Going to the Dogs:

Towards an Interactive Touchscreen Interface for Working Dogs

Clint Zeagler
Georgia Institute of Technology
clintzeagler@gatech.edu

Scott Gilliland
Georgia Institute of Technology
scott.gilliland@gatech.edu

Larry Freil
Georgia Institute of Technology
larry.freil@gatech.edu

Thad Starner
Georgia Institute of Technology
thad@gatech.edu

Melody Moore Jackson
Georgia Institute of Technology
melody@cc.gatech.edu

ABSTRACT
Computer-mediated interaction for working dogs is an important new domain for interaction research. In domestic settings, touchscreens could provide a way for dogs to communicate critical information to humans. In this paper we explore how a dog might interact with a touchscreen interface. We observe dogs’ touchscreen interactions and record difficulties against what is expected of humans’ touchscreen interactions. We also solve hardware issues through screen adaptations and projection styles to make a touchscreen usable for a canine’s nose touch interactions. We also compare our canine touch data to humans’ touch data on the same system. Our goal is to understand the affordances needed to make touchscreen interfaces usable for canines and help the future design of touchscreen interfaces for assistive dogs in the home.

Author Keywords
Animal Computer Interaction; Assistance Dog Interface Design; Touchscreen Interactions; Fitts’ Law

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces---user-centered design

INTRODUCTION
Touchscreens surround all of us. Just as Weiser envisioned they are now ubiquitous in many domains [35]. We interact with our touchscreen phones and tablets constantly throughout the day. We see touchscreen futures promoted in Corning and Samsung videos [5,7] where everything around us becomes an interactive surface. Touchscreens and interactive surfaces work so well and seem so promising because of the research that has gone into creating good touchscreen interactions. A whole segment of HCI research is dedicated to predictive models and human factors associated with on-screen and touchscreen interactions. However, extending this research to working dogs could significantly impact the effectiveness of assistance dog communication.

Recent work has shown that assistance dogs can interact with wearable sensors on their vests to provide important, potentially life-saving, information to their handlers [13]. In the home, however, most assistance dogs do not wear their vests, for comfort reasons. Touchscreens could provide a viable alternative to wearable sensors for assistance dog communication.

Assistance Dog Communication
Since formal guide dog training began around 1918, assistance dogs have improved the lives of many thousands of people with disabilities [3, 30]. Dogs can work in many ways: guide dogs serve people with visual impairments; service dogs aid people with physical disabilities; and hearing dogs alert people with auditory disabilities to sounds (Figure 1). These highly trained canines can provide independence from human assistants and significantly enhance quality of life. However, communication between human and canine partners is limited. Handlers give verbal or hand signal commands, and dogs respond with trained behaviors, which can sometimes have ambiguous meanings to the handlers and to others around the handler.

For example, imagine that Sam, who has epilepsy, is hosting a dinner party for his colleagues, most of whom do not know that Sam is epileptic. Sam’s medical alert dog, Gilbert, is loose in the house, helping Sam to greet his guests. A short time into the party, Gilbert detects that a seizure is imminent, before Sam or his or dinner guests can know what is happening. Gilbert nudges Sam to alert him, but Sam is so intent on greeting his guests he does not

ACM 978-1-4503-3069-5/14/10…$15.00.
http://dx.doi.org/10.1145/2642918.2647364

realize he is about to have a seizure. If Gilbert could walk to a touchscreen mounted on the wall in the living room, and touch a sequence of icons with his nose, he could send a clear and direct message to Sam's cell phone, as well as Sam's wife's cell phone, and possibly even call 911. Sam could get the help he needs before the situation becomes life-threatening.

Hearing assistance dogs alert their handlers to sounds by physical contact, such as nudging with a nose or paw, and then leading their handler to the source of the sound [3]. However, if a dog could tell his handler immediately whether the source of the sound was the doorbell or the tornado siren, the handler could make better decisions about how to respond. Improving dog-to-handler communication could have profound implications for assistance dog teams.

Figure 1. (Left) Guide dog and handler [30]; (Right) Hearing dog and handler [3]

Our previous work [13] shows that dogs can operate sensors based on their natural abilities of biting, tugging, and nose touching [10, 16]. These on-dog-body interactions are appropriate for typical service dogs accompanying their handlers outside the home, but service dogs often do not wear their vests in their home environments. However, if an assistance dog was at home without his communication-enabled vest on, he could still easily walk up to a touchscreen interface and make a selection combination sending the *Tornado Alarm* text to his handler's smart phone. These life saving use scenarios indicate why it might be important to extend touchscreen interfaces to working dogs.

This study explores the research question of whether dogs can effectively make selections using touchscreens, and proposes some possible design guidelines for canine touchscreen interfaces. Does a dog have the ***ability*** to interact with his/her own touchscreen computer in the house? If a dog had a touchscreen at his level and was trained to use the touchscreen to make selections, what would those interactions look like? What ***distances*** and selection ***target sizes*** should the interface have to conform to a dog's needs? How long will a dog interact with a touchscreen before becoming ***fatigued*** and what ***other insights*** might we gain from the data collected by touchscreen interactions from the dogs interacting with them? Do the prevalent predictive models, which designers use to create touchscreen interfaces for humans have any correlation when designing for dogs? Basic foundation theory is needed to help ground this field of dog-computer-interaction, based on previous work in human-computer interaction.

BACKGROUND AND RELATED WORK

Animals have operated machines since the time of Skinner in scientific experiments [31]. However, here we wish focus on improving the affordances of devices for Animal Computer Interaction (ACI), as opposed to focusing primarily on animals using machines in an aid to understanding animal cognition [6, 26, 29]. Amundin et al. [2] explain a very interesting system for dolphins to interact with using echolocation, like our system it is a type of touchscreen. Amundin's was built to work with dolphins, and tested to provide insight into how dolphin might best use a touchscreen system.. In Mankoff *et al* [18], researchers describe a "Fitts' Law" test consisting of throwing a tennis ball to a particular location to gauge speed of access; however it does not report results for this study, but does start to think about canines using computer interfaces. Other researchers have explored novel approaches to animal interactions. Games such as "Cat Cat Revolution" [20] and "Feline Fun Park" [37] allow humans to play with cats mediated by computing. The "Canine Amusement and Training" (CAT) system focuses on games as a way to teach humans to train and interact with dogs [36]. Remote interaction systems allow a human to monitor, care for, and play with their pets at home when they are away [12, 15, 18]. Researchers have trained an assistance dog to take commands from a speaker worn on his body [28]. While some of these studies support handler-to-dog communication or monitoring, they have not fully addressed dogs activating interface devices.

DOG TOUCHSCREEN INTERACTION ABILIITY

To be able to understand a dog's ***ability*** to interact with a touchscreen interface, we designed a touchscreen system and application for dogs which we also hoped we could compare to human interactions.

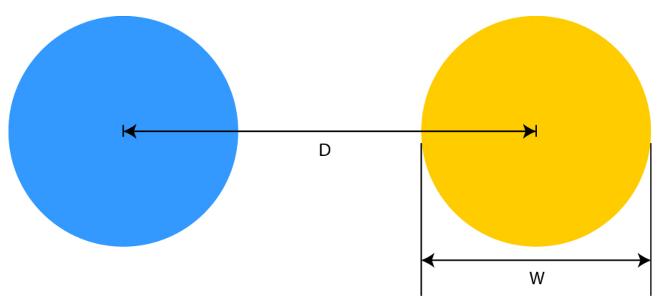

Figure 2. Tapping targets were chosen to be circles, both the distance between the centers of the target and the width of the targets are important.

We modeled our dog touchscreen interaction system and study after a Soukoreff and MacKenzie's *multidirectional* *tapping task* [32]. Circles were chosen as our tapping targets to ease the target selection analysis; with oblong or irregular shapes it becomes more difficult to understand the dog's selection intention. By using this type of study we are able to compare a set of dogs' interactions to a set of humans' interactions more effectively.

We wrote a Java program to display the targets in a series of sizes and distances. The sizes and distance selections can be controlled and changed by the dog handler before administering the interaction test to the dog (Figure 4). The program can also change the angle of targets displayed.

One circle-tapping target is blue and the other circle is yellow. Dogs are not completely colorblind as many people believe, but they do have difficulty seeing the difference between red and green [19]. Yellow and blue are the colors they can most easily differentiate. On a spacebar keystroke, both the blue and yellow circle targets are displayed to the dog at the same time on a large touch surface. We measure the time for the dog to touch the blue and then the yellow circle target with his nose. We also measure where on the screen the dog touches, even if the dog misses the target. In this way we can collect the target distance, target time, target selection speed, and location of selection.

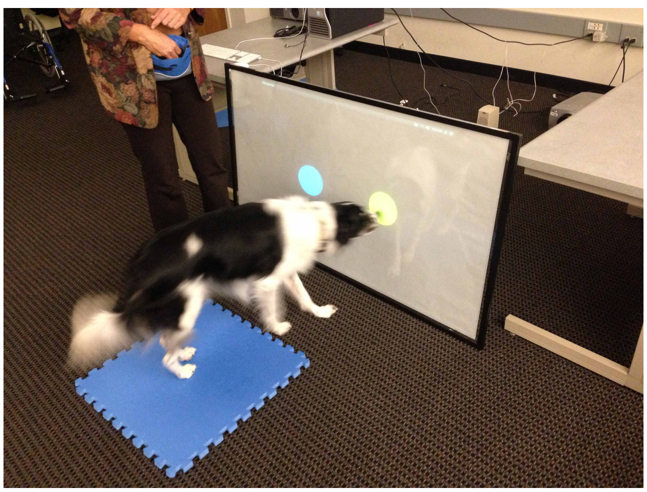

Figure 3. Dog user selecting the yellow dot after first touching the blue dot with his nose.

The location of selection is important to record because humans, through the years of target selection studies, have been found to 'optimize' when targets are large and close together. We touch the inside of the closest edge of tapping targets.

The reason for training the dogs to perform a color picking order is so we can also test for directional effect on interface difficulty. It is important that as the targets move around the screen the dog knows which target to choose first and which to choose second.

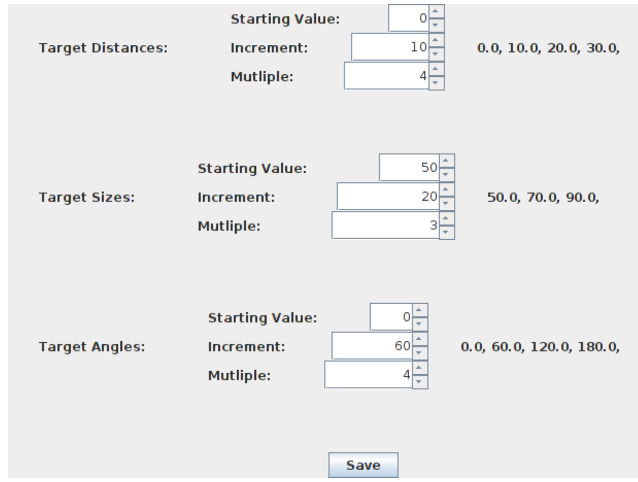

Figure 4. The configuration screen allows the test administrator to choose which target distance variations, target size variations, and target angle variations to cycle through and what multiple to cycle through.

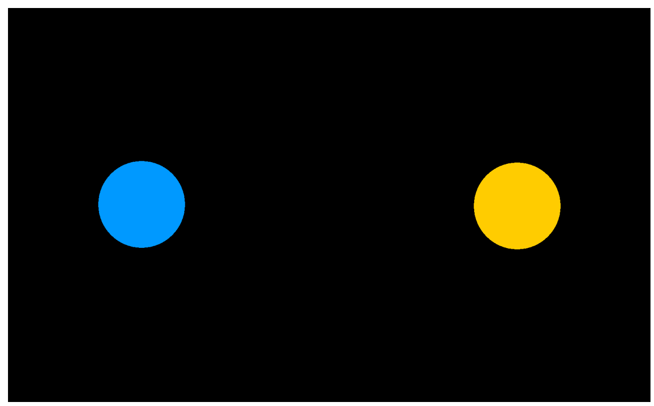

Figure 5. The dog is presented with a blue and yellow dot on a black background. The dog first selects the blue then yellow target with his nose.

Touch Surface, and Projector / Display Selection

The hardware used in building a touchscreen interface for canines has great influence on the dog's ***ability*** to operate the system effectively. Dog saliva and nose moisture matter. The first touchscreen we selected, like most current touchscreens, was a capacitive touchscreen. Moisture from the dog's nose or mouth that remained on the screen from the tapping task also has a capacitive change effect on the screen, thus holding the mouse cursor in the location of the dog saliva. Because of this effect it was not possible to use a capacitive touchscreen for our study. The next touchscreen we attempted was an ultrasonic touch screen, which also had the same issue. Finally we were able to find and use an infrared touch surface. The dog was able to leave moisture on the infrared touch surface without altering his ability to make selections.

To run our study we used the infrared touch sensor mounted to a surface made from glass. We began by using rear projection to produce the visual image the dog was selecting (Figure 3). When selecting a projector we first selected a color wheel style projector. This type of projector creates colors by flashing RGB (or other colors) in series through a grey-scale LCD faster than the human eye can detect. Thanks to the persistence of vision in the human eye, these images blend together to form a single color image. The dogs that interacted with this projector seemed to have difficulty finding the yellow tapping target consistently. We believe this is because the dogs may have seen the red/green flashing instead of a solid yellow target. We then switched to a 3-LCD projector with a constant color projection over time, and the dogs seemed to find the yellow target much easier. While we never pinpointed any problems to this display, we were concerned that the wavelength of the light coming from the projector's gas-discharge lamp might be perceived differently by the dog's eye, as dog's color vision is more or less sensitive at different wavelengths than humans.

As a result, our final system included a 60" LED flat screen television for the display. (Figure 6) The television works much better and the brightness of the tapping targets are now much easier to view in a lighted room. Additionally, we confirmed that the backlight is a smooth curve across all wavelengths, so the dogs should perceive the colors equally well. We began our study after building a rugged secure frame and stand to hold the touch surface with the television.

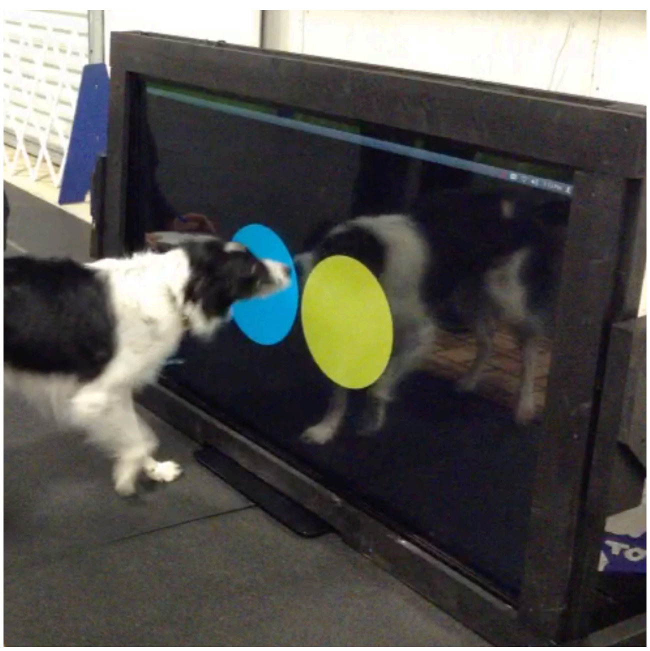

Figure 6. Infrared touchscreen held within robust mounting in front of 60" LED television.

TOUCHSCREEN INTERACTIONS

Much HCI research has been done in how humans interact with touchscreens. Potter, Weldon, and Shneiderman describe three main ways interfaces can be designed to accept touch interaction. [23]

Land-on, where the curser is under the touch, and only the first impact point counts. [23]

First-Contact, where the cursor is under the touch, but the first contact with the target counts even if its not the first impact with the surface. [23]

Take-off, cursor is offset, and selections are made by where the touch lifts off the surface. [23]

We chose to use a *first-contact* model for this round of dog touchscreen interaction experiments. To be able to train the dogs efficiently we believed the *land-on* type of interaction might initially be too strict and difficult for the dogs to be able to offer. We also did chose to initially stay away from the *take-off* interaction style because it would be hard to use other predictive models to compare this interaction type to humans.

To be able to compare our findings with canines to humans we decided to look at the data we collected from our testing apparatus through the lens of Fitts' law.

Soukoreff and MacKenzie [32] state:

"Fitts' law (1954) describes the relationship between movement time, distance, and accuracy for people engaged in rapid aimed movements. It has been verified over a wide range of conditions. Of interest to HCI researchers is that the law applies to pointing and dragging using a mouse, trackball, stylus, joystick, and touchscreen. Fitts' law has been applied by HCI researchers as a predictive model."

Computer interface designers use Fitts' law when developing interfaces for human interactions. Understanding and predicting the load and difficulty of using certain aspects of an interface can help a designer lay out the interface to be used more quickly and easily.

$$MT = a + b * ID_e$$

The Fitts' law equation is parameterized by the effective index of difficulty as well as the intercept and slope parameters of a line. The effective index of difficulty can be calculated from movement data collected during an experiment. An interface's parameters can be estimated using linear regression as described by Soukoreff and MacKenzie [32].

$$ID_e = log_2(\frac{D_e}{W_e} + 1)$$

The effective index of difficulty is a log ratio of effective distance between centers of the targets and the effective width of the target. Again, we use Fitts' law as a framework for comparing the dogs' interactions with a set of humans' interactions, and not as a definitive statement about how dog interactions should be measured.

Dog Training method

Although we initially trained several dogs, we selected three subjects to completely train for testing. All the subjects have had previous training in targeting (touching the handler's hand or a specified target with his nose). Dog1 and Dog2 are agility dogs, and Dog3 has been previously trained as an assistance dog. The dogs have already been trained with operant conditioning techniques [31], specifically *shaping*, which is building new behaviors by selectively reinforcing behaviors the dog offers [24]. For the experiment, we only used positive reinforcement (R+); we did not employ any type of correction or punishment.

We classically conditioned [22] the dogs with high-value reinforcement (food) to a tone generated by a computer. This tone became a "reward marker" that allowed the dog to know when he had accomplished the dog interaction test task. By marking desired behaviors with the tone at the moment of execution, we shaped the dog towards the final interaction goal.

This dog touchscreen interaction task is a complex series of behaviors, so initially we subdivided the task, teaching the dog to touch the blue dot (reward was given when the tone sounded) and the yellow dot separately. Canines sense objects with sight, touch of their whiskers, and scent. As the virtual "objects" on the touch screen can only be sensed with sight, we needed to teach the dog to interact with only sight. The dog was rewarded for first touching the screen with his nose, then for seeking out the dot shape to touch with his nose. The dots on the screen sometimes cannot be easily seen at close proximity, so the dog started his task sitting on a mat (Figure 3 & 7) approximately two feet from the screen to help him locate his targets.

Once the dog understood the task of touching a dot with his nose, we trained him to touch the dots in sequence with *backchaining* [24]. Backchaining is a shaping method that teaches the dog to perform a complex task ("behavior chain") with multiple behaviors by training the last behavior first, then adding the next-to-last behavior, and so forth. We began with teaching the dog to place himself in the correct position on the mat. Then we added touching the yellow dot with his nose. When the dog was proficient with that simple behavior chain, we taught him to go to his mat, then touch the blue dot, then the yellow dot, and return to his mat for reward. Through a *variable reinforcement schedule*, we increased the dog's speed by rewarding only when he touched the blue then yellow dots quickly and in sequence.

When the behavior chain was confirmed, we began the dog interaction testing sessions, varying the size and distance of the dots. The dogs understood the new requirements of the task without additional training, locating each of the dots as quickly as possible. We tested the dog in sessions of no longer than 15 minutes, with at least 30 minutes rest in between sessions.

EXPERIMENT

For this initial exploration we tested three dogs. Two were border collies previously trained as agility dogs and one was a labrador retriever trained as an assistance dog. We try to avoid making claims with this limited dataset but feel that the observations and challenges to date are of sufficient value to report.

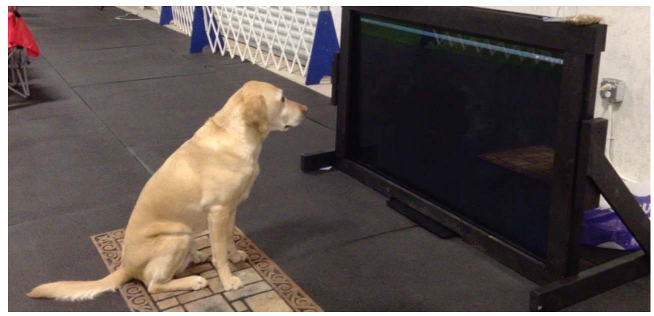

Figure 7: Dog 3 waiting for the handler to turn on the interface.

The dogs completed 15 runs. ***Runs*** were defined as a set of 16 tapping target size and distance combinations. Each individual ***tapping task trial*** was defined as selecting the blue then yellow target. So each run contained each of the 16 tapping task trials, which were displayed to the dog in a random order. A ***session*** was defined as any number of runs performed at the same sitting or general time period. Most dogs could complete 3-5 runs in one session before becoming tired of the task. At the end of 15 runs the dogs have completed each of the 16 tapping task trials 15 times. Every session was video recorded to be able to compare anomalies in the data with what happened in the actual session.

Target Distance Between Circle Edges	
20 pixels	½" (~13 mm)
120 pixels	3 ¼" (~82.5 mm)
220 pixels	6" (~152.5 mm)
320 pixel	8 ¾" (~222.25 mm)

Table 1: Actual Target Distances as measured from the 60" LED touchscreen.

Each tapping task trial consists of one nose press on the blue target, zero or more erroneous touches, followed by one touch on the yellow. When the dog makes a correct selection, first hitting the blue target, a lower frequency tone is played to signify to the dog he/she has made the blue selection. After selecting the blue target if the dog selects the yellow target a higher frequency tone is played, and the targets disappear from the screen upon lift off of the successful yellow target touch, signifying that the dog has completed the task. For each touch, we record the time that the dog nose first contacted the touchscreen and the time the dog nose leaves the touchscreen. For the purposes of comparing to Fitts' law, we consider the ***task time*** between touches to be the time between the dog's noses first correctly contacting the two targets, ignoring erroneous touches.

Target Diameter	
100 pixels	2 ½" (~63.5 mm)
200 pixels	5 ½" (~140 mm)
300 pixels	8" (~203 mm)
400 pixels	10 ¾" (~273 mm)

Table 2: Actual Target Sizes as measured from the 60" LED touchscreen.

The times and distances are measured by the software displaying the targets to the dog, and actual distance and target size are automatically recorded with the timing data. We measure target distance as the distance between the target centers, and we measure the target width as the diameter of the targets. The program developed to display the targets uses the inside edges of the circle targets to determine distances. Therefore, if the program is asked to display four different distances, it will display these as the distance between the circle edges. Once the different sizes and distances are selected the program will display them in a random order. Our distances were originally collected in units of screen pixels. For the purpose of reproducing the study the converted sizes and distances used can be seen in Tables 1 and 2. During training sessions we have seen that at least one dog has the ability to follow the changing angle and learned to select blue then yellow, but for the purposes of this study we decided to start with just researching a horizontal dog interaction.

To be able to compare a dog's interactions with a human's interactions we also asked three people to complete the same tapping task trials in the same way on the same system. We asked the humans to complete the tapping tasks as fast as possible.

RECORDED AND OBSERVED INTERACTIONS

We recorded the locations and timing of all interactions on the touchscreen while the tapping task targets were displayed. Figure 8 shows a human's interaction with the touch screen. All 15 tapping task trials' touch interactions for distance 120 pixels and size 300 pixels are shown on one diagram. The blue and yellow circles are representative of the tapping targets that were on the screen when the touches were performed. The green dots represent where a successful first touch was made to select the blue target. The red dots represent where a successful second touch was made to select the yellow target. Green lines passing through green dots (as in Figure 9) indicate drags on the touch screen, which triggered a successful blue target selection, whereas lines intersecting red dots indicate drags taking place after a successful yellow target selection. Orange lines indicate a drag, which left the blue target and continued dragging until successfully selecting the yellow target. Grey X's indicate erroneous touches, which did not activate any targets.

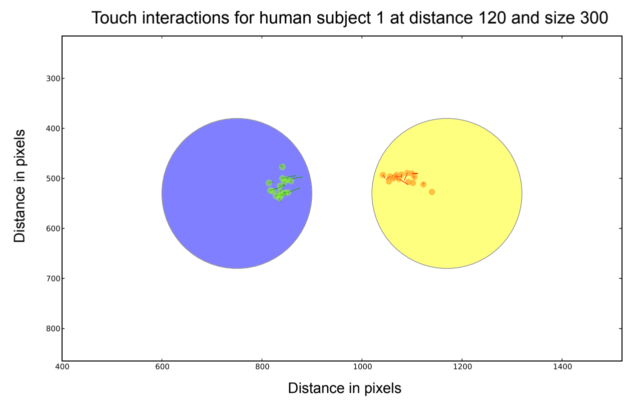

Figure 8. Example diagram of recorded touchscreen interactions from Human 1. Green dots are the first successful touch; red dots are the second successful touch.

Notice in Figure 8 when asked to perform the "tapping task" the human tapped and lifted his finger without any intentional dragging. We can also see the human intentionally touched the inside edges of the targets to be able to select them as quickly as possible.

Each dog participant developed different strategies to be able to select the targets as quickly as possible. Two of our canine participants (both the agility trained dogs) commonly selected the blue target and then dragged into the yellow target. As can be seen in the example in Figure 9, Dog1 and Dog 2 (not shown) selected the inside edge of the blue target and then dragged directly into the inside edge of the yellow target. This strategy was particularly common when the target separation distance was small. The dragging selection was made possible because we chose the *first-contact* interaction model [23].

This dragging significantly changed the type of interaction the dogs had, and occurred because of the way we presented the task to the dogs. To them, any interaction that got the software to 'beep' was good enough, as the 'beep' was their reward marker. Since our software allowed drags into, out of, and between the targets, the dogs had no incentive to perform very precisely.

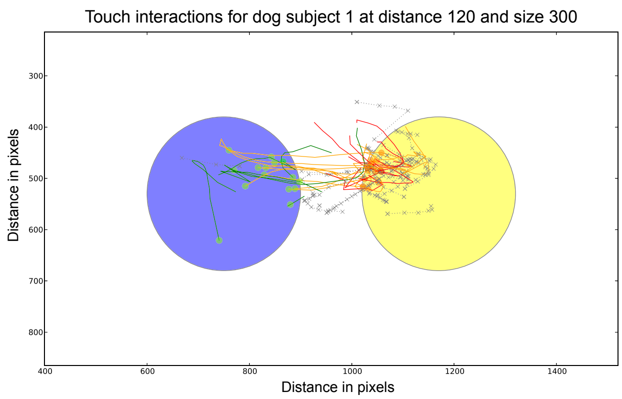

Figure 9. Example diagram of recorded touchscreen interactions from Dog 1. Green dots are the first successful touch, red dots are the second successful touch. Green lines are drags from the first touch, and orange lines are drags from the second touch.

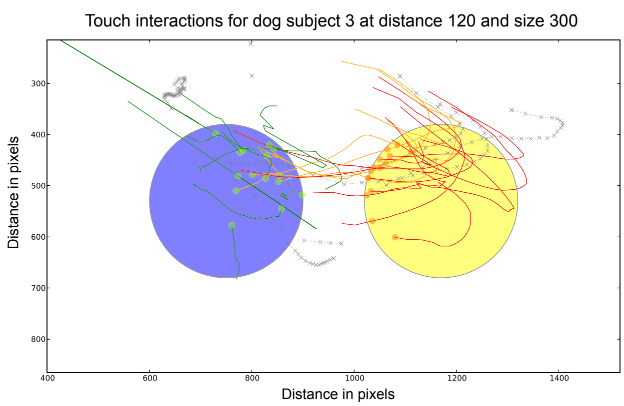

Figure 10. Example diagram of recorded touchscreen interactions from Dog 3.

Accordingly, the interactions the dogs performed in these cases were closer to the discrete orthogonal goal-crossing or continuous orthogonal goal-crossing task as defined by Accot and Zhai [1]. It would certainly make for a more accurate system to use the *take-off* model of interaction [23], but this approach would also make it harder to use our Fitts' Law comparison.

Dog3 was trained as a wheelchair assistance dog. He had a much more methodical approach to selection. Figure 10 shows he did not drag to select nearly as much as his agility dog counterparts. He also lingered longer on the screen after the selection. After his yellow selection he always looked back up slowly to the trainer for approval, and this behavior can be seen in the red trails following the orange selection circles on the yellow target.

The dogs' selections are not as consistent as the humans' selections, and there are many more erroneous touches. Some of these extra or mistaken touches can be explained by the dog's fur. As the dog nears the touch screen, the infrared detectors pick up anything that passes through its detection plane, about 1/8" (3mm) from the surface of the glass, including the dogs' fur. Using a capacitive screen could solve this problem, but we have already ruled out capacitive screens due to selection problems associated with dog saliva. There are ways to design for the addition of some erroneous touches, and we will cover these in our design guidelines for canine touchscreen section.

RESULTS

The results shown are from the three dogs that participated in our study. Outliers have been removed from the data to make the data easier to read and also more understandable. We removed the outliers by first looking at the data and then comparing anomalies in the data with the recorded video of the sessions. On more than one occasion, the monitor displaying the targets accidentally lost video synchronization and turned off, and this failure accounted for some erroneous task times of up to 96 seconds. These very large task times skewed the results of the data tremendously and were removed. We had a total of 721 tapping task trials of which we pruned out 35 that had more than five seconds between touching the blue target and touching the yellow target. We omitted another 50 tapping task trials that had more than three touches in the trial. In total we excluded 11.8% of the dogs' trial data.

In other trials, the dogs made an initial attempt, missed one of the two targets, and then got distracted or confused by the failure. For example, they might activate the blue target, then miss the yellow, and then try the entire task again, beginning with blue. These instances were obviously not clean blue-yellow interactions, and we felt confident in a decision to remove any dog tapping task which exceeded three touches between activation of blue and activation of yellow, or which had a task time of greater than five seconds.

All of the dogs at some point dragged their noses from the blue target to the yellow target to make a selection; such events are shown as one touch in Figure 11. These one-touch drag interactions create the fastest task times. We have found that our system records a multi-touch press1+press2+liftoff1+liftoff2 interaction as one single press+drag+liftoff. When the distance is very small between the two targets, as it is in our 20-pixel condition, a single dog nose could accidentally trigger such a multi-touch interaction. These multi-touch interactions account for the very short single touch task times.

Figure 12 shows a seemingly improbable finding. Dog2's approximate 200-millisecond interaction at a separation distance of 320 seems suspect, and we determined the cause upon viewing the video. Dog2 began using his nose and paw at the same time to select both tapping targets at once. This agility trained Border Collie (Dog2) found it most effective (quicker) at larger distance target tasks to lunge at the screen with his nose and right paw up. This behavior was hard to extinguish because the system responded by giving him reward beeps, and unlike a human we could not explain to the dog to only use one hand (or his nose) to complete the task. Because we wanted to view the data with instances of quick interaction time and we could not tell the dogs not to drag or use multi-touch interactions, we decided to leave this data in the dataset we used for calculations.

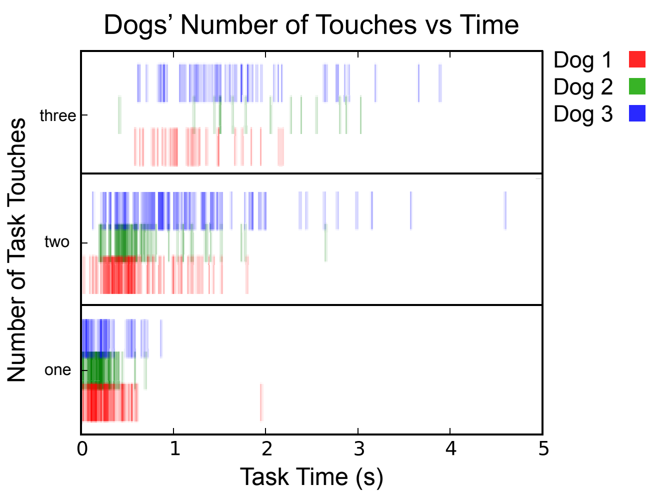

Figure 11 The number of dog touches to complete each tapping task trial versus the time it took the dog to complete each tapping task trial. Each line represents a single tapping task trial colored coded by the dog performing the trial.

When determining effective width for our Fitts' law comparison calculations we chose to use the point where the yellow target (second target) was first activated. It is important to note that on tapping trials where dogs dragged into the circle, this point shows up as an edge or near edge condition. We chose to include these conditions because most of the drags seemed intentional by the dogs as the quickest and shortest way to get from blue to yellow.

To be able to compare the dogs' interactions against a humans' interactions we decided to analyze both the dogs' dataset and the human dataset using Fitts' Law. We are not claiming here that dogs follow the same predictive models as humans, but it is an interesting comparison. Fitts' Law would expect that the graph in Figure 14 and 15 to have linear regressions intercepting the y-axis (time) at zero [32]. However, Soukoreff and MacKenzie [32] expect a good model to fit with an intercept of the time axis between -200ms and 400ms. Our results from our dog trials are only slightly outside this range

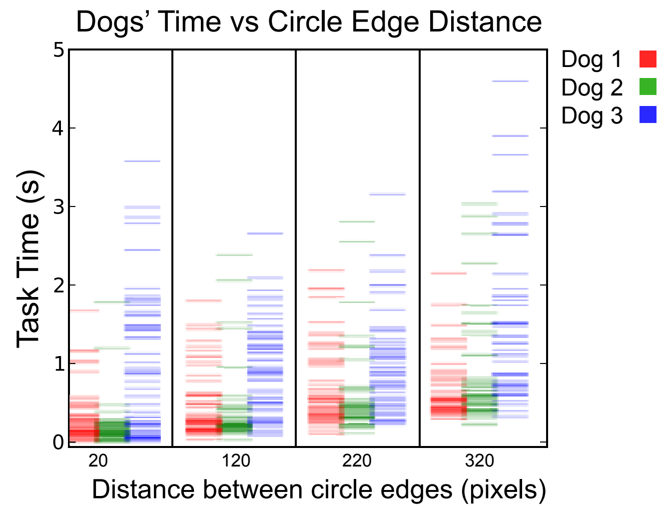

Figure 12 The dog's task time compared to the distance between the inside edges of the tapping targets. Each line represents a single tapping task trial colored by the dog performing the trial.

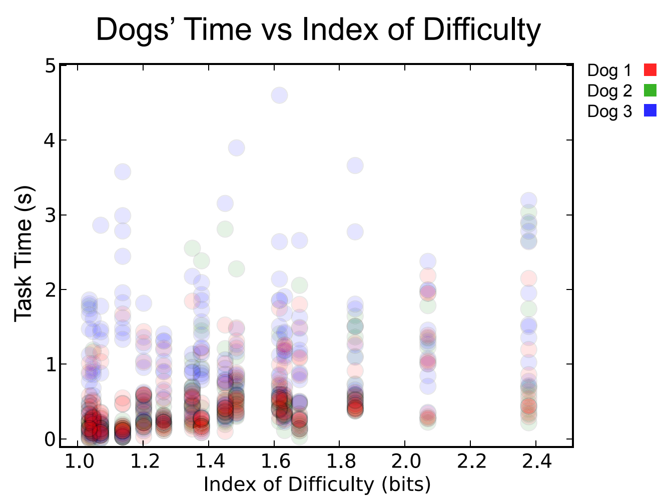

Figure 13 The dog's task time as compared to the displayed target-width's Fitts' Law Index of Difficulty. Each dot indicates a single tapping task trial colored by the dog performing the trial.

By looking at looking at Figure 14 we also see an interesting correlation of the graphed data to the dogs' drive, or eagerness. The dogs' drive levels were described a priori by their owners who train/compete at a national level. "Drive" is a common feature described when seeking appropriate dogs for particular tasks. Unlike with humans who can understand that the task must be performed as fast as possible, with dogs we have to use a motivating factor, such as praise or dog treats. Dog3 who shows the highest times was trained to be an assistance dog and has much lower drive than the other dogs, who are trained as agility dogs. It seems to be possible to view this temperament difference in the graph, although it is very hard to make any claims with only three dogs and no quantifiable way to describe dog drive. If dogs can be trained to perform this task, it might be used in the future as a good indicator of dog temperament and drive.

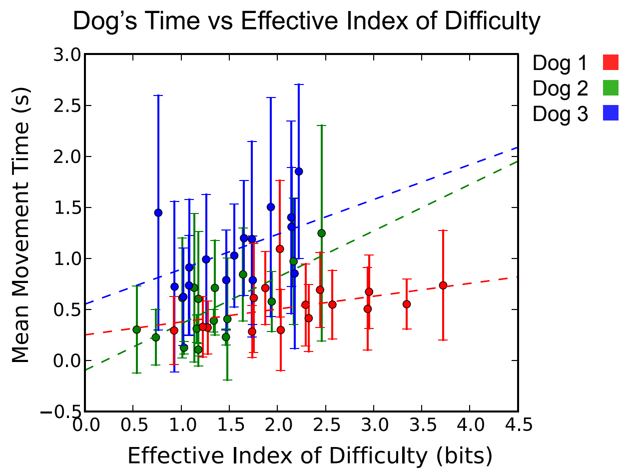

Figure 14 The dog's task time as compared with Fitts' Law Effective Index of Difficulty. Each dot represents an individual participant's average performance for each tapping task trial size/distance.

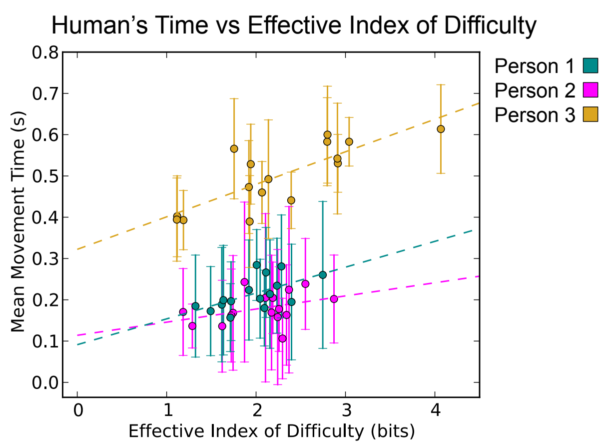

Figure 15 Human's task time as compared with Fitts' Law Effective Index of Difficulty. Each dot represents an individual participant's average performance for each tapping task trial size/distance.

DISCUSSION AND POSSIBLE DESIGN GUIDELINES FOR CANINE TOUCHSCREEN INTERFACES.

We summarize the key points from our preliminary efforts below.

Ability – Dogs have the ability to be trained to perform touches on a screen in response to virtual/displayed shapes. The selection interactions can be somewhat complex. We have seen dogs learn to select first one, then another target. We have observed that dog can devise multi-touch techniques such as near simultaneous nose and paw touches of their own accord. We have also seen all three dogs in our study decide to drag from one selection point to another on the touch surface.

Distance – We found when the distance between selection points is very short, in our case 20 pixels apart, our dog participants had a tendency to select both targets at the same time. This result could be due to the width of a dog's nose, and that dogs, like humans, aim for the inside edge of tapping targets. It seems advisable to place targets, or selection points in an interface further apart so that dogs can make more accurate distinctions between intended selections. Intention here is key; if a dog was trying to call emergency services (911), designers should create interfaces which will account for a large nose or furry face by providing adequate distance between selection points.

Target Size – We noticed that target size was important for our dog participants. Obviously it is harder to hit a smaller target, but in the dogs' case they are also selecting the targets with their noses. We chose this method of selection because dogs tend to use their face and nose as the first method of physical investigation. When a dog gets close enough to make a selection of the 100 pixels (or smaller) target the dog can no longer see the target. With a larger size target (200 pixels or larger) the dog can still see the target in his field of view if he misses and can adjust quickly to make the correct selection. It seems that targets or selection points for dog touchscreen interfaces should be larger than 2 ½", and probably should be 3 ½" or larger. There might be some future work allowing for offset cursor selection with dogs as seen in the work by Cockburn et al. done with humans [4]. The concept of an offset cursor might be outside the understanding of a dog, and harder to train.

Fatigue – From our observation our dog participants were only able to complete at most five runs of 16 tapping task trials in a single session. Towards the end of the last run in each session the dog was less responsive to prompts and seemed slower at the tasks. Dog2 seemed to actually become less patient with the system and would bark at the screen and the handler if he was unable to quickly make a correct choice. The consensus among the handlers and Dog2's owner was that Dog2 was not just physically tired after five runs, but was also emotionally tired and frustrated.

Other Insights – Because we have video of the dogs that performed the tapping tasks and have worked with these dogs before in other studies, we can glean the general temperament of the dogs within this study. It is interesting to compare handlers' observations of the dogs' temperaments with the findings in Figure 14. The lower drive of Dog3 can be seen in his interactions with the touchscreen. Dog1, on the other hand, is highly driven and motivated to complete tasks as fast as possible, and his task times are much lower. Drive is an important indicator for a good assistance dog. Dog 3 (Figure 7) was actually trained, but released as an assistance dog because of low drive. It costs on average $25K to train assistance dogs [3], and if a test could be developed to help predict suitability it could be of great help in saving money for non-profit assistance dog training programs.

Another interesting finding involving dog saliva came during the training sessions for the dogs to use the touch surface. As the dogs were given treats as food rewards for completing portions of the tapping task, the screen started to smell of the treats from saliva left on the screen from the tasks. Some dogs found this stimulus distracting when interacting with the screen. When moving across the screen if they passed over a previous selection spot with strong smelling saliva, the dog would pause to sniff before completing the tapping task. This pause in between taps greatly influences the outcome of the data and produced some of the outliers we have seen in our data. We learned it is important to wipe the touch surface with water between every round of 16 tapping task trials to lessen the saliva sniffing effect.

FUTURE WORK

One obvious next step in our work is to train other dogs and collect more data. It would be interesting to reprogram the system to only allow selection on touch lift-off; this modification would eliminate drag interactions and would more closely match Potter's *Take-off* style of touchscreen interaction [23]. Changing the system in this way might also have drawbacks in that where the dog lifts off the target might not be where he was aiming originally. These types of lift off selections might produce data, which will be inconsistent when trying to fit to Fitts' law, but might be the correct interactions for designing a canine touchscreen. We also would like to collect data on how the angle change of the tapping task affects the dogs' ability to perform the task.

Assuredly dogs of different breeds will perform differently on the tapping tasks, but will they perform in scale and relation to other dogs or does each breed have its own logarithmic scale of performance? We have already seen a difference between a labrador retriever and a border collie. Would we be able to test other dogs in the future to find out which breeds work best with touchscreens? There may be more variables than just intelligence involved; the amount of dog saliva and the length of a dog's fur/hair seems to also affect a dogs ability to interact with a touchscreen. Would a pug with a flat face be able to make selections with its nose as easily as a long snouted dog?

We would also like to create a more realistic interface. A product prototype of a touchscreen selection interface ready to test will make a great case study of our findings here. With dogs now already trained to interact with the touchscreen we can easily produce a system ready for use. We might even be able to place the system within the Georgia Tech Aware Home for a more real world venue our observations [14].

Eventually our research team would also like to look at other classic HCI standards and laws and see if they apply to interfaces that are used by dogs. For example, we might compare dog data to human data with respect to the power law of practice. In this way we can continue to aid and inform the design process of dog computer interfaces.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant No. 1320690.

REFERENCES

1. Accot, J., and Zhai, S. (2002, April). More than dotting the i's---foundations for crossing-based interfaces. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 73-80). ACM.
2. Amundin, M., Starkhammar, J., Evander, M., Almqvist, M., Lindström, K., & Persson, H. W. (2008). An echolocation visualization and interface system for dolphin research. *The Journal of the Acoustical Society of America*, *123*(2), 1188-1194.
3. Canine Companions for Independence. www.cci.org (last accessed 4/16/14)
4. Cockburn, A., Ahlström, D., and Gutwin, C. "Understanding performance in touch selections: Tap, drag and radial pointing drag with finger, stylus and mouse." *International Journal of Human-Computer Studies* 70.3 (2012): 218-233.
5. A Day Made of Glass... Made possible by Corning. https://www.youtube.com/watch?v=6Cf7IL_eZ38 (last accessed 4/16/14)
6. Delfour, F., & Marten, K. (2005). Inter-modal learning task in bottlenosed dolphins (Tursiops truncatus): A preliminary study showed that social factors might influence learning strategies. *Acta Ethologica*, *8*(1), 57-64.
7. Display Centric World by Samsung: Future. https://www.youtube.com/watch?v=ZSn0lnjgFag (last accessed 4/16/14)
8. Fitts, P.M., The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, 47 (6) (1954), pp. 381–39
9. Forlines, C., Wigdor, D., Shen, C., And Balakrishnan, R. (2007, April). Direct-touch vs. mouse input for tabletop displays. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 647-656). ACM.
10. FSR 400 Data Sheet: FSR 400 Series Round Force Sensing Resistor.

http://dlnmh9ip6v2uc.cloudfront.net/datasheets/Sensors/ForceFlex/2010-10-26-DataSheet-FSR400-Layout2.pdf (last accessed 4/16/14)

11. History of Guide Dogs International Guide Dog Federation. www.igdf.org.uk/about-us/facts-and-figures/history-of-guide-dogs/ (last accessed 4/16/14)
12. Hu, F., Silver, D. and Trudel, A. "Lonely Dog@Home", *Proc of the Conf on Web Intelligence and Intelligent Agent Technology Workshops*, 2007, pp. 333-337.
13. Jackson, M., Zeagler, C., Valentin, G., Martin, A., Martin, V., Delawalla, A., Blount, W., Eiring, S., Hollis, R., Kshirsagar, Y., And Starner, T., "FIDO – Facilitating Interactions for Dogs with Occupations: wearable dog-activated interfaces." *Proceedings of International Symposium on Wearable Computers ISWC*, Sept 2013, pages 81-88.
14. Kidd, C. D., Orr, R., Abowd, G. D., Atkeson, C. G., Essa, I. A., MacIntyre, B., and Newstetter, W. (1999). The aware home: A living laboratory for ubiquitous computing research. In *Cooperative buildings. Integrating information, organizations, and architecture* (pp. 191-198).
15. Lee, S. P., Cheok, A. D., And James, T. K. S. "A mobile pet wearable computer and mixed reality system for human-poultry interaction through the internet", *Personal and Ubiquitous Computing*, v.10, 2006, pp.301-317
16. LilyPad Arduino. http://arduino.cc/en/Main/ArduinoBoardLilyPad
17. Mancini, C., van der Linden, J., Bryan, J., & Stuart, A. (2012, September). Exploring interspecies sensemaking: dog tracking semiotics and multispecies ethnography. *In Proceedings of the 2012 ACM Conference on Ubiquitous Computing* (pp. 143-152).
18. Mankoff, D.; Dey, A.; Mankoff J.; and Mankoff, K. Supporting interspecies social awareness: using peripheral displays for distributed pack awareness, in *Proc of UIST*, ACM Press, 2005.
19. Neitz, J., Geist, T., & Jacobs, G., Color Vision in the Dog, in *Visual Neuroscience* (1989), 3, pages 119-125.
20. Noz F. and An, J. Cat cat revolution: an interspecies gaming experience, in *Proceedings of CHI '11*, ACM Press, 2011.
21. Paldanius, M., Karkkainen, T., Vaananen-Vainio-Mattila, K., Juhlin, O., and Hakkila, J. . (2011). Communication Technology for Human-Dog Interaction: Exploration of Dog Owners' Experiences and Expectations. *Proc. CHI 2011*.
22. Pavlov, I.P. *Conditional Reflexes*. New York: Dover Pubs, 1927.
23. Potter, R. L., Weldon L.J., and Shneiderman B. Improving the accuracy of touch screens: an experimental evaluation of three strategies. *Proceedings of the SIGCHI conference on Human factors in computing systems*. ACM, 1988.
24. Pryor, K. *Reaching the Animal Mind*: Scribner, Simon & Schuster, Inc., 2009.
25. Resner, B. I. *Rover@home: Computer Mediated Remote Interaction Between Humans and Dogs.* (Master's Thesis), Massachusetts Institute of Technology, 2001.
26. Reiss, D., & McCowan, B. (1993). Spontaneous vocal mimicry and production by bottlenose dolphins (Tursiops truncatus): Evidence for vocal learning. *Journal of Comparative Psychology*, *107*(3), 301.
27. Sasangohar, F., MacKenzie, I. S., And Scott, S. D. (2009, October). Evaluation of mouse and touch input for a tabletop display using Fitts' reciprocal tapping task. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 53, No. 12, pp. 839-843). SAGE Publications.
28. Savage, J., Sanchez-Guzman, R. A., Mayol-Cuevas, W., Arce, L., Hernandez, A., Brier, L., . . . Lopez, G. Animal-machine interfaces. *Proc. The 4th Intl Symp on Wearable Computing*, IEEE. (2000)
29. Savage-Rumbaugh, E. S. (1986). *Ape language: From conditioned response to symbol*. Columbia University Press.
30. The Seeing Eye. http://www.seeingeye.org/
31. Skinner, B.F. *The behavior of organisms: an experimental analysis*. Oxford, England: Appleton-Century, 1938.
32. Soukoreff, W., And MacKenzie, S., Towards a standard for pointing device evaluation, perspectives on 27 years of Fitts' law research in HCI. *International Journal of Human-Computer Studies*, Volume 61, Issue 6, December 2004, Pages 751-789
33. Teensy USB Development Board. http://www.pjrc.com/teensy/
34. Weilenmann, Alexandra, & Juhlin, Oskar. "Understanding people and animals: the use of a positioning system in ordinary human-canine interaction." *Proc. SIGCHI Conference on Human Factors in Computing Systems*, 2011.
35. Weiser, Mark. The computer for the 21st century. *Scientific American* 265.3 (1991): 94-104.
36. Wingrave, C.A.; Rose, J.; Langston, T.; And LaViola, J.J. "Early Explorations of CAT: Canine Amusement and Training", in *Extended Abstracts of CHI '10*, ACM Press, 2010, pp.2661-2670.
37. Young, J.; Young, N.; Greenberg, S.; and Sharlin, E. Feline Fun Park: A Distributed Tangible Interface for Pets and Owners, in *Video Proceedings of Pervasive*, 2007.