Detector dog training shows companion-dogs rapidly remember the what and where of instinctively significant scents.

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Abstract: All of the companion dogs demonstrated that they were capable of rapid training to remember 'the what' of trained-for scents of evolutionary significance. In training, all the dogs made the cognitive transition of realising the tug-o-war-towelling-incentive-toy TOWIT they were chasing and fetching had a scent and when they could no longer see their TOWTIT they scent-searched for it instead. The next day all the dogs remembered those scents that they had been trained-for. The dogs remembered the where of their trained-for scents by rapidly finding them. When the dogs identified their trained-for scents from the distractors, they went to the boxes presumably because they thought that in a box was where it should be. Four of the six dogs rapidly identified their trained-for scents from the distractors showing that they had remembered what and where. The other two dogs knew the game (training) was to find a scent what and that the scent should be in a cardboard box where, but did not understand the implied (but impossible to state) rule, that it had to be that particular instinctively significant scent rather than any of the others.

Both their training and testing involved a lot of walking and running around so we feel that our dogs showed procedural memory as well as declarative memory.

Our evidence showed that like humans our dogs demonstrated a sense of self. They did this by displaying higher order cognition with (1) their range of sophisticated thinking skills, such as understanding the training (concept acquisition) searching for their TOWTITs (systematic decision making), distinguishing their trained-for scents from the distractors (rule usage) and (2) by demonstrating procedural memory which is a critical component for sense of self.

The first-night-effect FNE, often used to deliberately disturb the sleep in humans and dogs' did not affect the sleep of our dogs in this study. This negative finding, was attributed to the naturally robust structure of dogs' polyphasic, short sleep-wake cycles, their behaviourally stable habitat of being at home in close proximity to their owners and that the study measured full 8 h recordings.

Sleep in dogs may not be as important for learning as believed because previously the small number of neurologically focused studies did not test dogs' major sense of smell and may have shown other behavioural design misunderstandings.

The training methods employed in this study can provide considerable enrichment in the lives of both companion dogs and their owners. For many of our dogs their training provided a catalyst for them to go on to further scent training and the use of their considerable cognitive abilities.

Keywords: procedural-memory; detector-dog; dog-training; first-night-effect; scent; sleep; self

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HIGHLIGHTS

• The companion dogs demonstrated that they were capable of rapid scent-training to remember 'the what' and 'where' of trained-for scents of evolutionary significance.

• When scents of evolutionary significant are used, sleep may have little or no effect on dogs' memory.

• Dogs' sense of self was demonstrated through their use of higher cognitive function and procedural memory.

• The training methods employed in this study can provide considerable enrichment in the lives of both companion dogs and their owners.

• The first-night-effect FNE often used to deliberately disturb the sleep in humans and dogs' did not affect the sleep of our dogs in this study.

INTRODUCTION

Drug Detector Dogs, Search & Rescue Dogs, Police Dogs, Guide dogs, military dogs, herding dogs and our millions of companion-dogs are very significant to our lives both because of their special trained abilities, the way they improve our health and happiness and their provision of unconditional affection (Adams & Johnson 1994a: Wells 2009).

Dogs' learning and memory

Now that neurologists are using dogs as models for the effect sleep has on human memory, here we introduce the key points about dogs' memory to highlight their similarities and differences. It has been found dogs trained just once or twice a week perform better than when trained daily (Demant et al. 2011). Also dogs learn better if given just one training session in the day rather than three. In a recent review paper researchers decided that compared to other animals' dog cognition is not remarkable (Lea & Osthaus 2018). Experimentally, the extent of dogs' cognitive ability is unclear but there has been some recent limited research into dogs' cognition (Belger & Bräuer 2018). Dogs can have a mental map of what they are searching for and can adjust when presented with different information (Bräuer & Belger 2018). Like humans, dogs use odours to recall spatial memories (Quaranta, d'Ingeo and Siniscalchi 2020; Fujita, Morisaki & Hori 2012; Macpherson & Roberts 2010). As a further indication of dogs' cognitive ability, other researchers have concentrated on studying dogs' memory using 'do as I do training' and it was found that dogs can remember after a time lapse of up to 10 min (Fugazza & Miklósi 2014). Also, dogs are capable of using their working memory to determine the disappearance of moving objects, reliably use their spatial memory in mazes and are able to recall past complex events (Fiset, Beaulieu and Landry 2003; Macpherson & Roberts 2010; Fugazza, Pogány, & Miklosi, 2016).

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Like humans dogs' memory improves when they are given socially significant active play after training and they made less errors and required fewer trials (Affenzeller, Palme & Zulch 2017; Affenzeller 2020). These findings are supported by the way Drug Detector Dogs are trained (Adams & Johnson 1994a). Others have provided evidence for dogs having procedural memory for up to 1 hour but from anecdotal observations, it is likely to be far longer (Fugazza, Pogány, & Miklosi 2016).

Dogs are able to remember complex tricks and remember shortcuts when hunting in a location they have not visited for a year. It is probable that they get additional clues when they get to a location by sniffing in the vicinity to get their bearings first. In a case study Adams (2020) witnessed what he believed to be procedural memory. A poodle had lameness but only in front of their owner. There was a 4-week history and specialist veterinary orthopaedic examination revealed no previous or current injury. The faked lameness started after another dog visited for a week and was given a great deal of the owner's attention. A sheepdog has the genetic ability to round up sheep but then it still needs 1-3 years training to learn how to direct a hundred or more sheep on its own or with other dogs. A sheepdog may simply be using its innate ability to recognise that sheep must be herded close together by minimising the gaps between them (Strömbom, Mann, Wilson et al. 2014). However, if we adopt this line of thinking and exclude the notion of procedural memory in dogs, we would have to admit that for example a human football player is also only using instinct and has not learned any of the skills of the sport (Vaughn et al. 2021).

Memory and self

Having considered what constitutes dogs' memory and learning, their "sense of self" is examined. Historically, the ability to recognise yourself as different from your surroundings has been a sign of higher functioning (Blakemore & Frith 2003). Originally, it was understood that, as dogs could not recognize themselves in a mirror, like humans and some other animals; they had no understanding of self (Howell & Bennett 2011; Pepperberg, Garcia, Jackson & Marconi, 1995). Then, in 2019 the validity of the mirror recognition test was seriously questioned when a Cleaner wrasse fish was able to pass the test (Kohda et al. 2019). There has been increasing evidence that dogs do have a sense of self but it manifests itself in different ways (Gatti 2016; Gallup & Anderson 2020; Bekoff 2001). Scent is the predominant sense in dogs and they understand their sense of self in this way (Horowitz 2017). In humans, to be stimulated by training, then to sleep and subsequently demonstrate memory, is considered to be a reliable way to determine recognition of self (Horton 2017: Bosenelli 1995). The research presented here will provide further evidence that through scent-recognition-training and memory, dogs do demonstrate a sense of self.

To detect underlying pathology researchers and clinicians have combined to provide a guide of how to interpret the results (Shrivastava et al. 2014). The 'First night effect' FNE was an occurrence discovered by Agnew, Webb, & Williams, (1966) where sleep in the laboratory was disturbed and the results were often discarded but now more recently FNE is being used to deliberately

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disturb sleep (Toussaint et al. 1995; Le Bon et al. 2001; Tamaki et al. 2005; Chee, Chuah & Lisa 2008; Reicher et al. 2020).

Sleep may not be as important for learning in dogs as previously believed.

The area of research into sleep and memory in dogs is very limited: Literature searches using the search term 'dog' and 'sleep' and 'memory' were carried out (on 15th January 2021 in Scopus, Web of Science and Google Scholar, via the Publish or Perish interface) and only returned 6 results they were: Iotchev, Kis, Bódizs, van Luijtelaar & Kubinyi (2017) & Iotchev, Kis, Bódizs, et al. Author Correction; Iotchev, Szabó, Kis, and Kubinyi (2020); Iotchev, Reicher, Kovács et al. (2020); Kis, Szakadát, Gácsi, et al. (2017); Piotti, Szabó, Wallis, Bognár, Stiegmann, Egerer, Marty, & Kubinyi (2017).

In their neurologically emphasised, review, Bódizs et al. (2020) say they believe sleep may contribute to memory consolidation in dogs (but this is based on scant evidence). Traditionally sleep has been the area for neurologists but now they are using dogs as models for human sleep, as they believe their sleep to be similar and find them to be largely cooperative subjects (Iotchev et al. 2017). Some findings of these key papers such as Iotchev et al. (2017); Iotchev et al. (2020) maybe challenged because of the researchers' limited understanding of dog behaviour. For example, dogs previously taught visually and verbally to sit and lay down, were then taught to sit and lay down in another language but no account was made for the dogs' reading of the trainers' body language or facial expressions. In another study Piotti et al. (2017) where sight was the sense tested (and olfaction was nominally controlled) they relied upon the number of incorrect choices the dogs made rather than a binary method that may have been better.

There are indications that one of the functions of sleep is its role in memory in people and dogs and our hypothesis was that the first night effect FNE would significantly affect the memory of our subject dogs (Klein, 2001; Kis, et al. 2013; Iotchev et al. 2017; Kis, Szakadát, Gácsi, et al. 2017; Iotchev, Szabó, Kis, Kubinyi, 2020).

In this behavioural study, we trained and tested companion dogs that had no previous scent training, at their homes, in their natural habitat to recognise the scent stimuli of production-food-animals, which from an evolutionary perspective would have been considered likely food sources. Previous studies of sound stimuli in dogs revealed a preference for those of evolutionary significance over every-day sounds of equal or greater volume (Adams & Johnson 1994b). For our scent training, we used an adapted version of the drug detector dog method (Bräuer et al. 2020; Adams & Johnson 1993; Adams & Johnson 1994a). Then, we tested their ability to remember those scents after sleep. It is possible that we tested declarative memory (knowing that) and also procedural memory (knowing how) as we used chase-and-fetch training and testing routines, which involved walking and running around as well as sniffing (Kaminski, Fischer & Call 2007; Quaranta, d'Ingeo and Siniscalchi 2020).

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SUBJECTS AND METHODS

Subjects

Privately owned companion dogs and their owners were recruited after being observed by the researcher, at public dog beaches and parks. Those dogs identified had a single minded, high drive to "fetch" when playing with their owners. The prospective dogs repeatedly "fetched" the ball, stick, or Frisbee to their owners showing no sign of deviating from their task even when they were within the close vicinity of other dogs. A written outline of the study, fully explaining their potential involvement and references to the researcher's previous papers was provided. The responsibility was then upon the dog owner to contact the researcher to participate in the study if they wished. The dog owner could withdraw their consent at any stage. There were no rewards or benefits for participating. All dogs were trained and studied in their home habitat and slept on, or, near their owners' beds.

Animals

Six dogs and their owners were recruited to the study. All dogs had received basic obedience training and were very responsive to their owners when playing "fetch." None of the dogs had received any prior scent-searching training. All dogs maintained focus during all the training and their owners displayed their enthusiastic praise throughout.

(1) "Fly" was a lean and energetic 2-year-old, entire-female Border collie companion-dog, who had been trained for sheep and duck herding as well as 'agility'. Fly lived with two older male Border Collies.

(2) "Pokey" a sedate but fit and regularly exercised, 12 year old, sterilized male Border collie x Flat coat retriever; who lived with 2 Chihuahuas and 3 cats.

(3) "River" a very active 3 year old, sterilized female Border collie crossbreed;

(4) "Yuki" a highly responsive, slightly anxious but dominant 2 year old female sterilized Border collie crossbreed;

(5) "Norman" a very active and socially engaging 6 year old, sterilized male Labrador.

(6) "Pinto bean" a dominant 8 year old, sterilized female Chihuahua. Pinto bean used a half-sized TOWTIT and likewise her training/testing cardboard boxes were half the height. She was trained, tested and observed but her sleep was unable to be filmed when she would only sleep 'under-the-covers' of her owners' bed, and therefore her results are included as supplementary.

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Methods

We tested the dogs' memory by testing their ability to recognise those scents that they had been trained to value by reward.

Scents

Six naturally occurring scents of the manure from production-food-animals were used: These were; goat, pig, sheep, horse (collected from source) and chicken and cow (from commercially available manure certified as organic, Australian agricultural regulations 1997 by label and further identified by smell). The manures were all allowed to air dry until they had a similar intensity of aroma. The scent preparations were then further diluted by adding small amounts of these manures to 1L of mineral water in 1.25L bottles and lightly shaken. The mixtures were further diluted, if required, until all scents had a similar low-grade intensity detectable to the human nose.

Training equipment

A collection of similar empty 6 bottle cardboard boxes, which were replaced between each subject dog, were kept in the experimenter's vehicle to avoid scent contamination.

Care was taken to present "scent-neutral" conditions. For consistency, the experimenter was the only person handling training and testing apparatus throughout.

Filming

A SONY HANDYCAM HDR CX405 video camera (with low light function) and tripod were used.

Training

The dogs were trained to recognize scents by being rewarded with exuberant praise similar to that previously described by us for the Australian Border Force, Drug Detector Dogs (Adams & Johnson 1994). The dogs were trained to detect two of the six scents, randomly allocated. The distractor scents were also randomly allocated.

The first allocated liquid scent was poured onto the TOWTIT and then thrown at least 4 m by the dog's owner into a test arena on their property. When the dog retrieved the TOWTIT it was highly praised by its owner and a game of tug-o-war was given. Then the TOWTIT was repeatedly thrown and retrieved until the dog was thoroughly familiar with the procedure and trained-for scent. The fetch training occurred over 15 -20 min and stopped when the dog started to lag. Then the training was escalated; the experimenter positioned the TOWTIT so it was hanging out of an upright (neutral-scent) empty cardboard box. The dog was told to fetch and the owner motioned towards the box as if throwing the TOWTIT; the dog walked around until it detected the TOWTIT (from the box) and fetched it, and was praised as before. The dog and owner left the arena and the experimenter placed the scented TOWTIT inside the cardboard box which was overturned so the TOWTIT could not be seen. Then the owner fleetingly showed their dog a blank TOWTIT said "fetch" and motioned a throw

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towards the arena; whilst their dog ran in that direction, they hid the blank behind their back or in their pocket. Now the dog could not see its toy, so had to scent-search for it. When the dog knocked the box over and discovered the toy (and then fetched it) it was rewarded with exuberant praise.

The experimenter always stood behind the dog owner to reduce the chance of the dog reading their body language or facial expressions. To reduce the effect of possible scent contamination, or any other interference, other toys and companion animals at the subject dog's home were physically excluded from the test site.

Sleep

Having taught the dogs to recognize a trained-for scent they were allowed sleep. All dogs were filmed over 8 hours over 2 consecutive nights and showed a full range of normal sleep with NREM finishing in REM and spontaneously waking.

NREM sleep (Quiet Sleep): the dog is lying completely still with its head on or between its forepaws and is either on its side or back with its neck muscles relaxed and its eyes closed.

REM sleep (Active Sleep): the dog is lying with its head down, usually on its side or sometimes on its back and its neck muscles are relaxed, but showing rapid movement of its eyes, rapid twitching of its nose, muffled vocalisations, jerky movements of its paws, ears or tail, tongue or muzzle. Whilst lying immobile on its side the dog in Active Sleep can also mimic locomotion with its paws and legs.

Alert: the dog was still lying down or sitting but had its head up and neck muscles tensed and could also be twitching its nose with its ears lifted or swiveling, or it was other-wise engaged in grooming but remaining within its own body length. Active: the dog was eating, drinking, urinating, defecating, playing, digging, running or pacing.

The dog's recognition of that trained-for scent was then tested the next day, with the dog being asked to find that scent in an upturned cardboard box from amongst 5 other scent-neutral boxes in an arena. The time for them to find their trained-for scent was recorded. Then, to further test whether the dog was targeting the specific trained-for scent, the experimenter excluded the dog and owner and added two unknown distractor scents to two boxes and replaced all six boxes in the arena. The trained-for scented box was also moved to a different location. This meant there were 6 boxes, 3 were scent neutral, 2 were distractors and one was their trained-for scent. The dogs were again observed and the time recorded to find their trained-for scent.

The second day

The dogs were retrained on another scent, using the methods described above.

Testing overview

Day 1 (A) The dog was trained to recognise the first trained-for scent and then

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it was allowed to have its normal day, evening and night time sleep.

Night 1 (B) That night the dog was filmed for 8 hours of night time sleep and

Day 2 (C) The dog was timed to find how long it took to find its first trained-for scent after sleep.

(D) Then the dog was trained to recognise its second trained-for scent. The dog was denied its day and evening sleep by replacing it with stimulating mental and physical activities;

Night 2.(E) Then it was allowed to sleep that second night.

Day 3 (F) The dog was tested for its ability to recognise the second trained-for scent.

(G) Then the dog was further tested for its' ability to find its second trained-for scent from two distractor (novel, untrained-for) scents.

Three dogs were trained and tested against distractor scents after their second night of sleep i.e. ABCDEF and two dogs were tested against distractor scents after their first night of sleep ABCGDEF.

Figure 1. Tug-o-war Toweling Incentive Toys TOWTITS, consisted of toweling rolled and taped with gaffer tape into a floppy stick toy

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Statistical analysis

As each dog acted as its own control, statistical analysis using correlated (matched pairs) t- tests were used to test for significant differences between the data sets.

Figure 2. Norman, one of the dogs involved in the training. To have access to a video, please visit https://vimeo.com/726503158 or click on this link

RESULTS

Times to find trained-for scents,

Normal day/evening and night sleep vs denied day/evening and normal night sleep (all dogs).

See Table 1 (a) the mean time (sec) to find trained-for scents after normal sleep (19) compared with denied sleep (50) was non-significant.

The paired-t test indicated that there was a non-significant medium difference between Before ($M = 24.8$, $SD = 19.4$) and After ($M = 47.6$, $SD = 55.3$), $t(4) = 0.9$, $p = 0.423$.

Times to find trained-for scents from Distractor scents.

See Table 1 (b) Four dogs distinguished their trained-for scents from the distractor scents but 2 of them had to be provided extra time and

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encouragement (Norman 81 sec and Pinto bean 162 sec). One old dog Pokey (12y) found his trained-for scent, much more quickly (27 sec) when he had to distinguish it from the distractors compared with his initial on its's own scent test (137 sec).

A comparison of the normal vs denied day/evening sleep showed there was no significant difference between the night sleep-wake cycles.

Dog	**Sleep 1st night** Time to find trained-for scent (sec)	**Sleep 2nd night (denied day and evening sleep)** Time to find trained-for scent (sec)	**Distractors** Time to find trained-for scent (sec)
Fly	11 (horse)	25 (goat)	20 goat (from sheep and cow)
Pokey	15 (sheep)	137 (cow)	27 Cow (from goat and chicken)
Yuki	57 (chicken)	64 (horse)	57 Horse (from goat and chicken.)
	Sleep 1st night (denied day sleep)	**Sleep 2nd night Time to find trained-for scent (sec).**	
River	5 (goat)	12 (chicken)	27 goat (from sheep and horse)
Norman	7 (goat)	29 (chicken)	81 Goat (from sheep and horse).
Means	19	53	42
Pinto Bean	No data	86 (cow)	162 cow (from pig and goat)

Table 1. Time to find trained-for scents after normal or denied day and evening sleep (a) and distractors (b). Dogs were only tested against distractor scents once with 2 dogs in reverse order.

(a) Sleep/wake cycles

Dog	**Number of sleep sessions per hour**		**Time asleep (% of 8 hour monitored period)**		**Sleep session length (Min)**		**Time in REM sleep (% of total time asleep)**	
	First night	**Second night (denied day/evening sleep)**	**First night**	**Second night (denied day/evening sleep)**	**First night**	**Second night (denied day/evenin g sleep)**	**First night**	**Second night (denied day/evening sleep)**
Fly	2.76	5.53	22	44	18	27	12	24
Pokey	2.95	2.1	61	61	19	27	25	28
River	3.96	4.17	51	72	25	24	19	20
Yuki	1.9	2.0	71	80	32	28	40	20
Norman	3.25	3.0	88	85	18	20	25	12
Means	2.96	3.36	59	68	22	25	24	21

(b) REM latency

Dog	**REM Epochs events totals over 8 hours**		**REM Epoch length minutes (mean)**	
	Normal day & night sleep.	**Denied day/evening and then normal night sleep**	**Normal day/evening and then night sleep**	**Denied day/evening and then normal night sleep.**
Fly	5	5	13.3	21
Pokey	19	17	8.84	12.18
River	15	11	9.33	17.36
Yuki	22	22	13.36	12.27
Norman	15	17	14.66	15.12
Means	15.2	14.4	11.9	15.59

Table 2. Sleep/wake cycles: normal day evening and night sleep vs denied day/evening and normal night sleep (a), and REM latency, normal day and night sleep vs denied day and normal night sleep (b).

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(a) (i), Number of sleep sessions (per hour), the paired-t test indicated that there is a non- significant medium difference between Before (M = 3, SD = 0.7) and After (M = 3.4, SD = 1.5), t (4) = .6, p = 0.559;

(ii) Time asleep (%) the paired-t test indicated that there is a non-significant medium difference between Before (M = 58.6, SD = 24.6) and After (M = 68.4, SD = 16.4), t (4) = 1.9, p = 0.131;

(iii) The sleep session length (min), the paired-t test indicated that there is a non-significant medium difference between Before (M = 22.4, SD = 6.1) and After (M = 25.2, SD = 3.3), t (4) = 1.1, p = 0.328.

(iv) Time in REM (%), the paired-t test indicated that there is a non-significant medium difference between Before (M = 24.2, SD = 10.3) and After (M = 20.8, SD = 5.9), t(4) = .6, p = 0.587.

(b) (i) REM latency: REM epoch events, the paired-t test indicated that there is a non-significant medium difference between Before (M = 15.2, SD = 6.4) and After (M = 14.4, SD = 6.5), t(4) = .8, p = 0.477.

(ii) REM epoch events (min), the paired-t test indicated that there is a non-significant medium difference between Before (M = 11.9, SD = 2.6) and After (M = 15.6, SD = 3.7), t (4) = 2, p = 0.117.

The methods used to train these dogs have proved valid with drug detection training and all the dogs recruited for this experiment were able to be trained to search for and detect the TOWTIT with the trained-for scents using the adapted methods (Adams & Johnson 1994a; Lazarowski et al. 2021).

DISCUSSION

Companion dogs were able to rapidly remember the 'what' and 'where' of instinctively significant scents.

All of the companion dogs demonstrated that they were capable of rapid training to remember the what of trained-for scents of evolutionary significance. In training, all the dogs made the cognitive transition of realising the TOWIT they were chasing and fetching had a scent and when they could no longer see their TOWTIT they scent- searched for it instead. Then the next day the dogs remembered those scents that they had been trained-for. Additionally, the dogs remembered the where of their trained-for scents by rapidly finding them in the upturned boxes. Certainly, the dogs could have found their trained-for-scents just by air scenting in the arena but they realised the where and scent searched the cardboard box. Perhaps just like when dogs sniff a post for the urine of other dogs.

When the dogs identified their trained-for scents from the distractors, they went to the boxes presumably because they knew where it should be but, (although its' unlikely) they might have gone there because all were giving off some scent. Four of the six dogs rapidly identified their trained-for scents from the distractors showing that they had remembered what and where. The other two

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dogs Norman and Pinto bean knew the training/game was to find a scent what and that the scent should be in a cardboard box where, but did not understand the implied (but impossible to state) rule, that it had to be that particular instinctively significant scent.

Declarative memory, procedural memory and memory reinforcement.

As our dogs recognised their trained-for-scents, their memory by default must have been declarative. Yet both their training and testing involved a lot of walking and running around so we feel they had also used procedural memory. The old dog Pokey took a long time to find his trained-for scent (137s). However, on the following test he rapidly found his trained-for scent from his distractors in 27s. We believe he had the scent memory reinforced and had further learned during the day (without sleep consolidation) and so was able to recognise it more quickly.

Sense of self, demonstrated through higher order cognition and procedural memory.

Our evidence showed that like humans our dogs demonstrated a sense of self. They did this by displaying higher order cognition with (1) their range of sophisticated thinking skills, such as understanding the training (concept acquisition) searching for their TOWTITs (systematic decision making), telling their trained-for scents from the distractors (rule usage) and (2) by demonstrating procedural memory which is a critical component for sense of self (Levine 2009; Klein 2001; Prebble, Addis & Tippett, 2013).

The validity of first-night-effect FNE testing in dogs.

Based upon our earlier findings Adams & Johnson (1994a) where some kennelled drug detector dogs showed the FNE and Reicher et al. (2020) whose laboratory dogs also showed the FNE, together with the practise of using the FNE to deliberately disturb sleep in humans, it was surprising that in this study our dogs were not affected. However, Reicher et al. (2020) recordings were only during the dogs' afternoon naps and were only for 3 hours and their recordings had "great time intervals" between them. Furthermore, van der Laan et al. (2021), in their study of Shelter dogs, like in our current study, they too, found that there was no FNE. Kis, Szakadát, Gácsi et al. (2017) have provided more insight into how dogs sleep maybe effected as they found that positive or negative emotions could affect dogs' sleep macrostructure. So, even though it was expected that by replacing our dogs day time and evening sleep with high mental and physical activities we would produce a FNE it didn't happen. These findings are important for two reasons, firstly it shows that dogs' short cycling sleep can be robust and secondly they can be highly motivated with positive praise.

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Sleep may not be as important for learning in dogs as previously believed.

The findings in this experiment that sleep did not have a significant effect on the memory of dogs' acts as a balance to the findings of the other limited studies saying that it may. These results show that when the dogs' primary sense of smell is tested, rather than the more convenient human centred senses of sight and hearing; and the scents are of evolutionary significance and the reward for memory is owner praise, the results indicate that sleep may not be as important as believed.

Previously it was thought that when sleep spindles occurred during NREM, declarative memory took place and that procedural memory took place during REM; now it has been discovered that sleep spindles also occur during REM, which in addition is involved in declarative memory tasks (Fogel, Smith & Cote 2007). Furthermore, distinct types of learning are encoded in separate parts of the brain across the night (Schonauer et al. 2019).

The results of this study are supported by others who also studied polyphasic non-human sleep: Sperm whales and elephants only sleep 2 hours a day with the latter only having recumbent (REM) sleep every 3rd or 4th day; Killer whales and dolphins (neonates and mothers) don't sleep for the first month of their lives; fur seals don't have REM sleep for extended periods when foraging in the open ocean (with no subsequent rebound) and dolphins which sleep unihemisperically don't have REM, yet all of these animals clearly display procedural memory (Miller et al. 2008; Gravett et al. 2017; Sekiguchi, Arai & Kohshima 2006; Lyamin, Mukhametov & Siegel 2017: Lyamin, et al. 2018). Accordingly, in our study the procedural memories of our dogs could have taken place in either REM or NREM or perhaps even when awake and did not need the consolidation of sleep.

In a small group study in a laboratory, it was found that extremely old dogs (16-18y) showed a marked reduction in REM; whereas our old dog Pokey (12y) showed normal REM over both nights (Takeuchi & Harada 2002). We attribute Pokey's normal REM sleep to his circumstances of being at home. Also, anxiety, arthritis and other old dog pain needs to be controlled for when measuring the reduction of REM in old dogs.

Fun training methods for companion dogs.

The training methods employed in this study can provide considerable enrichment in the lives of both companion dogs and their owners. For many of our dogs their training provided a catalyst for them to go on to further scent training, where for example Norman has learned to track his owner by scent-searching her over rough terrain in the Australian bush.

Critique of method

Four of our dogs were Border collies or crosses, recognised as easy to train and

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highly intelligent. It may be that different results would be found with other breeds, although all our dogs showed the prime behavioural requisite of enthusiastically fetching. It would have been useful to have had greater numbers but this project was highly labour intensive. Because of severe Covid restrictions in Western Australia, considerable time was required for the initial observing and recruiting in the public spaces and then time allowances for the potential subjects to make a commitment to be filmed. Those volunteers then had to commit themselves and their families to filming in their bedrooms over consecutive nights to comply with the rigours, consistencies and practicalities of the experiment. There have been many studies where the subject numbers have by necessity been small e.g. Takeuchi, & Harada (2002), who used 4 dogs, Bekoff (2001) used only 1 dog and Adams, & Johnson (1994) also used 6 dogs. However, by using each dog as its own control these data displayed consistent findings. In addition to the quantitative data, this project has provided considerable qualitative findings. A larger team of researchers with considerable resources may find a different or similar result. We hope our detailed project will provide a window of insight into the minds of dogs and their interaction with their owners.

CONCLUSION

All of the companion dogs demonstrated that they were capable of rapid training to remember 'the what' of trained-for scents of evolutionary significance. In training, all the dogs made the cognitive transition of realising the TOWIT they were chasing and fetching had a scent and when they could no longer see their TOWTIT they scent-searched for it instead. Then the next day the dogs remembered those scents that they had been trained-for. The dogs remembered the where of their trained-for scents by rapidly finding them. When the dogs identified their trained-for scents from the distractors, they went to the boxes presumably because they knew where it should be. Four of the six dogs rapidly identified their trained-for scents from the distractors showing that they had remembered what and where. The other two dogs took longer. They knew the game was to find a scent what and that the scent should be in a cardboard box where, but did not understand the implied but impossible to state rule, that it had to be that particular instinctively significant scent.

As our dogs recognised their trained-for-scents, their memory by default must have been declarative. Yet both their training and testing involved a lot of walking and running around so we feel they had also used procedural memory.

Our evidence showed that like humans our dogs demonstrated a sense of self. They did this by displaying higher order cognition with (1) their range of sophisticated thinking skills, such as understanding the training (concept acquisition) searching for their TOWTITs (systematic decision making), telling their trained-for scents from the distractors (rule usage) and (2) by demonstrating procedural memory which is a critical component for sense of self.

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Although the FNE has been used to deliberately disturb the sleep of humans and dogs it had no effect in our study; we attributed this to the naturally robust structure of dogs' short sleep-wake cycles, their behaviourally stable habitat of being at home in close proximity to their owners and that the study measured full 8 h recordings.

Sleep in dogs may not be as important for learning as previously believed. The limited studies beforehand did not test dogs' major sense of smell and there was an oversimplification of dogs' complex behaviour.

The training methods employed in this study can provide considerable enrichment in the lives of both companion dogs and their owners. For many of our dogs their training provided a catalyst for them to go on to further scent training and the use of their considerable cognitive abilities.

ETHICS

The researcher is now a private individual who is no longer affiliated to any tertiary institution: The dog owners' conducted the experiments at their own homes.

Additionally, this project was fully compliant with the Australian Code for the Responsible Conduct of Research 2007 and the Australian Code for the Care and Use of Animals for Scientific Purposes and the Animal Welfare Act (WA) for which the researcher was accredited.

CONFLICT OF INTEREST

There was no conflict of interest.

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