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Dogs fail to recognize a human pointing gesture in two-dimensional depictions of motion cues

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Abstract:	Few studies have investigated biological motion perception in dogs and it remains unknown whether dogs recognise the biological identity of two-dimensional animations of human motion cues. To test this, we assessed the dogs' (N=32) responses to point-light displays of a human performing a pointing gesture towards one of two pots. At the start of the experiment the demonstrator was a real-life person, but over the course of the test dogs were presented with two-dimensional figurative representations of pointing gestures in which visual information was progressively removed until only the isolated motion cues remained. Dogs' accuracy was above chance level only with real-life and black-and-white videos, but not with the silhouette or the point-light figure. Dogs' accuracy during these conditions was significantly lower than in the real-life condition. This result could not be explained by trial order since dogs' performance was still not higher than chance when only the point-light figure condition was presented after the initial demonstration. The results imply that dogs are unable to recognise humans in two-dimensional depictions of human motion cues only. In spite of extensive exposure to human movement, dogs need more perceptual cues to detect equivalence between human two-dimensional animations and the represented living entity.
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Cover Letter

DIPARTIMENTO DI BIOMEDICINA COMPARATA
E ALIMENTAZIONE

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Padova, 13 December 2020

Dear Editor,

Please consider the attached manuscript entitled '**Dogs fail to recognise a human pointing gesture in two-dimensional depictions of motion cues**' for possible publication in Behavioral Processes. The manuscript has not previously been published or submitted simultaneously for publication elsewhere.

The study deals with dogs' ability to recognize humans motion cues. To assess such ability, dogs underwent a classical pointing task, where their performance was initially assessed with a real-life demonstrator, and subsequently with videos/animations where visual information was progressively reduced, until being left with mere 'motion' information given by point-light displays. Dogs were able to perform above chance level only with the real-life stimuli and a black-and-white video of the demonstrator, but not with a silhouette or the point-light displays. The results show dogs do not recognize human motion in point light displays. We believe the results of this manuscript would be of particular interest to the readership of Behavioral Processes.

On behalf of all authors, thank you for your consideration.

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Highlights

Dogs underwent a pointing task, where demonstrators had progressively poorer visual information

Stimuli were, in order: a real person, a video, a silhouette, and three types of point light displays

Dogs only responded above chance level to the real-life and the black and white video

Presenting the point-light displays first did not improve dogs' performance

Dogs seem unable to recognise humans in two-dimensional depictions of human motion cues

ABSTRACT

Few studies have investigated biological motion perception in dogs (*Canis familiaris*), and it remains unknown whether dogs actually recognise the biological identity of two-dimensional animations of motion cues, especially those representing humans. To test this, we assessed the dogs' responses to point-light displays of a human performing a pointing gesture towards one of two pots. The sample included 32 pet dogs. At the start of the experiment the demonstrator was a real-life person, but over the course of the test dogs were presented with two-dimensional figurative representations of pointing gestures in which visual information was progressively removed (black and white person video, black and white silhouette video) until only the isolated motion cues remained (point-light displays). Results revealed that dogs' accuracy was above chance level only with real-life and black-and-white videos, but not with the silhouette or the point-light figure. Moreover, dogs' accuracy during these conditions was significantly lower than the 'real-life' condition. This result could not be explained by the trial order since dogs' performance was still not higher than chance level when only the point-light figure condition was presented after the initial demonstration with real-life stimuli. The results of the current study imply that dogs are unable to recognise humans in two-dimensional depictions of human motion cues only. In spite of their extensive exposure to human movement, dogs need more perceptual cues to detect equivalence between human two-dimensional animations and the represented living entity.

Dogs fail to recognize a human pointing gesture in two-dimensional depictions of motion cues

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ABSTRACT

Few studies have investigated biological motion perception in dogs and it remains unknown whether dogs recognise the biological identity of two-dimensional animations of human motion cues. To test this, we assessed the dogs' (N=32) responses to point-light displays of a human performing a pointing gesture towards one of two pots. At the start of the experiment the demonstrator was a real-life person, but over the course of the test dogs were presented with two-dimensional figurative representations of pointing gestures in which visual information was progressively removed until only the isolated motion cues remained. Dogs' accuracy was above chance level only with real-life and black-and-white videos, but not with the silhouette or the point-light figure. Dogs' accuracy during these conditions was significantly lower than in the real-life condition. This result could not be explained by trial order since dogs' performance was still not higher than chance when only the point-light figure condition was presented after the initial demonstration. The results imply that dogs are unable to recognise humans in two-dimensional depictions of human motion cues only. In spite of extensive exposure to human movement, dogs need more perceptual cues to detect equivalence between human two-dimensional animations and the represented living entity.

KEYWORDS

Biological motion, Canis familiaris, Pointing, Point-light display, Recognition, Video

1. INTRODUCTION

Biological motion refers to the pattern of movement which characterises animals, in accordance with their body morphology and the effects of gravity. This motion was first isolated by Johansson (1973) who placed small light bulbs on strategic joints of a human body, and then recorded the person walking in the dark. Despite the sparse visual information provided by the point-light displays (PLD), previous research has found that human observers are able to identify the stimulus as a person walking, even when as few as five light dots were presented (Laicāne et al. 2017), or when the figure was masked by additional light dots (Bertenthal and Pinto 1994; Pavlova and Sokolov 2000; Troje 2003; Troje and Westhoff 2006). Moreover, using human PLDs, participants were able to identify the actor's gender (Kozlowski and Cutting 1977; Barclay et al. 1978; Mather and Murdoch 1994; Troje 2002), action performed (Dittrich 1993; Blakemore and Decety 2001), emotional state (Dittrich 1996), and even recognise themselves and other familiar individuals (Cutting and Kozlowski 1977; Beardsworth and Buckner 1981; Stevenage et al. 1999; Loula et al. 2005; Troje et al. 2005). This ability to identify PLDs was even possible when the biological entities depicted were animals (e.g. Mather and West 1993; Pavlova and Sokolov 2001).

Biological motion perception has also been investigated in animals, although very few studies have attempted to determine whether animals associate the configural dynamic structure of the dots to the actual biological entity represented by the PLD. For instance, Dittrich and co-authors (1998) revealed that a subset of pigeons (*Columba livia*) trained to discriminate videos of pigeons walking or pecking were able to transfer some of this learning to PLDs depicting the same actions. On the other hand, the same authors found that pigeons trained to discriminate PLDs of pigeons walking or pecking were not able to generalise this learning to videos of the same actions. Another demonstration of animals' capacity to learn features of PLDs was provided by MacKinnon and co-authors (2010). These authors trained rats (*Rattus norvegicus*) to discriminate human PLDs walking left or right, but failed to find any transfer to novel PLDs of humans walking backwards. Also, Parron and co-authors (2007) who trained baboons (*Papio papio*) to discriminate human and baboon PLDs found limited transfer to novel PLDs suggesting that the baboons did not process the stimuli according to their global form, but instead focused on their constituent parts. Finally, Vallortigara and co-authors (2005) found that visually naïve chicks (*Gallus domesticus*) showed no preference towards upright coherent PLDs over scrambled PLDs, and approached PLDs depicting potential predators (cat) to the same extent as they did with PLD of a hen.

In dogs, only a handful of experiments have investigated biological motion perception. Kovács and co-authors (2016) explored the effect of oxytocin on dogs' preference for human PLDs. The study revealed that sensitivity to human PLDs was significantly affected by oxytocin. However, the study did not assess dogs' preference for different types of PLDs, leaving it unknown whether dogs prefer human biological motion, or the biological motion per se. A more direct comparison of dogs' preference towards heterospecific or conspecific PLDs was conducted by Ishikawa and co-authors (2018). Their results revealed that dogs' preference for human or dog PLDs were variably affected by individuals' sociability toward humans or dogs: dogs characterised by low human or low dog sociability preferred upright human and dog PLDs in the lateral orientation respectively, whilst only dogs with high sociability preferred upright, frontally orientated dog PLDs. The effect of sociability on dogs' preference for PLDs of different species suggests dogs may have recognised the identity of the figures represented in the PLDs. However, it is not possible to assert whether dogs oriented more towards different upright PLDs because they recognised the biological entities, or they preferred viewing upright biological motion of different types. In fact, biological motion can be processed in different ways because in addition to the overall configuration of a PLD, biological motion is also captured in the trajectories of individual dots which move according to certain constraints – such as the laws of gravity (Troje 2004). It is for this reason that scrambled PLDs in the upright orientation have been rated as being more animate/biological than their inverted counterparts (Chang and Troje 2009). Consequently, by consistently comparing upright with inverted human PLDs (e.g. Ishikawa et al. 2018) it cannot be determined whether dogs recognised the identity of the figure represented in the PLDs or processed the PLD on the basis of its individual components. A recent study by Eatherington and collaborators (2019) showed that dogs have do not show any attentional bias towards PLD of laterally walking humans over their scrambled or inverted counterparts. However, dogs do look preferentially at upright PLDs of frontally walking humans (Delanoeije et al.

2020), suggesting that frontal orientation facilitate the detection of a bipedal biological motion, and yet not proving dogs did recognize a human in the projected stimuli. Overall, evidence collected so far does not provide a clear indication of whether or not dogs recognize humans from PLDs.

Dogs are able to perform complex feats of human visual identification, such as recognizing individual humans from visual cues about their faces (Mongillo et al. 2016, 2020; Adachi et al. 2007). In addition, dogs can be trained to discriminate between an image of their owners' face and that of a strangers' (Pitteri et al. 2014a), or of another familiar person's face (Huber et al. 2013). One of the most remarkable, and largely explored ability, is dogs' responsiveness to human pointing gestures, whereby dogs are retained able to understand the communicative content of such signals (for a review see Kaminski and Nitzschner 2013). While most of the studies on the topic employ live demonstrations, Pongrácz and co-authors (2003) found that dogs responded equally well to human pointing, even if the gesture is show through by a real-sized video projection of a person, rather than live. As it was demonstrated that the pointing gesture can only be correctly interpreted by dogs when enacted through movement of a human body part (and not, for instance, a stick manipulated by a person) (Soproni et al. 2002), the results of the study by Pongracz and collaborators are important as they prove dogs did recognize the video as portraying a human person. It is believed that the majority of dogs naturally learn about the gestures function as a communicative signal from a young age by interacting with their owner (Dorey et al. 2010). In addition, pointing can be used as part of a simple and straightforward paradigm (object choice task) emphasising the social aspect of species recognition.

The current study used a pointing gesture as part of an object choice task in order to assess whether dogs can recognise the identity of a human in two-dimensional depictions of motion cues such as PLDs: a correct choice performed by dogs after being presented with a pointing gesture performed by a PLDs would imply recognition of the latter as a human person.

2. METHODS

Two experiments were performed to assess whether dogs correctly interpret a communicative action when performed by a PLD, implying recognition of the PLDs as representing a person.

In Experiment 1, dogs were first presented with a real-life demonstrator performing the pointing gesture and afterwards with videos of a pointing gesture containing progressively reduced visual information, until presented with PLD of a human making a pointing gesture. We chose to present trials in a fixed order, so to provide dogs with a gradual transition to stimuli containing limited information and give them the best possible condition for correctly responding to such stimuli. A fixed order of presentation, however, has the drawback of potential interference of earlier trials with the dogs' performance along the sequence; for instance, dogs may not respond accurately to the last trials (the PLDs) due to fatigue or decreased motivation, rather than for being unable to recognize the PLD as representing a human. In order to rule this possibility out, a second experiment was performed where the PLD performing the pointing gesture was presented at the beginning of the test sequence.

2.1. Experiment 1

2.1.1. Subjects

Thirty-two dog-owner dyads were recruited through the database of volunteers at the Laboratory of Applied Ethology in the University of Padua. Twenty dogs were pure-breeds (4 Australian Shepherds, 3 Czechoslovakian Wolfdogs, 2 Greyhounds, 2 Weimaraners, 1 Akita-Inu, 1 Border Collie, 1 Bernese Mountain Dog, 1 Brittany, 1 Dachshund, 1 Dogue de Bordeaux, 1 Golden Retriever, 1 Pointer, 1 Rhodesian Ridgeback) and 12 were mixed-breed dogs (5 small, ≤ 35 cm at the withers; 1 medium, > 35 and < 55 cm; 6 large ≥ 55 cm). The sample consisted of 23 females and 9 males (mean age±SD: 5.1±3.0 years). To ascertain that dogs were extensively exposed to human motion, only dogs that had lived inside with their owner for at least the past six months were enrolled. Other restrictions for recruitment were that dogs were in good health condition, including no visual deficits, and at ease in unfamiliar contexts.

2.1.2. Stimuli

Each dog was presented with six types of stimuli, containing different amounts of visual information from the same person performing a pointing gesture (Figure 1): real-life demonstration, black and white video, silhouette video, point-light figure (PLD), arm dots only, two point-light figures.

The ‘real-life’ stimulus (Figure 1A) consisted of a female demonstrator (about 170 cm tall) standing in front of a white screen. The demonstrator was dressed in black, including long sleeves and gloves to contrast against the background. Initially, the demonstrator had her fists held together in front of the stomach, then one arm extended in a distal point, with her index finger outstretched, towards either the left or right pot. The gesture was held for approximately one second, before returning to the start position.

The ‘black and white video’ stimulus (Figure 1B) consisted of pre-recorded video of the same demonstrator performing the action described for the ‘real-life’ trials. It was projected at full-size (i.e. 170 cm tall) onto a white screen. The video was rendered black and white using Adobe Premier Pro CC (2015).

The ‘silhouette video’ stimulus (Figure 1C) was created from the black and white video by rendering the figure of the demonstrator entirely black, so no features were shown – only a solid grey interior. This was created using Adobe Premiere Pro CC (2015).

The ‘point-light figure’ stimulus (Figure 1D) was a PLD representing the demonstrator performing the pointing gesture. It was obtained by filming the demonstrator who was wearing black clothes, with white markers placed on her frontal surface, in correspondence of selected joints: atlas-occipital, cervical vertebrae 6-7, shoulders, elbows, wrists, lumbar vertebrae 4-5, hips, knees and ankles. The movie clip was imported into Tracker (Brown 2017), where the coordinates for each joint marker were recorded frame-by-frame. Using these coordinates, point-light animation (white dots on a black background) of the pointing action was created via BioMotion Toolbox (van Boxtel and Lu 2013) for Matlab. Dots had a diameter of 5.5 cm, which made them clearly individually visible by dogs (compare with similar dogs’ ability to discriminate a single dot from another similarly sized shape reported in Pitteri et al., 2013, with similar ratio between observation distance and dot size)

The ‘arm dots only’ stimulus (Figure 1E) was created using only the dots on the elbow and wrist for both arms from the ‘point-light figure’ in their normal locations. The stimulus was obtained by deleting points from the ‘point-light figure’ stimulus. This stimulus was introduced to control for the possibility that dogs’ choices were simply directed by the movement of the ‘arm’ dots, rather than by recognizing the dots as belonging to a human.

The ‘two point-light figures’ stimulus (Figure 1F) was a PLDs portraying two point-light figures representing the demonstrator. At the start of the presentation both figures stood at the center of the screen, then they simultaneously walked in opposite directions towards either edge of the screen. After two steps, the figures turned forward to face the dog and performed the pointing gesture towards the nearest pot. One of the two figures was presented upright and pointed downwards; the other figure was presented upside down, although it still pointed downwards to the pot (when filmed, the demonstrator raised her arm pointing at the ceiling and slightly at her side). This condition was included to provide the dog with all the features relevant for biological motion perception, that is a walking motion; the presence of the second, upside-down figure, was necessary since, had the stimulus portrayed only one figure and this being required to walk across the screen, it would have been impossible to balance the spatial cues (i.e. the distance between dots and pot) between the two pots. Thus, spatial cues were balanced by adding a second figure with the same spatial distribution of dots and the same amount of motion for each dot, but with biological motion features disrupted by inversion. Apart from the different direction of the gesture, and the combination of the two figures in a single clip, the stimulus was created exactly as described for the ‘point-light figure’ stimulus.

<< FIGURE 1 ABOUT HERE >>

Figure 1. Photographs exemplifying different types of stimuli viewed by the dogs in the experimental conditions: real-life demonstrator (A), black and white video (B), silhouette video (C), point-light figure (D), arm dots only (E), two point-light figures (F) (dashed line denotes a break in the display as in reality the figures were further apart)

2.1.3. Experimental setting

The experiment was conducted in a quiet, dimly lit room (470 x 580 cm) with a large white plastic screen (206 x 263 cm) at one end, and a Toshiba TDP T100 projector mounted 207 cm high on the opposite wall. The screen contained two separate pieces of plastic (206 x 81 cm) hinged on opposite sides to create doors which opened in the center. These allowed an experimenter to hide behind the wall when needed (see below), without leaving the area from either the left or the right side, which could have influenced dogs' behaviour in the task. At the bottom of each screen was a hole (22 x 17 cm), large enough to pass the pots through, positioned 140 cm apart. Holes were used during the procedure to remove the pots. In each trial, one pot (the one pointed at by the demonstrator) contained an accessible piece of sausage (approximately $1cm^3$), whereas an identical piece of food was placed in a perforated false bottom in the other pot, so that odor cues were balanced between the two pots.

During testing, dogs faced the middle of the screen at a distance of 240 cm, either standing or sitting in between their owner's legs who was seated on a small stool behind them (Figure 2). Two pots were placed 140 cm apart from each other, 60 cm in front of the screen, and 180 cm away from the dog. Owners were instructed to gently hold the dog in place, but to look straight ahead so as not to influence the dog's behaviour. Stimulus presentation was controlled by an experimenter standing at the back of the room, using a MacBook Air. Two CCTV cameras mounted on the ceiling (one directly over the dog and another from behind) captured dogs' looking orientation and choice behaviour.

<< figure 2 about here >>

Figure 2. A still of the experimental setting during the presentation of a black and white video of the demonstrator pointing

2.1.4.Experimental procedure

Dogs were initially given ten minutes to explore and become familiar with the testing environment, including the demonstrator and experimenter. After these familiarization phase, dogs underwent a practice phase, with the 'real-life' stimulus. This was aimed at: 1) familiarize the dog with the task procedure 2) assess dogs' ability/willingness to follow pointing provided by a real-life human experimenter and 3) obtain a reference to which performance of dogs with projected stimuli would be compared to. The phase was composed of a series of trials, at the start of which dogs were positioned facing the screen with their two left and two right paws either side of a central line marked on the floor. The demonstrator, who was concealed behind the screen, opened the central doors, stepped forward, closed the doors behind her and placed both pots on the floor simultaneously in front of the dog's view. Standing up straight, the demonstrator held her fists together in front of her stomach (elbows out). The demonstrator waited either for the dog to look at them or captured the dog's attention by calling his/her name, then pointed towards the baited pot with an index finger outstretched, before returning to the initial starting position, as described in the 'real-life' stimulus. The owner was permitted to release the dog at any time from when the demonstrator started the pointing gesture. During the practice trials, if the dog made a correct choice (approached the pot pointed at by the demonstrator) it was allowed to eat the content of the pot. If the dog made an incorrect choice, it was encouraged by the demonstrator to go to the baited pot and eat food from it; this was intended to make it clear to dogs that the task was to follow a pointing gesture. In order to advance to the actual test phase, each dog was required to make a correct response on three practice trials in a row, within a maximum of ten practice trials. Dogs that did not accomplished this criterion were eventually excluded from the experiment and were replaced with different dogs.

Once criterion was achieved, another two real-life trials were presented. The procedure differed from that described above for now the experimenter did not call the dog's name to capture its attention, and if the dog made an incorrect choice first, the correct pot was picked up so the dog could not reach it. Performance of the dog in such two trials would serve as reference against which performance in trials featuring a projected stimulus would eventually be compared.

Following the last two 'real-life' trials, two trials for each of the 'black and white video', 'silhouette video', 'point-light figure', 'arms dots only' and 'two point-light figures' conditions were presented, in this order. For each condition, the side of the baited pot of the first of the two trials was randomly determined, whereas in the second trial the pot was placed in the opposite side. For example, a dog may have been presented with the following order of presentations: real-life L, real-life R, black-and-white video R, black-and-white video L, silhouette R, silhouette L, point-light L, point-light R, arms dots L, arms dots R, two point-light figures R, two point-light figures L. The procedure during the trials was identical to that employed during the last two real-life trials, with the difference that, after placing the pots down, the experimenter returned behind the apparatus, and projection of the stimulus began as soon as the doors were shut and the experimenter no longer visible. In any case, owners were told that they could release the dog as soon as the figure started pointing, or, for the two-figures PLD, as soon as the figures started walking.

2.1.5.Data collection and analysis

Behavioural data was collected from videos recorded through ceiling mounted CCTV cameras. Using Observer XT software (version 12.5, Noldus, Groeningen, The Netherlands) a continuous sampling technique was used to collect data about dogs' orientation, which was coded as either looking towards the screen or looking elsewhere in the room. Orientation data were collected in an interval of time spanning from when the gesture started until the dog started to move (latency). The collected data was used to calculate the percentage of time, relative to latency, in which the dog was oriented to the screen (OS), rather than elsewhere. The use of a percentage was necessary to compare dogs' orientation across different presentations, since some of the stimuli had different durations, in turn influencing the absolute amount of time dogs could have been looking at the screen before being released. The observer was blind to the condition and to the side of the correct pot. Interobserver reliability on dogs' choices was assessed on data collected by a second, independent observer on all videos, resulting in 100% agreement between the two. Inter-observer reliability was also assessed using data collected by a second observer for dogs' looking time and dogs' latency on a randomly selected subsample of videos (30% of the total number) and was revealed to be excellent for both (Intraclass Correlation coefficient > 0.90 for both variables).

Binary logistic Generalised Estimating Equation (GEE) models were run to verify whether dogs were relying on the pointing gesture to choose the pot, in each of the different conditions. GEE models can take into account covariance between measures repeatedly taken from each subject, as was the case of the two trials for each condition which dogs underwent in this experiment. In order to find whether dogs choices were above chance level when presented with different stimuli, separate

GEE models were run for each condition, using data from the two trials of such condition (this included the last two trials of the real-life practice, labelled hereafter as 'real-life' condition). In the model, the dog's response was used as a dichotomic dependent variable (pointed pot = 1, non-pointed pot = 0). The dogs' name was included as a random term, accounting for repeated measurement from the same subjects. No other factor was included in the models, which were therefore run as 'intercept-only'. In such models, the following equation holds true for the model solution for the intercept term:

$$B = \ln \frac{P}{1 - P}$$

where P is the probability of observing the expected response. Thus, B would be 0 for P = 0.5 and would increase for P > 0.5. A hypothesis test was then run, to test the null hypothesis H_0 that B was significantly different form 0 (i.e. that the probability that dogs chose the pot indicated by the gesture was higher than 0.5), for each experimental condition.

Based on previous findings of our own (Eatherington et al. 2019) and other laboratories (Pongracz et al. 2003), we expected choices to be significantly different from chance in the 'real-life' and 'black and white video' conditions, and not significantly different from chance in the conditions featuring PLDs; only for the 'silhouette video' condition we had no predictions about the significance of choices. Due to such expectations, and in order to limit the possibility of obtaining false-negative results, we did not apply corrections to P values obtained from running these models.

Following these analyses, a comprehensive binary logistic GEE model was used to assess factors influencing dogs' choice accuracy across the experiment. The dependent variable was again represented by the dogs' choice (0/1). Condition and side of the correct pot were included as fixed factors and the percentage of looking time towards the screen was included as a covariate. The rationale for the inclusion of this term was that the assessment of the effects of attention could provide relevant information on possible reasons for dogs' ability/inability to perform above chance, including insufficient attention paid to the stimuli. The dog's name was included as a random factor to account for the repeated sampling from each dog. As the inclusion of factors made outcomes less predictable, a sequential Bonferroni-correction was applied to post-hoc comparisons, which were performed when a significant effect was found. For post-hoc comparisons, the case of condition, the 'real life' trial type was taken as reference, against which performance in other conditions was compared.

2.2. Experiment 2

In Experiment 1 we presented dogs with several presentations in a fixed order, gradually reducing the amount and the nature of visual information dogs could use to solve the task. However, dogs' responses to point-light displays could have been influenced by trial order, for instance due to fatigue, or experience with previous trials. To control for this problem, we run a second experiment where only the 'point-light figure' and the 'two point-light figures' were presented, right after the real-life trials.

2.2.1. Subjects

Twenty different dog-owner dyads were recruited in the same manner as Experiment 1. Ten dogs were pure-breeds (1 Australian Cattle Dog, 1 Australian Shepherd, 1 Boxer Dog, 1 Bracco Italiano, 1 Cocker Spaniel, 2 Golden retrievers, 1 Labrador, 1 Pointer, 1 Rhodesian Ridgeback) and 10 were mixed-breed dogs (6 medium, > 35 and < 55 cm at the withers; 4 large ≥ 55 cm). The sample consisted of 12 females and 8 males (mean age±SD: 6.1±3.9 years). The same eligibility criteria imposed in Experiment 1 were applied to Experiment 2.

2.2.2. Stimuli, experimental setting and procedure

Each dog viewed only two types of video stimuli previously used in Experiment 1: 'point-light figure' (Figure 1D) and 'two point-light figures' (Figure 1F); the rationale for presenting these stimuli was that these were the only ones in which an entire human PLD was presented, potentially recognizable as a demonstrator performing a pointing gesture.

The experiment was conducted in the same room, using the identical apparatus and setup as in Experiment 1. The initial phase of Experiment 2 proceeded in the same way as Experiment 1, with dogs being allowed ten minutes to habituate to the testing environment and then given practice trials. The experimenter performing the demonstration was the same who performed this role in Experiment

1. Dogs which did not make three correct responses in a row were excluded from the experiment and replaced with different dogs. Following the practice trials, dogs were presented with two further 'real-life' trials and then with the two 'two point-light figures' and the two 'single point-light figure' trials, using the same procedure as Experiment 1.

2.2.3. Data collection and analysis

Behavioral data were collected using the same method described in Experiment 1.

To verify whether dogs chose the pointed pot baited with accessible food significantly above chance level in each condition, an intercept-only binary logistic GEE model was run separately for each condition. The dogs' choice (non-indicated bowl = 0, indicated bowl =1) was used as dichotomous dependent variable, and the dogs' name was included as random term. A hypothesis test was run on the estimates of each model, to assess the null hypothesis H_0 that the intercept's B = 0.

Following this, a binary logistic GEE model for each PLD condition ('point-light figure' and 'two point-light figures') was used to assess the effect of the type of experiment (Experiment 1 or 2), percentage of looking time dogs directed towards the screen, and the interaction between these two factors, on dogs' choice accuracy. This analysis was intended to assess changes in dog's accuracy if the PLDs were presented right after the real-life trials, rather than as the last trials of the test sequence. The dog's ID was included as a random factor to account for the repeated sampling from each dog.

Analysis was performed with SPSS (ver. 26; IBM, Armonk, NY). Results are reported as mean±SD unless otherwise stated.

3. RESULTS

3.1. Experiment 1

Dogs required on average 5.0±2.2 trials to reach learning criterion in the practice phase. Seven dogs were unable to reach the required criterion and were replaced with other dogs. Data of dogs' looking time towards the screen, and latency during the different types of experimental conditions, are summarised in Table 1.

Table 1. Mean±SD latency, and time spent looking at the screen expressed in seconds and as a percentage of latency during each type of experimental condition

Experimental condition	Latency (s)	Looking time (s)	Looking time (% of latency)
Real-life	0.74±0.60	0.74±0.60	100±9.23
Black and white video	1.14±0.77	1.02±0.62	89.5±19.35
Silhouette video	1.22±1.61	1.05±1.05	86.1±20.40
Point-light figure	1.69±1.78	1.34±1.36	79.3±26.14
Arm dots only	1.31±0.98	1.05±0.69	80.1±29.18
Two point-light figures	2.30±2.56	1.91±2.02	83.0±32.98

Figure 3 shows the estimated probability and 95% confidence intervals of choosing the pot indicated by the pointing gesture, in each condition. The intercept-only GEE models showed that the probability was significantly higher than what predicted by chance in the Real-life and Black-and-white video conditions, but in none of the other conditions (Table 2).

Figure 3. Estimated probability ± 95% confidence intervals of choosing the pot indicated by the pointing gesture in different conditions. RL = Real-life demonstrator; V = Black and white video; S = Silhouette; PL = Point-light figure; A = Arms dots only; 2PL= Two point-light figures. Binary logistic GEE model.

Table 2. Estimated values of B or the intercept term, as resulting from separate GEE models for each condition, and P-values of the hypothesis tests assessing the null hypothesis H_0 that B = 0.

Experimental condition	B	P
Real-life	1.33	< 0.001
Black and white video	0.51	0.015
Silhouette video	0.35	0.104
Point-light figure	0.19	0.456
Arm dots only	0.08	0.786
Two point-light figures	0.13	0.561

The findings of the comprehensive GEE model indicating the effect of factors influencing dogs' choice accuracy are summarised in Table 3. A significant effect was found for the condition, whereby accuracy when presented with the real-life stimuli was significantly higher than in the silhouette video (*P* = 0.008), point-light figure (*P* = 0.029), arm dots only (*P* = 0.009), and two point-light figures: *P* < 0.001); only for the black and white video the probability of choosing the correct pot was not significantly different from the real-life condition (P = 0.119), confirming the results of the intercept-only model. Furthermore, a significant effect of looking time was found. The longer dogs looked at the screen, the lower their probability of making a correct choice (B = 1.19, upper – lower 95% confidence intervals = 0.079 – 2.31), indicating that choice accuracy was not influenced by dogs directing an insufficient proportion of attention towards the screen.

Table 3. Results of the GEE model indicting the effect of factors on dogs' choice accuracy across trials of Experiment 1

Factors	**Wald X^2**	**df**	***P***
Condition type	23.106	1	0.000
Side of correct pot	0.106	1	0.745
% of looking time towards the screen	4.626	1	0.031

3.2. Experiment 2

Dogs required on average 5.0±2.6 practice trials to pass the threshold of 3 correct choices in a row, with a minimum of 3 and maximum of 10. In the two point-light figures condition, on average dogs chose the correct pot on 52.9% of trials, with an average looking time of 2.13±2.64 s towards the screen, a latency of 2.45±2.68 s before the dog started moving, and percentage of looking time towards the screen of 86.9±27.8 %. The intercept-only GEE models indicated that the proportion of choices of the pot indicated by the pointing gesture was significantly above chance for the last two 'real-life' trials (B = 0.81, P = 0.026), but not in the 'point-light figure' (B = 0.40, P = 0.132) and the two point-light figures' (B = -0.09, P = 0.819) conditions. The results of the two GEE models investigating the effect of experiment type (Experiment 1 and 2), percentage of looking time dogs directed towards the screen, and their interaction, on dogs' choice accuracy during the 'point-light figure' or 'two point-light figures' conditions, are summarised in Table 4 and revealed no significant effects in either condition.

Table 4. Results of the GEE models evaluating the influence of experiment type (Experiment 1 and 2), percentage of looking time dogs directed towards the screen, and their interaction, on dogs' choice accuracy during the 'point-light figure' or 'two point-light figures' conditions

Condition	Factors	Wald X^2	df	*P*
Point-light figure	Experiment type	2.506	1	0.113
	% of looking time	0.453	1	0.501
	Interaction	1.506	1	0.220
Two point-light figures	Experiment type	2.198	1	0.138
	% of looking time	1.379	1	0.240
	Interaction	2.388	1	0.122

4. DISCUSSION

The aim of the current study was to determine whether dogs can recognise the identity of a human in a two-dimensional depiction of motion cues, such as a human PLD. In Experiment 1, dogs were able to respond correctly to a pointing gesture performed by a human person presented live or in video, but not when the same gesture was performed by a projected silhouette of a human or by a human PLDs. Experiment 2 showed that the inability to correctly respond to the PLDs was not due to satiation or fatigue, as dogs were still unable to respond to the PLD even when these were the first stimulus presented, rather than at the end of a longer sequence of stimuli. Since the categorisation of the stimulus performing the pointing gesture as a human is necessary for dogs to correctly respond to such gesture, the lack of response to PLDs indicates that dogs do not classify a human as such, based on motion information provided by the PLD.

Our finding that dogs did not recognise the identity of human's PLDs falls in line with previous research showing that even though animals can be trained to discriminate between biological and non-biological motion, they show very little transfer when trained to recognise an action using real-life or video displays and then tested using PLDs (Pigeons: Dittrich et al. 1998; Baboons: Parron et al. 2007; Rats: MacKinnon et al. 2010). The best explanation for these findings is that animals are able to solve the discrimination between biological and non-biological PLDs using the display's features but without recognising the figure's identity. This is supported by evidence of very young animals' ability to distinguish biological from non-biological motion, which is clearly not based on the PLDs identity because they approached the biological display even if it depicted a potential predator (Vallortigara et al. 2005). The literature also reports examples of animals responding to human gestures represented through PLD, such as one of the dolphins (*Tursiops truncates*) in the study by Herman and collaborators (1990). However, the dolphin's response did not imply recognition of humans, since their performance did not deteriorate when the signal (either real or represented as a PLD) was not presented in the context of a human figure. Conversely, in dogs the pointing signal can only be correctly interpreted when displayed as part of a human figure, as shown by others (Soproni et al. 2002) and, in our experiment, by their performance in the arms only condition.

Animal's difficulty in recognising PLDs is unlikely due to an inability to recognise two-dimensional versions of three-dimensional objects, since many observations have been reported of different species reacting to video stimuli as if they were real (Lizards (*Anolis spp*): Jenssen 1977; Bonnet macaques (*Macaca radiata*): Plimpton et al. 1981; Squirrel monkeys (*Saimiri spp*): Herzog and Hopf 1986; Jumping spiders (*Maevia inclemens)*: Clark and Uetz 1990; Cockerels: Evans and Marler 1991; Burmese fowls (*Gallus gallus spadecius*): McQuoid and Galef 1993; Pigeons: Shimizu 1998). Also, recognition of humans from two-dimensional video stimuli has been demonstrated in dogs by Pongrácz and co-authors (2003) during an experiment where they projected a video of a full-size person performing a pointing gesture towards one of two pots in an object choice task. The present finding that dogs' performance during the black and white video condition was significantly above chance level, and not significantly different from the real-life condition, supports the ability of dogs to recognise a person in two-dimensional videos even when colour features are removed.

It was previously suggested that animals' difficulties in recognising PLDs owe to the fact that compared to humans they have a reduced sensitivity to perceptual grouping, for which previous research has provided evidence in many species (e.g. Baboons: Deruelle and Fagot 1998; Chimpanzees (*Pan troglodytes*): Fagot and Tomonaga 1999; Pigeons: Cavato and Cook 2001; Capuchins (*Cebus apella*): Spinozzi et al. 2006). Perceptual grouping refers to the phenomenon by which parts or local elements of a visual scene are perceived as a unit or a global percept. Without this ability dogs would be unable to perceive the individual dots of the PLD as representing a single unit. However, previous research has shown that, as a species, dog do preferentially process the global dimensions of hierarchical stimuli compared to the local structure (Pitteri et al. 2014b; Mongillo et al. 2017), making this level of explanation unlikely. Moreover, dogs' performance in the present experiment was not significantly above chance level, even in the 'silhouette video' condition. With the latter stimulus, information about the figure's movements was provided, but unlike the PLDs the joints were connected, and the form outlined. This indicates that, even without the necessity to perceptually group local elements into a global figure, dogs are unable to infer human identity from movement information.

Dogs of the present study did not prove able to recognise the identity of human PLD in spite of their extensive exposure to humans. Research in humans showed that exposure is a crucial factor in determining an individual's ability to recognise species identity in PLD. For instance, the ability of human infants to accurately identify a variety of species-specific actions (human walking/running, dog walking, bird flying) increases from 3 to 5 years of age (Pavlova et al. 2001). Such increase cannot be attributed to strictly developmental constrains, as the younger infants are rather good at recognizing a PLD of a laterally walking dog, but not that of a human being performing the same action. The authors explained such finding by appealing to the limited visual experience of the specific stimuli in the younger children, as they are more likely to be approached frontally by human adults; moreover, due to their small stature, their habitual view of a human could differ substantially from the one portrayed in the PLDs they were shown. This level of explanation, however, is unlikely to account for our study, as we presented life-sized stimuli and our dogs' visual experience was hardly scarce of laterally walking humans. However, the ability to identify motion in a PLD is subject not only to passive visual experience, but also to begin experienced in performing the action being viewed. This would justify why the younger children in the study by Pavlova and collaborators (2001) more easily recognized a walking dog, than a walking human. This idea was further captured in a functional magnetic resonance imaging reporting cortical activity in premotor areas of adult humans shown PLDs portraying a variety of human actions (Saygin et al. 2004). Responses of the motor cortex to perceptual stimuli is attributed to the activity of mirror neurons, which presence, while not explicitly proven, can be assumed in dogs' cortex (Palagi et al. 2015). Such neurons would not be activated by viewing actions not expressible by dogs, such as bipedal walking or pointing. This, in turn, would explain dogs' inability to appropriately respond to the PDLs of our test, in spite of their extensive exposure to humans. The relatively limited efficacy of dog training methods based on the imitation of humans, when applied to 'free' body movements (e.g. actions performed in the lack of an object and an overt goal) (Fugazza and Miklósi 2015), provides further support to the notion that the ability to perform an action influences its identification by dogs. Much as these ideas are intriguing, our data cannot shed light on the neurobiological substrates of motion recognition by dogs, and the hypotheses will have to be explored in further studies.

The finding that dogs' sociability impacts their preference for human lateral PLDs (Ishikawa et al. 2018) seems to be contradicted by evidence from the current study that dogs are unable to identify humans in PLDs. However, rather than suggesting that a dog's sociability impacts their preference for lateral human PLDs because they identify them as a human partner, it could be speculated that sociability influences a dog's preference for biological motion *per se*. In fact, low-sociability dogs had no preference between upright and inverted human lateral biological motion, and highly social dogs preferred the inverted display. Without appealing to recognition of the display's identity, it could be that highly social dogs are very familiar with biological motion and therefore attracted by the novelty of inverted PLD, as reported in mice (*Mus musculus*) (Atsumi et al. 2018) and previously suggested in dogs given oxytocin treatment enhance their visual attention towards unfamiliar scrambled PLDs (Kovacs et al. 2016).

5. CONCLUSIONS

Our research points to the conclusion that human PLDs are far from being the most appropriate stimuli to test dogs' complex representational abilities and suggests caution in the interpretation of studies presenting human motion to dogs in the form of PLDs. Identification of perceptual cues which contribute efficiently to human action recognition in video animations, and are lacking in PLDs, was out of the scope of the present study. However, in this species reduced sensitivity to perceptual grouping does not seem to be the reason for their inability to recognise human actions in PLDs. It is clear from the current and previous studies that biological motion perception in dogs is not analogous with biological motion perception in humans. Whereas human adults are able to effortlessly perceive the actions of PLDs as representing humans, from which they can extract a large amount of social information including identity, there is currently no evidence that dogs recognise human actions in PLDs. Interestingly, unlike human infants, this ability does not benefit from extensive experience with human movements. Whether this also applies to the ability to process two-dimensional depictions of dogs as equivalent to a real conspecific remains unexplored.

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Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: The study was conducted in accordance with relevant legislation for research involving animals, and according to the type of procedure used, no formal ethical approval was required.

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Figure 1

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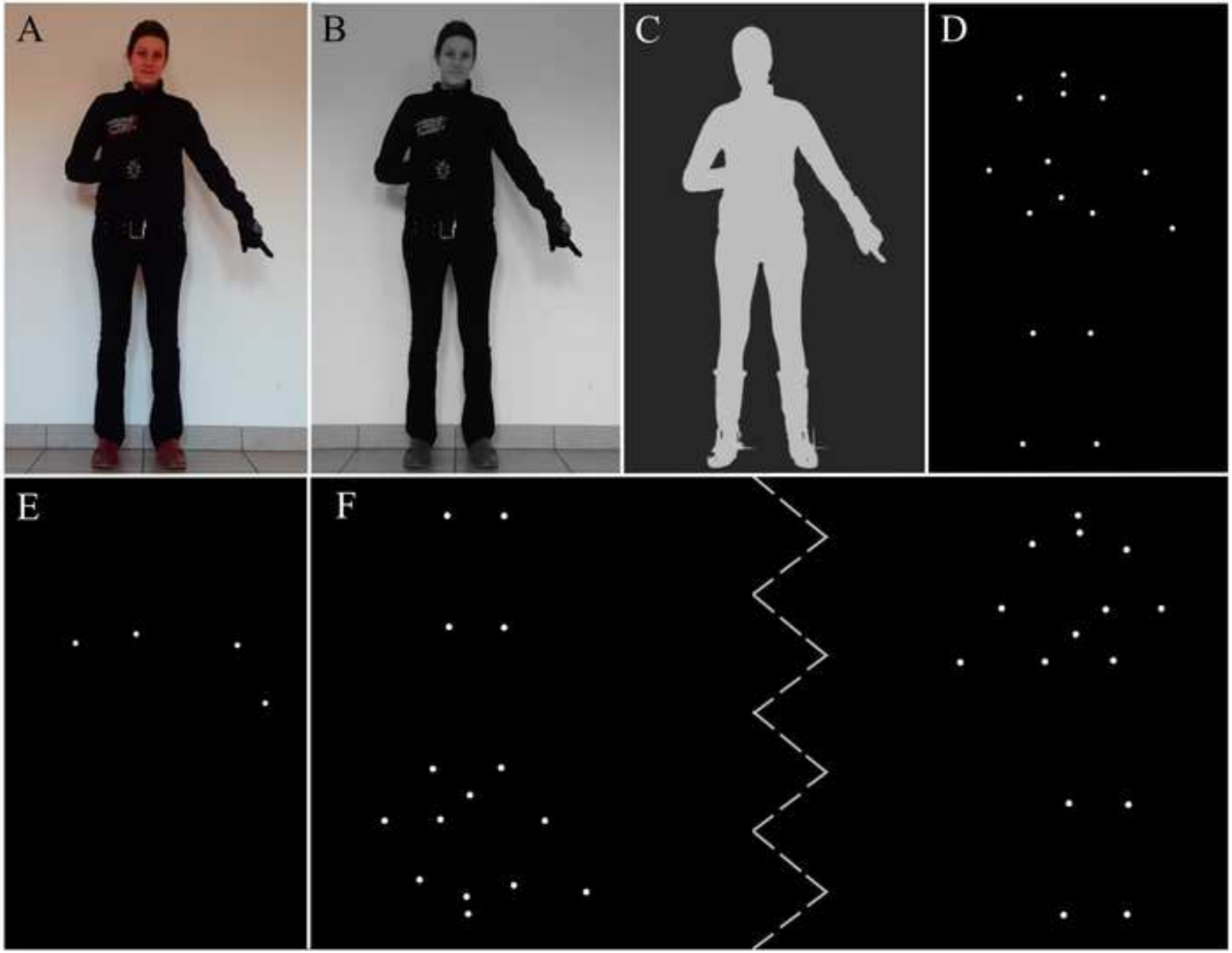

Figure 2

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Figure 3