Fig. 1** Experimental setting: the dog is facing the owner in the starting position 4.5 m away
581 from the objects; three objects on which actions can be demonstrated are placed in
582 predetermined randomized positions at a distance of 3.5 m from each other; the curtain used
583 to obstruct the view of the objects during the retention interval is behind the owner at a
584 distance of 14 m from the objects.

585

586 **Fig. 2** Percentage of dogs' performances scored as 'match' in the different conditions. **
587 indicate statistically significant difference compared to the No demonstration condition after
588 Bonferroni correction **a.** Familiar actions after different delays; **b.** Familiar actions with
589 distractions during the retention interval; **c.** Novel action after a delay of 1 minute, familiar
590 action in a different context after a delay of 1 minute and 'Do it!' command given by a
591 different 'naïve' experimenter after a delay of 1.15 minutes; **d.** Two-action tests on novel
592 actions after a delay of 1.30 minutes. The figure shows that the matching percentage does
593 not typically change with increased delays from 0.40 to 10 minutes (2a), with the
594 introduction of distractions (2b), when novel actions are demonstrated, changing the context
595 of retrieval and in the Clever Hans control test (2c) and when different novel actions on the
596 same objects are demonstrated (2d).

597

598

599 **Table 1** Behaviours used for the testing, description of the human demonstration and
600 description of the expected dog's behaviour
601

Name of the behaviour	Description of the owner's demonstration	Description of the expected dog's behaviour
Walk around bucket	The owner walks around a bucket placed on the ground	The dog walks around a bucket placed on the ground
Muzzle in bucket	The owner puts his face in a bucket placed on the ground	The dog puts his muzzle in a bucket placed on the ground
Put muzzle in colander	The owner puts his face in a colander placed on the ground	The dog puts his muzzle in a colander placed on the ground
Climb on chair	The owner climbs with his feet on a chair	The dog climbs with all fours on a chair
Touch chair	The owner touches the seat of a chair with his hands	The dog touches the seat of the chair with his front paw
Walk around cone	The owner walks around a cone placed on the ground	The dog walks around a cone placed on the ground
Touch cone	The owner touches with his hand a plastic cone that is placed on the ground	The dog touches with his front paw a plastic cone that is placed on the ground
Pull rolling toy	The owner pulls a string attached to a children's toy with wheels using his hand and makes it move on the ground	The dog takes in his mouth a string attached to a children's toy with wheels and pulls it making it move on the ground
Ring bell	The owner rings a bell that is hanging from a bar	The dog rings a bell that is hanging from a bar
On table	The owner climbs on an agility table	The dog jumps on an agility table
Hoop	The owner puts his feet and hands in a hoop placed on the ground	The dog puts his four paws in a hoop placed on the ground
Open box	The owner removes the lid of a box using his hand	The dog removes the lid of a box using his mouth
Touch stool	The owner touches a small stool with his hand	The dog touches a small tool with his front paw
Drop bottle	The owner touches a bottle that is placed on the ground using his hand and makes it fall	The dog touches a bottle that is placed on the ground using his front paw and makes it fall
Take object	The owner takes with his hand one of two objects that are placed on a chair and goes toward the curtain with it	The dog takes the other object that is placed on the chair with his mouth and goes toward the curtain with it
Jump in high packaging	The owner steps inside a	The dog jumps inside the

box	cartoon packaging box raising his legs to enter in it	packaging box
Roll ball	The owner touches a ball and makes it roll	The dog touches a ball and makes roll
Swing hanging object	The owner touches with his hand a toy that is hanging from a hurdle	The dog touches with his front paw a toy that is hanging from a hurdle
Touch target	The owner touches with hand a small pad on the ground	The dog touches with front paw a small pad on the ground
Jump over hurdle	The owner jumps over a hurdle	The dog jumps over a hurdle
Enter wooden box	The owners puts his feet and hands in a wooden box	The dog enters in a wooden box with his all fours
Look inside wooden box	The owner looks inside a wooden box	The dog looks inside a wooden box
Touch wooden box	The owner touches a wooden box with hand	The dog touches a wooden box with front paw
Knock over tube	The owner knocks over a cartoon tube placed vertically on the ground using hand	The dog knocks over a cartoon tube placed vertically on the ground using his front paw
Walk around tube	The owner walks around a cartoon tube placed vertically on the ground, moving from left to right	The dog walks around a cartoon tube placed vertically on the ground, moving from left to right

Table 2 Subjects (dog's name and breed) and actions chosen for each subject in the different testing conditions. Wrong performances of the dogs are marked by *. Actions and conditions are listed in the actual order of testing.

FAMILIAR ACTION CONDITION	
DOG'S NAME - BREED	RANDOMLY CHOSEN FAMILIAR ACTION
Emma – Shetland Sheepdog	Roll ball, Muzzle in colander, Touch stool, Muzzle in colander, Muzzle in colander, Touch stool, On table, Muzzle in colander
Phoebe – Border Collie	On table, Ring bell, Muzzle in bucket, Touch stool, Touch stool, Muzzle in bucket, Touch stool*, Touch stool
Bambù – Border Collie	Climb on chair, Muzzle in bucket, Walk around cone*, Climb on chair, Jump over hurdle, On table, Climb on chair, On table
Lilly – Yorkshire Terrier	Pull rolling toy, Open box, Swing hanging object, Jump in high packaging box, Open box*, Drop bottle, Pull rolling toy, Drop bottle
Adila – Mixed breed	On table*, Ring bell, Touch cone, On table, Ring bell, Touch chair, Touch cone, Walk around bucket
Minnie – Border Collie	Muzzle in bucket, Touch stool, Muzzle in bucket, On table, On table*, Ring bell, On table, Touch stool

Soley – Border Collie	Touch chair, Jump over hurdle, On table, Muzzle in bucket, On table, Touch chair*, Jump over hurdle*, Touch chair
India - Czechoslovakian Wolfdog	Jump over hurdle, Touch chair, Drop bottle, Drop bottle, Touch chair, Jump over hurdle, Touch chair, On table
NOVEL ACTION CONDITION	
DOG'S NAME	NOVEL ACTION
Emma, Phoebe, Bambù, Lilly, Adila*, Minnie, Soley, India	Enter wooden box
DISTRACTING ACTION CONDITION (Distraction: lay down command)	
DOG'S NAME	RANDOMLY CHOSEN FAMILIAR ACTION
Emma	Hoop, Roll ball*, Hoop
Phoebe	Take object, Ring bell, Take object
Bambù	Climb on chair, Muzzle in bucket, Climb on chair
Lilly	Swing hanging object, Drop bottle, Pull rolling toy
Adila	Touch chair, Walk around bucket, On table
Minnie	Take object, Muzzle in bucket, Touch stool
Soley	Jump over hurdle, Touch chair, On table*
India	Drop bottle, On table, Touch chair
DISTRACTING ACTION CONDITION (Distraction: play with ball)	
DOG'S NAME	RANDOMLY CHOSEN FAMILIAR ACTION
Emma	Muzzle in colander, Hoop
Phoebe	On table, Take object
Bambù	Jump over hurdle, Muzzle in bucket
Lilly	Jump in high packaging box, Open box
Adila	Ring bell, Touch cone
Minnie	On table, Ring bell
Soley	Touch chair*, Walk around cone
India	Jump over hurdle, Touch chair*
CHANGED CONTEXT CONDITION	
DOG'S NAME	RANDOMLY CHOSEN FAMILIAR ACTION
Emma	Touch target
Phoebe	Muzzle in bucket
Bambù	Muzzle in bucket
Lilly	Drop bottle
Adila	Touch cone
Minnie	Take object
Soley*	Walk around cone
India	Ring bell
CLEVER HANS CONTROL CONDITION	
DOG'S NAME	RANDOMLY CHOSEN FAMILIAR ACTION
Emma	Roll ball
Phoebe	On table
Bambù	Muzzle in bucket
Lilly	Jump in high packaging box
Adila	On table

Minnie	Take object
Soley	Jump over hurdle
India	On table
TWO-ACTION ON BOX CONDITION	
DOG'S NAME	NOVEL ACTION
Emma, Phoebe, Bambù, Minnie, Soley	Touch box
Lilly, Adila, India	Look inside box
TWO-ACTION ON TUBE CONDITION	
DOG'S NAME	NOVEL ACTION
Emma, Phoebe, Minnie, India	Walk around tube
Soley*, Lilly, Adila, Bambù	Knock over tube

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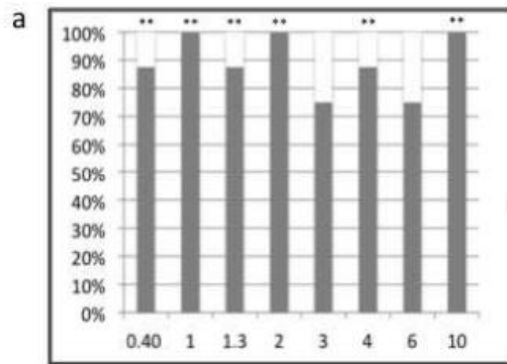


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Delay between human demonstration and dog's action (min)

■ % match

