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Utilising dog-computer interactions to provide mental stimulation in dogs especially during ageing

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ABSTRACT

Aged dogs suffer from reduced mobility and activity levels, which can affect their daily lives. It is quite typical for owners of older dogs to reduce all activities such as walking, playing and training, since their dog may appear to no longer need them. Previous studies have shown that ageing can be slowed by mental and physical stimulation, and thus stopping these activities might actually lead to faster ageing in dogs, which can result in a reduction in the quality of life of the animal, and may even decrease the strength of the dog-owner bond. In this paper, we describe in detail a touchscreen apparatus, software and training method that we have used to facilitate dog computer interaction (DCI). We propose that DCI has the potential to improve the welfare of older dogs in particular through cognitive enrichment. We provide hypotheses for future studies to examine the possible effects of touchscreen use on physiological, behavioural and cognitive measures of dogs' positive affect and well-being, and any impact on the dog-owner bond. In the future, collaborations between researchers in animal-computer interaction, dog trainers, and cognitive scientists are essential to develop the hardware and software necessary to realise the full potential of this training and enrichment tool.

Author Keywords

Dog computer interaction; Touchscreen; Animal welfare; Motivation; Learning; Senior; Dogs.

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INTRODUCTION

Improving the welfare of captive, domestic or wild animals is recognised as an important aim of Animal-Computer Interaction (ACI) [25]. Since animal welfare scientists realised that welfare problems in animals can be better addressed with a greater understanding of how animals feel, there has been a surge of interest in studying animal sentience [7]. It is universally accepted that animals feel pain and can suffer; however, well-being is not just the absence of pain and fear, but is predominantly the presence of positive affects. Studies in humans have determined that happiness is promoted by both positive emotions and positive activities [49]. Positive affect is difficult to measure in animals, however, evidence from recent studies show that animals living in enriched environments can benefit from the creation of situations where there is anticipation of positive rewards, by promoting play, and opportunities to collect information, such as in problem solving tasks, which results in positive physiological and behavioural reactions [12, 32,35]. When these positive emotional experiences are sustained or repeated, a global state of "well-being" may ensue, which could help to improve health, and give the animal a better quality of life [7].

In the UK, nearly one quarter of all households have a dog [55]. Britain's spent a record-breaking £7.16bn on their pets last year, a growth of 25% since 2010 [40]. For the majority of dog owners, their dogs' health and well-being is important as they are considered family members. One particular section of the market, which is often ignored, is the ageing dog. As pet dog numbers increase in the UK, so does the number of old dogs living in our households. The age at which a dog enters the senior phase of their life varies according to breed and size, but most dogs can be considered senior from between five and 10 years of age. As part of the normal ageing process, senior dogs suffer from a reduced metabolism and an increase in the occurrence of arthritis and joint issues, resulting in reduced mobility and activity levels, which can affect their daily lives, and also influence the dog-owner bond [3,22].

Previous research has determined that dog personality changes over the course of a dog's lifetime [20,45,51], which can lead to changes in dog and owner demographics, such as in the case of when a dog begins to show signs of ageing. Reductions reported by owners in their dogs' personality traits of trainability, and activity/excitability that occur with increasing age result in a decline in owner positive attitude towards their dog, and in turn, a reduction in the amount of time the owner spends together with their dog in activities such as walking, playing and training [59]. It is quite typical of owners of older dogs to reduce all activities with their dog, since their dog may no longer seem to need or want that type of stimulation, as there is often a large increase in the time the dog spends sleeping, and/or inactive during the day [15]. Additionally, the owner's attitude to ageing in dogs may also influence how much time they spend active with their dog, such that if they believe that a dogs golden years should be spent in quiet and relaxation, then they are likely to reduce activities with their dog regardless to its ability to take part in those activities.

Numerous studies have documented the benefits of physical activity and cognitive enrichment on the performance of laboratory dogs in different cognitive tasks, and the effect is particularly strong in aged dogs [34]. There is also evidence that lifelong training experiences in pet dogs (measured via owner questionnaires) have the potential to maintain cognitive function in aged dogs, in a similar way to higher education in humans. Such that dogs with a high level of lifelong training perform better in problem solving tasks than novice dogs [27–29,44] regardless of age, and additionally have higher levels of attentiveness [9]. Dogs can similarly benefit from repeated exposure to cognitive enrichment. For example, old dogs with prior experience on discrimination learning tasks were quicker to learn new discriminations than dogs with no such experience [33]. All of these studies point to the fact that ageing seems to be slowed by mental and physical stimulation, and thus stopping these activities might actually lead to faster ageing in dogs.

To address the possibility of a reduction in mental and physical stimulation in (aged) pet dogs caused by changes in lifestyle, personality, and mobility status, in this paper, we explore the potential of touchscreen technology to improve dogs' positive affect and novel motivational experiences through cognitive training. Below we discuss how boredom, learning opportunities, and motivational changes in dogs can influence their positive affect and well-being, as well as detailing the possible benefits of various types of enrichment.

BACKGROUND

Captive and domestic animals are often passive recipients of stimulation, rather than having choice and control over their experiences and behavioural options [61]. For example, for some social animals, being confined alone for long periods leads to boredom. Signs of boredom include increased drowsiness with bouts of restlessness, avoidance and sensation-seeking behaviour [8]. Captive animals lacking sensory or cognitive stimulation (such as when exercise, exploration and/or learning opportunities are reduced) have weakened neural pathways, which can result in their brains becoming physically smaller [63]. Some of these boredom behaviours have been described in dogs that lack physical and mental stimulation [31]. By providing dogs with cognitive and environmental stimulation, their quality of life can be improved, and the prevalence of abnormal behaviours may be reduced.

Previous research has shown that humans and non-human animals prefer to work for reward, rather than receiving a reward for "free" [14,30]. There is no doubt that dogs find food to be rewarding, as reflected in pleasurable responses to receiving high value food items. However, one study determined that providing food directly to dogs, without the necessity to perform a specific action to get it, may reduce the hedonic value of the food item [56]. McGowan et al. [30] showed that dogs displayed higher positive affect (as revealed through eagerness to enter the test room, increased activity and tail wagging) when they could control access to a reward through executing an operate task, than when they could not control access and only expected a reward. They concluded that opportunities to solve problems, make decisions, and exercise cognitive skills are important to an animal's emotional experiences and ultimately, their welfare. Problem-solving opportunities have been found to be intrinsically motivating as shown by evidence that dopamine is released during learning and memory consolidation [6]. Researchers have suggested that dopamine acts to stamp in response–reward and stimulus–reward associations that are vital for the control of behaviour motivated by past experience [62].

As part of normal ageing in human and non-human animals, there is a loss of dopamine neurons, which contributes to a decline in episodic memory [10]. According to the 'NOvelty-related Motivation of Anticipation and exploration by Dopamine' (NOMAD) model proposed by Duzel et al. [11], dopaminergic dysfunction in old age should also be associated with diminished motivational drive and energy to engage in exploratory behaviour, as well as mild motor dysfunction. The model suggests that cognitive training combined with reinforcement learning principles and mobility interventions should result in improvements in cognitive function and memory, as well as motivation, novelty seeking, goal orientation, stimulus salience and exploratory behaviour. Recently, evidence to support this model came from a study that found that cognitive training using a memory game on an iPad improved episodic memory, visuospatial abilities, increased engagement and heightened motivation in people with age related mild cognitive impairment [48]. In parallel to the rise in interest in human brain training, recently there has been a surge of interest in cognitive training and enrichment for dogs, which can be implemented by dog owners in the home environment.

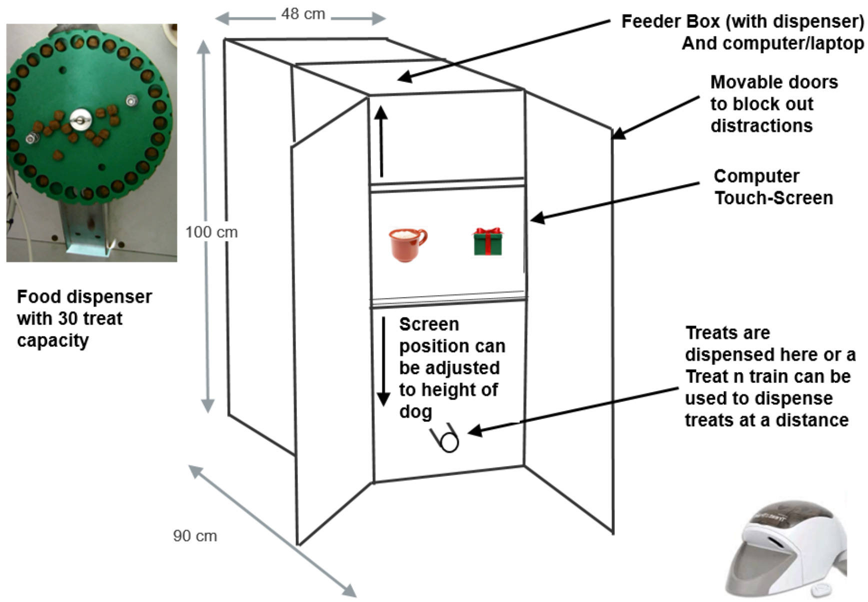

Figure 1. Schematic diagram of the touchscreen apparatus, including: Feeder box (containing food dispenser and computer/laptop), movable doors to block out distractions, and adjustable computer touchscreen. Treats are dispensed through a tube from the feeder box, or a feeding device such as the Treat & Train can be used to dispense treats at a distance. Top left: Photograph of the food dispenser used in the studies. Bottom right: Treat & Train automatic food dispenser with remote control.

Dogs' need for cognitive enrichment can differ according to their lifestyle and status, for example, working dogs may not require additional stimulation in their daily lives. However, for non-working and senior dogs, technology can provide an alternative or additional method of cognitive training. Many new dog intelligence toys and training tools are now available to buy, and more "cognitive" training methods using positive reinforcement are being promoted. Additionally, many Apps have been developed for use by dog owners to help improve dog welfare, and one has even been produced for use with dogs, "Game for Dogs". An owner, who provides their dog with the use of intelligence and manipulative toys, might increase the dog's positive affect, due to the fact that the dog can "work" for the reward, which increases the perceived value of the reward. However, these types of toys quickly become less interesting to the dog once they learn how to successfully operate them.

One other way of increasing dogs' positive affect and well-being is owner-dog play. There is evidence that many dogs find playing with the owner rewarding, but not all dogs like to play, and play levels are known to decrease in senior and geriatric dogs [46,47]. The quality and type of play is mostly determined by the owner, and can include authoritarian commands, different levels of enthusiasm, praising, and petting, as well as physical manipulation, which the dog may find aversive or pleasant depending on the individual. Differences in the behaviour, mood and motivation of the owners can influence the dogs own motivation and behaviour during play [17]. Not all owners know how to engage in play with their dog, or are even motivated to play with their dog at all. Thus, although play can be beneficial in reducing stress and improving the dog-human bond in some dogs, it is not suitable for all dogs, especially older dogs, and those that have mobility issues.

One type of technology that can be implemented for use with pet dogs, and that has already been used in humans is cognitive training utilizing games played on touchscreens and iPads. The power of the touchscreen as a training tool is in its flexibility, reliability and controllability, and in its ability to provide novel motivational experiences. The number of cognitive training possibilities are limitless, as the stimuli (clipart, photo and even video), acoustic feedback, reward type, and cognitive paradigm tested can all be varied [53]. Unlike humans, which can be surprisingly inconsistent in their behaviour (e.g. when deciding when to praise or reward dogs, and when giving commands (tone of voice)), the touchscreen will always give consistent immediate audio feedback when the dog makes a correct choice, accompanied by a food reward. The dog learns that the choices it makes dictate the feedback they receive (positive or negative), thereby giving a measure of controllability to the dog.

We hypothesize that the touchscreen procedure helps to create a state of pleasant anticipation in the dog. From the work of Gregory Berns, we know that there are striking similarities between dogs and humans in the functioning of the caudate nucleus, an area of the brain that is associated with pleasure and emotion. fMRI studies in awake unrestrained dogs have revealed positive and consistent responses in the caudate nucleus to objects and stimuli that dogs liked [4,5]. This means that when the dog begins to learn to associate the touchscreen and stimuli with a positive reward, the stimuli and the apparatus itself can create the state of anticipation of reward even without the presence of food.

Within the ACI literature, so far only Zeagler and colleagues have focused on designing a touchscreen interface for use with dogs [64,65]. They designed a system for service dogs to relay emergency information about their handlers from a home or office environment. Therefore, they did not focus on the touchscreen as a method of cognitive enrichment; however, they did test several different methods of training dogs to interact with screens to produce a preliminary foundation for touchscreen "best practices", which we have discussed more in the methods section (see below).

TOWARDS NOVEL EXPERIENCES FOR OLDER DOGS

For too long the old saying "You can't teach an old dog new tricks" has been prevalent in society, despite numerous studies proving the contrary [23,58,60]. We set out to quantify dogs' cognitive abilities utilising the Vienna Comparative Cognition Technology (VCCT), a touchscreen interface specifically adapted for the use of pet dogs [53]. Owner and dogs participated voluntarily, and dogs were trained using positive reinforcement. Since 2006, Ludwig Huber and his colleagues at the Clever Dog Lab have trained over 200 dogs to use the touchscreen, and have pioneered touchscreen research in learning, memory, and logical reasoning abilities of pet dogs [1,18,37,43], and many other species (such as pigeons [52], marmosets [21], Kea [39], ravens, tortoises [36], and pigs). Since then, dog cognition labs around the world have begun to use this technology as a way to tap into the cognitive capacities of dogs [66,67].

We propose that the use of touchscreen technology has great potential to improve the quality of life particularly of aged dogs, by providing an opportunity to participate in a cognitive enrichment program, which can be tailored and adapted for the use of senior and geriatric dogs. By providing an activity that dogs can participate in, which relies almost exclusively on repeated positive reinforcements, and problem solving opportunities, we speculate that the continued use of the touchscreen could result in an increase in dogs positive affect and motivation. We used the dogs' behaviour as reported by the owner and trainer, as a non-invasive indicator of welfare and positive affect, and to ensure that the user requirements and experience (UX) were evaluated. Although we did not measure physiological changes during touchscreen training and testing, an increase in affect can be reflected in dogs' motivation to continue participating, and additionally the owners' and the trainers report of the behavioural responses of the dogs during training, and any changes in the dog's personality and/or willingness to participate in activities in the home environment.

Here we present a methodological contribution, which aims to detail the necessary hardware and the different training techniques, which we have so far used to facilitate dog computer interaction (DCI) in our labs. We emphasize the changing needs of aged dogs (such as reduced mobility) and how this may influence the training and testing procedure. We will also discuss the various methods that can be used to measure the impact of touchscreen training on dogs' positive affect and well-being, and the dog-owner bond in the future applications section. It is our hope that collectively we can contribute to designing technology to improve the lives particularly of aged dogs. We anticipate that this paper will start a dialogue between different institutions and lay the foundation for future collaborations.

THE TOUCHSCREEN APPARATUS

The touchscreen apparatus consists of a laptop, a 15" TFT computer monitor that is mounted behind an infrared touchframe, and a feeding device that distributes treats (Figure 1). An infrared touchframe was chosen as the best option for use with dogs, since it allowed for a level of moisture, and saliva from the nose presses of dogs, whilst still functioning. However, dogs with excess saliva may result in the touchframe becoming unresponsive; therefore, the screen should be wiped regularly to avoid this occurring. The monitor and touchframe can be slid up and down to adjust to the height of the dog. The centre of the screen should be located at the dog's eye level (Figure 2).

The feeding device was designed and built by Wolfgang Berger from the Messerli Research Institute, and contained a wheel with 32 holes, which rotated to release a single treat when the dog touched the correct stimulus. Since this system was complicated to design and make, required regular maintenance, and was limited in the number of treats that can be dispensed, several additional options exist regarding feeding devices, which enable a more multi-functional approach. The "Treat & Train", which is relatively inexpensive, and commercially available from PetSafe, utilises a remote control that the owner/trainer can press to dispense a single treat, if the dog makes a correct choice [68]. Another available dispenser is the "Pet tutor", which has the additional advantage of Bluetooth connectivity [69]. The distance between the screen and the dispenser can be varied. It would also be possible to use the device designed by Wolfgang Berger as a moveable dispenser if it is not integrated within the touchscreen Feeder Box. This has the benefit of causing the dog to move away from the screen to obtain the reward, and may help to give the extra seconds required for the dog to view the screen and make a correct choice. When utilising this feeding method, the size of the touchscreen apparatus can be substantially reduced. For example, the screen and touchframe can be mounted onto a wall, and any cables covered, to ensure the dog could not gain access to them. If using a laptop to run the software, it should be placed out of reach of the dog, on a nearby shelf or table, so as not to confuse the dog with access to two screens. Movable doors or screens are located at the front of the touchscreen, which can be folded out to create a "testing niche", which helps to prevent distraction from the external environment, and also serves to position the dog in the ideal location to utilise the touchscreen (Figure 2). Many dogs approached the touchscreen from the side in the initial training, and not head on. This could cause a side bias to develop; therefore, the dogs need to be guided into the testing niche to position them centrally and to allow optimal viewing of the stimuli.

Both the "Treat & Train" and the "Pet tutor" can be adapted to integrate them with the computer, which would allow the automatic triggering of the feeding device once a correct choice has been made by the dog, (by touching the correct stimulus on the screen). When utilising this method, the pressing of a remote device by the trainer would no longer be necessary. Please note that on occasion these devices may fail, which may result in food becoming jammed in the feeder, and/or no food reward being dispensed. If this is a regular occurrence, then the trainer can have some extra treats in a food pouch, which she/he can quickly drop into the dispenser food bowl when necessary, before fixing the device. Careful consideration should be given to the type of food used as a food reward. The dietary requirements of the individual dogs should be determined, and in most cases the dogs' usual dry food, or semi moist food, can be used. In the case of over-weight dogs, a dry food with reduced calories can be utilised, or a low calorie training treat. In our experience, some of the dogs were too quick to eat the dry food in their haste to return to the touchscreen, which sometimes resulted in occasional choking. We experimented with the consistency of the reward, and found that a chewy or semi-moist option worked better with these types of dogs. Using wet food as a reward in automatic feeders is not currently possible; however, for dogs that require more motivation, small pieces of cubed hard cheese and/or hotdog can be mixed in with the dry food. Please note that these softer foods may become jammed in the devices, apart from the feeder designed by Wolfgang Berger, which was set up to allow the use of different food types. On training days, the dog's food allowance should be lowered to incorporate the amount of food used during touchscreen training. Additionally the dog should not be fed for at least two hours before training, to ensure sufficient motivation.

SOFTWARE AND PICTURE STIMULI

At the Clever Dog Lab, and the Wolf Science Center, to present the stimuli and record the dogs' responses, we use a software program called CognitionLab by Michael Steurer (version 1.9; see ref. [53] for detailed description). The software presents picture stimuli (in jpeg or bmp file types) according to the users specifications. We used a "First-Contact" touch system, where the first contact with the target counts, even if it is not the first impact with the surface. This method was also found to be the easiest to learn for dogs by Zeagler et al. [65]. The software allows great flexibility in modifying inter-trial intervals, stimulus positions, auditory feedback, background colour, use of correction procedures, and presentation time. Data are logged into a single text file per subject, and contains such information as, which stimulus was touched first, the precise location of the touch, and additionally undefined touches (areas the touchscreen was touched that did not contain stimuli) including all precise timings of the touches. In the near future, CognitionLab will become open source, and therefore available for all to use. One other open-source program available that could be used is called OpenSesame. Recently, at the Clever Dog Lab, our newest touchscreen apparatuses are run utilising open source software called "DogTouch" designed by Messerli Research Institute Computer Technicians Michael Pichler and Peter Füreder. We base our newest hardware on commercial-level components and custom solutions. We integrate Arduino, an in-expensive open-source electronics platform based on easy-to-use hardware and software, into the design. Additionally, we are experimenting with microcomputers (e.g. Raspberry Pi), the emerging standard widely accepted in the do-it-yourself "maker" community. This will lead to inexpensive hardware becoming accessible to a large community, capitalizing on the fast-growing "ecosystem" of companies serving the maker community.

Figure 2. A dog standing in the "testing niche" (moveable doors folded in) demonstrating the correct position for the dog to best utilise the touchscreen apparatus.

The stimuli displayed on the touchscreen consist of jpeg clip art images obtained from the internet presented on a white background. The stimuli should differ in colour, global outline, and internal features. This will allow the dog to more easily discriminate them. When training aged dogs, we found the optimum size of the stimuli to be 200 by 200 pixels, which is equivalent to about 2 inches in size. However, if a dog has mobility problems, and touching precisely on a small square image is more of a challenge, the stimulus size can be increased to 300 x 300. Please note these picture sizes were presented on a 600 x 800 pixel screen, so the resolution of the screen must be taken into account when sizing stimuli. For comparison, Zeagler et al. in their touchscreen methodological study used stimuli at a size of at least 3.5 inches [65].

SUBJECTS

So far, around 265 dogs, and 20 wolves were trained to use the touchscreen in several different studies in several different labs, including the Clever Dog Lab and Wolf Science Center in Austria, and the Family Dog Project in Budapest. Most of the dogs were pet dogs living with Austrian or Hungarian families, however, 20 dogs were raised, socialized, and kept in enclosures at the Wolf Science Center in a similar way as to the 20 wolves housed there. One hundred pet Border collies (aged from 5 months to 14 years), and 115 dogs (aged 6 years and over), from different pure breeds and mixed breeds were trained at the Clever Dog Lab. Thirty pet dogs of various breeds and ages were trained at the Family Dog Project, and 20 dogs and 20 wolves were trained at the Wolf Science Center, Austria.

TRAINING PROCEDURE

Here we will focus on the preliminary steps necessary to train a dog to interact with the touchscreen. The dog receives a training programme consisting of several phases of progressive complexity. The goal of the auto-shaping and pre-training procedures is to familiarize dogs with the touchscreen apparatus and the food dispenser (Phase 1), to teach them to touch a stimulus on the screen, first at a fixed location (Phase 2), then at varying locations (Phase 3). Then finally, to select a picture from two or more to obtain a reward (discrimination training, Phase 4). Only then can the dogs start to solve more difficult cognitive tasks, which can further examine their learning, memory and logical reasoning skills [1,43,60]. Students and research assistants, some of which had considerable previous dog training experience trained the dogs at our labs. All were briefly instructed in the basics of the different training techniques, however, needed some practice before perfecting their training skills. Therefore, when we refer to a "trainer" in the text, we denote someone who has an understanding of how to train dogs, and a good knowledge of the individual dogs being trained.

Phase 1 Familiarization with the touchscreen apparatus and the food dispenser

Owners brought their dogs to the lab once a week and participated in three to four sessions, over a half-hour period, with short breaks in between sessions. Initially the trainer had to help the dog using a variety of techniques (such as shaping, target training, and luring), to approach the apparatus and the screen, which is of course, not a natural behaviour for the dog, and additionally the dog needed to learn how to use the feeding device. We found that during this early stage, the movable doors at the front of the touchscreen should be positioned in a wide-open position, so that the dog and the trainer can approach the front of the apparatus unimpeded. The quickest method to familiarise the dog with the apparatus is to use luring, which consists of the use of food to guide the dog into a desired position or behaviour. Liver sausage is a treat that most dogs enjoy, and can be obtained as a paste in a handy tube dispenser. Cream cheese or peanut butter can also be used for fussy eaters, or dogs with specific food allergies. Initially, the paste should be smeared on the touchscreen to attract the dog to the apparatus, this step is especially important in fearful dogs, as the apparatus itself as a novel object may be potentially scary. If the dog is familiar with the owner/trainer using shaping when training, and is used to offering behaviours and interacting with objects, as well as knows the "touch" command (used specifically to ask the dog to touch an object with its nose), then this is often the quickest method of training the dog to approach the screen. Shaping involves breaking down a behaviour into tiny increments, and reinforcing the dog at each incremental step until you've achieved the full behaviour. Here the dog is rewarded for approaching the apparatus, then for sniffing the apparatus, then touching, then touching specifically the screen. The use of a clicker device if the dog is familiar with it can speed up training. Generally, we found the shaping technique to work well for the Border collies, as most were already highly trained and familiar with the use of the clicker, and shaping technique. For these dogs, many of them only required one or two visits before performing reliably, and moving onto the next training phase. This method was not suitable for many aged pet dogs, which had no such experience with shaping training methods.

Once the dog is familiar with the touchscreen apparatus, the dog should also be accustomed to the feeding device. The feeding device is necessary to avoid that the dog begins to focus too much on the trainer during training and testing. Some dogs that have never worked with a feeding device may paw or chew the device in an attempt to open it to get at the food they can smell (and in some models, see), inside. In most cases, a short training session with the feeding device is necessary for the dog to learn that food will only be available when the trainer presses the remote (or is triggered automatically by the software); the device emits a beep, the motor turns and the food reward drops into the feeding bowl. For noise sensitive dogs, the volume of the beep can be lowered, or even turned off, and can be slowly increased as the dog becomes accustomed to it. Some dogs may find it very hard to inhibit standing/lying next to and/or manipulating the feeding device to the extent that it can be very hard to lure them away. In these specific cases, we recommend that the feeder be placed inside the touchscreen housing, and only the dish at the bottom (where the dispensed treat appears) should be available to the dog. Once the dog has no problem with approaching the apparatus, and is familiar with the feeding device the software program should be initiated. Some dogs needed only one visit to reach this point, others needed two.

Phase 2 Touch a stimulus on the screen (fixed location)

In the approach training, which consists of the presentation of a single stimulus, when the stimulus is touched, the infrared light grid on the touchframe is interrupted, which triggers an acoustic signal and, in the case of an automated system, the delivery of a food treat. The training requires that the dog learns the association between touching the picture – and gaining a food reward. From our experience of testing dogs with many different picture stimuli, and from the dog's visual capabilities, we have determined that a stimulus with a roughly circular global shape and blue and yellow in colour is particular eye catching for dogs, and serves as a good starting stimulus. For dogs familiar with shaping and the touch command, in a final step, the dog can be rewarded for touching the stimulus on the screen. The finger can be used to lure the dog to the screen, and to get it to touch the screen in the correct location. Luring is by far the easiest method of teaching the dog to touch the stimulus. However, it took us some time to perfect the technique, and avoid that the dog becomes too focused on the trainer, or on the hands. Luring and shaping were also used in Zeagler's study to train service dogs to use touchscreens in a tapping task [65]. Zeagler found that the luring approach was less effective than shaping, as the dogs did not associate the completion of the task with the reward, as they focused instead on the screen where they expected the reward to appear. To help combat this problem we recommend the following procedure as the quickest and most efficient method to train aged dogs to utilise the touchscreen.

Once the single stimulus (here the blue flower) appears on the screen, the trainer stands to the left side of the touchscreen (facing away from the screen), takes a blob of paste onto his/her right index finger, and then with the left index finger should reach over and touch the edge of the touchscreen. Next, the trainer uses his/her right index finger to smear the paste directly on top of the stimulus. By touching the edge of the screen with the left hand, the trainer ensures that when the right hand touches the stimulus, it will not trigger the touchscreen to activate a correct choice. After placing the paste on the stimulus, the trainer withdraws the right hand, and then the left, and holds their hands behind their back, to avoid the dog being distracted by the presence of the nice smelling fingers. Once the dog begins to lick off the paste from the screen, the tongue will activate the touchscreen, and the computer will register a correct choice and produces a beep, and the stimulus will disappear. At which point the feeding device is activated (in the case of an integrated system) or the owner/trainer should activate the feeding device via the remote control. In the latter case, the timing is crucial, and the device should be activated as quickly as possible upon hearing the beep from the computer. Effectively, in this phase the dog is rewarded twice, once when licking off the paste and the second time by the feeding device. Therefore, we can avoid that the dog focuses only on the screen or the reward, but learns that the action of touching the screen also results in a reward from a separate location.

Now that the dog is familiar with the feeding device, the best position for the device can be determined during this phase, taking into account the physical ability of the dog. For some dogs, placing the feeder a few meters away can provide some much-needed additional exercise, helping to increase the dog's activity level, and has the added benefit of giving the extra seconds required for the dog to view the stimulus before reaching the touchscreen, and therefore may touch more precisely. Other dogs, which have specific mobility problems, can be helped by placing the feeder close by or even under the touchscreen, and the device can additionally be raised up, so the dog does not need to lower its head to the ground. The touchscreen can be operated by the dog from a sitting, or even a lying position if necessary, for those dogs with chronic pain and mobility issues.

In the first instance, it may be necessary for the trainer or owner to point to the location of the dispensed treat, to assist the dog in finding it. While the dog is eating the food reward, the trainer can immediately repeat the process of touching the screen with the left hand, and applying the paste with the right onto the new stimulus presented on the touchscreen. The dog will begin to learn to associate the beep and the sound of the feeder with the food treat. However, some time is necessary for the dog to learn the routine of first licking the screen, and then looking for the food reward. In general, most dogs were able to pass this stage in several visits, but occasionally some older dogs needed three visits.

Phase 3 Touch a stimulus on the screen (varying locations)

In a slight change to the approach training, the position of the stimulus is randomly alternated between the left of centre and right of centre positions. The same training technique as detailed in Phase 2 can be implemented. Once the dog learns to touch precisely the stimulus, the trainer can slowly reduce the amount of paste that is applied to the screen, until the paste is no longer necessary. At this point, the dog generally switches to a nose press, instead of a lick. The movable doors at the front of the touchscreen should be slowly closed, to ensure that the dog stands correctly, and to minimize outside disturbance. Several visits may be necessary to reach this stage, but if the dog becomes confused, and does not offer the correct behaviour after prompting, the use of the paste can be reinitiated until the dog reliably executes the touch action, and immediately goes to the dispenser to receive a food reward. By the end of the Phase 3 training, the dog should successfully complete one session (30 trials) with no help from the trainer. In our experience, the aged dogs needed an average of three visits to reach this criterion. Therefore, in total from Phase 1 to completing Phase 3 aged dogs required around seven visits (range = 1 – 15). All dogs were able to complete the approach training, and then moved on to the next training phase, a two-choice discrimination.

Phase 4 Discrimination training

In the final training step, using a forced two choice procedure (which just means that the dog must press one of two possible stimuli), the software presents one positive picture stimulus (S+) and one negative picture stimulus (S−), positioned randomly on the left and right side from trial to trial (for an example, please see Figure 2 and 3). When the positive stimulus is touched, both stimuli disappear, a short tone is emitted by the computer, and a food reward is provided. If the wrong stimulus is touched (S−), both stimuli disappear, a short buzz sounds, and a red "time out" screen is presented for three seconds. In this case, a correction trial is immediately initiated: the stimuli of the previous trial are presented again in the same position as previously. If the dog makes a correct choice, the trial terminates and results in a food reward and the presentation of a new trial. A second incorrect response results in a further correction trial. After each trial (with the exception of correction trials), an inter-trial interval of two seconds is initiated where an empty white background is presented. In order for the dog to learn the difference between the positive and negative stimuli, both positive feedback (tone and treat) and negative feedback (short buzz, red screen and three second time out) are necessary.

Figure 3. A Border collie working on the touchscreen in the two choice discrimination

The dogs' task is to discriminate reliably between the two stimuli. We set an arbitrary criterion (20 or more correct choices in 30 trials (66.7%) in four out of five sessions) for moving onto the next training phase. When this task is first initiated, the dogs may become confused and unsure of how to respond. Indeed many dogs tried to touch in the middle between the stimuli, or tried to touch both by sliding the nose across the screen. The first few times the dog touches the negative stimulus can cause a measure of frustration to the dog when the action does not produce the expected food reward. Help from the trainer/owner is often necessary to get the dogs to continue touching the stimuli, for example, verbal encouragement to approach the screen and touch, and occasional pointing. The dog may also attempt to use strategies other than discrimination to solve the problem, such as always choose the stimuli on the left, and when incorrect choose the right stimuli, or a win-stay lose-shift strategy. Some dogs can benefit from extra time to process the stimuli, so here the feeder may be moved further away from the screen, or the trainer may use their arm to prevent the dog from entering the testing niche for a few seconds, to allow the dog to slow down, and view the stimuli. However, the trainer should not block the dog with their arm, or hold the dog by the collar/harness whilst watching the stimulus presentation. It is our experience that the trainer may unconsciously release the dog when it is attending to the correct stimulus, and thereby the dog can use subtle cues from the trainer to solve the discrimination, without actually learning the correct contingencies of the stimuli.

Eventually the dog will learn the discrimination after a certain number of sessions elapse, depending on the dogs learning abilities. On average, dogs over 6 years took 15 sessions (range = 4 – 40) to reach criterion. Only two older dogs (out of a total of 130 dogs aged above 6 years) failed this training stage, so it is well within the capacities of the majority of senior dogs. Our research indicates that dogs' ability to discriminate stimuli on the touchscreen improves with the training of new additional stimulus pairs (publication pending). However, the dogs are heavily influenced by the characteristics of the stimuli themselves, such as brightness, colour, contrast, and luminosity. We are currently researching, which stimulus properties the dogs attend to in two-choice discriminations. The touchscreen apparatus and software offers an almost limitless opportunity to examine the cognitive capacities of dogs. Once they master the pre-training, then many of the dogs moved onto more difficult tasks, such as categorization [43], face discriminations [41], emotional discriminations [2,37], numerical discriminations [42], and inference by exclusion (a kind of fast mapping, exemplified by Ricoh, the Border Collie [19]) [1,60].

OWNER FEEDBACK

To assess the user requirements and experience (UX), the trainers of the dogs spoke to the owners regarding their dog's progress as well as their expectations, during every weekly visit. Initially many owners were sceptical regarding whether their dogs were capable of learning the touchscreen paradigm, especially the owners of aged dogs. However, all the owners were interested in the studies and motivated to participate. Some owners travelled for over an hour by car to reach the labs, and some even came twice a week. After several visits, the owners were often amazed to see how well their dogs were progressing, and the enthusiasm of their dogs, when they began to anticipate their weekly training sessions. Many owners referred to their dogs as computer geeks and were quick to express the fact that they believed their dogs enjoyed participating in the study. So much so, that there was a low drop-out rate (around six dogs in total), despite the fact that for some dogs, the full training and then testing in more complex tasks lasted over a year, and owners were not compensated for participating. The positive association to the touchscreen is so strong that on several occasions when the dog was alone (the trainer had stepped out to answer the phone), and the feeder failed, dogs continued to work on the touchscreen with no reward until the end of the session. Additionally, several dogs were trained on the touchscreen when they were younger, and then had substantial gaps of between 3 and 7 years, before they returned to the lab for a new study. These dogs not only remembered the touchscreen procedure, but also in several cases recalled the correct stimuli on a discrimination learnt over three years previously.

Watching the dogs learning on the touchscreen was illuminating for the owners, as it revealed much about the dogs' character regarding the strategies they used, and had the added bonus of tiring the dogs out mentally. After the training when the dogs returned home, many of them fell into a restful sleep, similar to that after a bout of exercise. For many owners this mental tiredness was a new concept, and stimulated them to try other mind games to play with their dogs on days when the dogs were not trained on the touchscreen. Owners received a certificate when their dog completed the training, and many of the owners framed it and placed it on display in their homes. We have no doubt that participating in the studies improved the dog-owner relationship, as reported via personal communication with the owners. However, we should point out that the dog-owner relationship was likely already quite positive, as the study was voluntary, and was likely to attract highly motivated owners. Studies are currently underway to analyse owner questionnaires designed to identify dogs' behavioural responses to touchscreen training.

THE ETHICS OF DOG-COMPUTER INTERACTIONS

A welfare centred ethics framework in ACI research has recently been proposed by Mancini [26]. A review of the aims of ACI (to improve welfare, benefit animals, and improve the human-animal relationship) as well as the potential harms and benefits was carried out by Grillaert and Camenzind [13]. They suggested that there is a need for greater focus on data collection, the long-term implications of ACI use, assessments of how it may influence animal time budgets, and the importance of preference tests. To address these issues, in the future we would like to implement video behavioural analysis, owner questionnaires, and dog activity monitors in long-term touchscreen studies.

We are aware of the fact that for certain personality and/or breed types, interacting with the touchscreen might induce anxiety, over-arousal, or other behavioural changes that might cause welfare issues for the individual or harm the human-animal relationship [57]. In our experience adverse reactions to the touchscreen paradigm were very rare, however, three dogs (1.5% of the sample) showed increased vocalizations, and/or a measure of frustration (such as pawing at the touchframe, excessive panting, turning or walking away from the apparatus) when presented with the second pre-training step – the two-choice discrimination. We interrupted training immediately if we detected signs of distress or undue frustration. After a break, the trainer attempted to give extra help to these dogs to learn the new procedure, and reduce their negative behavioural reactions to the fact that touching one of the stimuli resulted in no reward (for example, by initially covering the negative stimulus with a piece of card). If stress signs re-emerged, then continuation in the program on a later occasion was discussed with the owner. Therefore, we should emphasize that although the majority of the dogs showed only minimal signs of frustration (such as occasional tongue flicks, yawning, or shaking off), for a small proportion of the dogs, the touchscreen paradigm is not suitable. Thus, for successful DCI it is a requirement that the trainer/owner have a good understanding and recognition of the dog's needs, stress behaviours, and learning abilities.

FUTURE APPLICATIONS

So far, the touchscreen apparatus has been used only within lab environments. Apart from one dog trainer, who holds workshops on dog-iPad interaction in the United States [24]. However, with the advance of technology, the development of new applications, and the relatively cheap production of touchscreen and feeding devices, the touchscreen apparatus has the potential to be further developed to produce a working system. An existing laptop could be combined with a monitor and touchscreen overlay (for example from Soladapt "Touch Genie" infrared overlay [50]), and a Treat & Train. The system (not including the laptop) would cost in the region of £350. The touchscreen apparatus could be marketed for use within the dog training community. Trainers at dog's schools could club together to buy the equipment necessary to set up their own touchscreen system. They could offer their services to provide owners with the opportunity for their dogs to participate in cognitive enrichment programs, and could run workshops on how to train dogs to utilise the touchscreen. Owners that are prepared to spend money on this training tool would also have the opportunity to purchase the system to improve their dog's well-being in the home environment. A rent-to buy scheme could be implemented, which would increase the affordability of the hardware, and allow owners to "try out" the system at home after completing an online training workshop/seminar on touchscreen training.

Software and application developers should team up with trainers and cognitive biologists to create new software, which could allow owners to become citizen scientists. This means that data from the dogs' progress on the touchscreen could be uploaded to a cloud on the internet, which would allow the data to become available to cognitive scientists, who could use it to write publications, which would further increase our knowledge on cognition in dogs. Such a system is already in place with the popular science-based games subscription service Dognition [54], that utilises owners to gather information about their dogs performance in standardized behavioural tests. One application programming interface (API) that currently is used to gather public data for scientific purposes is Fitbark. Fitbark has a health baseline database of over 200 breeds of dogs from over 100 countries, which could be used by third party developers to create new web and mobile apps that could be geared towards gathering additional data about the positive effects of cognitive enrichment technology.

The healthy ageing of dogs and the specific needs of the senior dog is slowly becoming more public knowledge, due to an increase in the information available, for example through ageing dog clinics at veterinary surgeries and physiotherapy centres, web resources, magazine articles and dog trainers. The touchscreen apparatus could become an important addition resource to provide cognitive enrichment. However, additional research is necessary to determine whether continued use of the touchscreen results in:

- Increases in aged dogs' positive affect during training (as measured via owner/trainer questionnaire, video analysis of behavioural responses during training (tail wagging and willingness to work), or increases in stress signs (vocalisations, destructive behaviours and avoidance).
- Increases in motivation, and learning, memory and visuospatial ability in subsequent touchscreen tasks, and other cognitive and behavioural tests.

- Changes in dogs' personality as measured via owner questionnaire: increases in trainability, activity and excitability, or behavioural test batteries: increases in motivation, novelty seeking, exploration, and activity, or in the daily environment: Fitbark measures of rest/active and playtime, sleep score, and overall health index.
- Decrease in short-term cortisol measurements and increases in dopamine during touchscreen training (indicating low stress and high motivation) combined with behavioural observations and owner/trainer questionnaires.
- Positive changes in the dog-owner relationship as shown by owner questionnaires, and the amount of time the owner spends active with their dog, which could also be measured using Fitbark/Fitbit.

In DCI studies, we are heavily reliant on owner questionnaires, and since dog owners vary in their experience in understanding and describing dog behaviour, tool such as the Dog Information Sheet (DISH) [16] can be utilised, to generate a more informed interpretation of the dog's feedback by the proxy-observer when using the touchscreen technology.

Intervention studies could examine the influence of the various types of cognitive enrichment (including touchscreen training, and intelligence and manipulative toys), as well as physical enrichment (physiotherapy and owner-dog play), and dietary antioxidant supplementation on successfully ageing dogs, and dogs with separation related anxiety, and canine cognitive dysfunction. Finally, dogs that have been trained to remain motionless in fMRI machines could be taught the touchscreen procedure to examine how their brain processes the touchscreen stimuli to provide more evidence of the cognitive enriching effects of the touchscreen, and to determine at which point the stimuli properties are encoded into long-term memory.

There has been considerable interest in producing technology that can be used by dogs in the home environment, to help relieve boredom and separation anxiety, while their owners are away at work [38]. The touchscreen as it has been described is suitable for use in the home, however, dogs should be supervised during use, as problems with the feeder malfunctioning, excessive saliva on the touchframe, or scratching the touchframe with the paw, can cause the hardware to become unresponsive and could result in unnecessary frustration and stress to the dog. However, once these issues have been addressed, an improved apparatus should allow unsupervised home use in the future after individual piloting by the owners.

CONCLUSION

In conclusion, we believe that the touchscreen apparatus and developed software could potentially improve the welfare of pet dogs and aged dogs in particular, through cognitive enrichment. However, further studies are necessary to determine the effects of long-term touchscreen use on dog personality, activity levels, and measures of well-being, as well as any influence on the dog-human bond. Collaborations between researchers in ACI, dog trainers, and cognitive scientists are essential to develop the hardware and the software necessary to realise the full potential of this training and enrichment tool.

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