An experiment in Animal Welfare Informatics: effects of digital interactive gameplay on the psychological welfare of home alone dogs

Annika Geurtsen

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Thesis Supervisor: Maarten Lamers & Marcel Schaaf

Abstract

The aim of this study is to explore the possible effects of digital interactive gameplay on the psychological welfare of dogs, which are home alone for extended periods of time. We hypothesize that the presence of a digital interactive game positively influences the psychological state of home alone dogs.

The psychological state of the subjects is measured during a period of 10 days, in which the canines are subjected to 5 days of stimulation by the digital interactive game and 5 days during which an unstimulated situation is measured. In order to assess the psychological state of the canine during the test period, salivary cortisol hormone levels were measured twice daily at set times. Furthermore, extensive video data was collected, from which ethograms were constructed and quantified. The quantified ethogram data is complimented by qualitative observations based on the video material. Results are presented and discussed in the context of canine welfare.

This study demonstrates a venture into the possibilities of improving the welfare of canines that live in an environment where they are dependent on human presence. Furthermore this study provides valuable insights that can advance the design of digital artefacts intended for animal use.

1. Introduction

Canines are social animals, wired for a life in a pack. However, throughout time, dogs have been domesticated [1] and humans have created artificial living environments for canines (amongst other animals that we domesticated) in which they are required to adapt. One of the situations resulting from living in this artificial environment is that dogs are left alone at home during the day, when their human companions are at work. Being a social animal, staying home alone, and thus being isolated from the pack, might have an impact on the well-being of the canine [2]. Social isolation [3] is considered a major stressor for a social species such as canines.

Previous studies on dogs indicate a high level of passive behaviour when being left home alone. Aslaksen and Aukrust [4] have shown that dogs (without separation anxiety) were lying down 95,3% of the time when being left alone at home for between 4 and 9.5 hours. Having another dog accompany the initial home alone dog does not seem to have a considerable effect on the activities of the dog when isolated from his owner. A study by Vestrum [5] shows that when dogs were left alone at home with a dog companion, they would lie down for 83% of the time. A common association made in relation to passive behaviour (such as lying down) exhibited by canines is that it is an indicator of the canine being in a calm and neutral state of mind. This might not always be the case however and assigned meaning of passive behaviour should be considered within the context of the situation wherein the behaviour is exhibited.

Apart from dogs possibly being bored [33], a considerable number of dogs have developed behavioural issues related to separation anxiety. A recent study conducted by Mark Evans for the tv program: "Dogs: Their Secret Lives" [6], shows that from a randomized group of dogs gathered in Bristol, with a total of 40 subjects, at least 10 subjects showed signs of separation anxiety. What is more confronting however is that another 25 subjects, who did not show anxiety issues, but slept or were lying down while their owners were away from the house, had cortisol levels that matched those of the dogs showing separation anxiety. The amount of cortisol has been shown to correlate with the amount of stress a dog experiences [60 – 63]. The lower the average amount of cortisol present in the dog, the less anxious the dog is. In other words, even though these dogs did not show behavioural issues, they were undergoing stress when they were isolated.

A study investigating whether human contact reduces stress for shelter dogs shows that dogs interacting with humans had lower cortisol levels than dogs that did not interact with humans [7]. Tuber et al. [8] found that removing a dog's kennel mate for 4 hours from the dog had no effect on the behavior or plasma glucocorticoid levels. Glucocorticoids are a class of steroid hormones (of which cortisol is one kind) that are indicators that positively correlate with anxiety. When tested in a novel environment, dogs did show elevated glucocorticoid levels at the end of the session, but the levels measured during the condition where the dogs were with their kennel mates were identical to when they were alone. Glucocorticoid levels were however not elevated if the dogs were exposed to the new environment in the presence of their human caretaker. The absence of human presence could allow for a dog to become stressed, and in order to ease the stress, the presence of a human is required.

Humans, like canines, are a social species and isolation from other humans often leaves the individual experiencing negative feelings [9]. Throughout time several solutions to social isolation have been provided. The Internet and applications thereof, such as Facebook or Skype, allow for online social networks, enabling individuals to remain socially connected even when they are physically seperated. Next to purely social applications, forms of gameplay are used to fill in time spent being alone. Online multi-player games, such as World of Warcraft, allow an individual to play games.

Next to using the Internet to connect with congeners, research into robotic companions and/or pets for humans aims to tackle the issues of (social) isolation by simulating human or pet interaction through a technological medium. In this case there is no need for the presence of an actual human being or pet, but the result (not feeling isolated and alone) is the same. Examples are Paro (Parorobots, 2003), AIBO (Sony, 1999) and Tamagotchi (Bandai, 1996). Even though these ventures are undertaken to improve the welfare of humans that are somehow isolated from a social network, research into improving the psychological conditions for canines that live in isolation (for several hours every day) using technology is scarce. Most applications aiming to improve the welfare of home alone dogs, such as SmartDog [10] or PetChatz [11] focus on strengthening the bond between the owner and the dog, by providing direct, live interactions between humans and canines. Providing the canine and owner with the option to initiate contact during separation is a wonderful aim, but we assume trying to solve the issue of canine isolation through these means does not solve the problem. Rather it circumvents the problem by ensuring the canine is not alone.

We assume the anxiety issues developed by some dogs might originate from the fact that the dog is too dependent on the human owner and that allowing the dog to interact without human (owner) interference might improve the dogs welfare and lower anxiety issues. If a digital interactive game is able to entertain the canine sufficiently, the canine may be enabled to become more (emotionally) independent from the human (owner) and as a result might experience less stress and negative emotions when separated from the human.

The research described in this paper falls within the scope of Animal Computer Interaction (ACI) and Animal Welfare Informatics (AWI) in that the researchers aim to foster the relationship between humans and animals by improving the quality of life of the animal (and consequently the human) using technology. The aim of this research is to explore the question: ***is it possible to improve a canine's psychological state during isolation at home, using the presence of a digital interactive game that can be played by the canine without human interference?*** We hypothesize that the presence of a digital interactive game, which the dog can play without the need of human presence or interference, will reduce the stress response in dogs that are left home alone by their owners.

2. Scientific Context & Related Work

A few studies have already been mentioned in relation to isolation in dogs. This research is situated in a much larger context than merely researching the issue of isolation in canines however. Its scientific context spans from animal testing in its classical sense, such as monitoring animal behaviour under set circumstances, to developing new technologies specifically designed for animals, such as games providing entertainment for animals.

Artifacts used for and by animals have been developed in previous decades, but usually not with the intention to specifically improve their welfare. B.F. Skinner conducted studies under the name of "ORCON", that included training pigeons to guide missiles through pecking at a target, in order to avoid having to use more complicated technological solutions [12]. Pavlov became famous for operant conditioning in canines. At the time the prevailing view on animals was that they were mechanical beings, having no such thing as emotions.

Since then, the view on animal cognition and emotion has drastically changed and with that the aspiration to serve the aims of animals other than humans in those studies has emerged. Clara Mancini [13] states that: "Animal Computer Interaction aims to understand the interaction between animals and computing technology within the contexts in which the animals habitually live, are active and socialise with members of the same or other species, including humans." More recently she coined the term Animal Welfare Informatics [14], which largely overlaps and includes the aims described under ACI.

Studies performed under the aims of ACI and AWI can be defined within a broader spectrum of research exploring the relation of technical artefacts and animals. One side of the spectrum focuses on new ways of computing using animals, while the other side of the spectrum aims towards using technology to improve the living conditions of the animal. There are studies exploring the option of digitally controlling an animal, such as research by W. van Eck and M. H. Lamers [15, 16] where a human player plays Pacman against crickets, and a study by Holzer and Shimoyama [17], in which electrical stimulation is used to control the motion of a cockroach. These neurological systems have also been developed on beetles [18] and rats [19]. Other studies look at how animals control a digital system, such as a project by Garnet Hertz, where the motions of a cockroach are translated to the locomotion of a robot [20].

These studies differ from research conducted under the principles of AWI and ACI in the sense that ACI aims to put the animal in control of the digital system with the intention of designing the digital system *with* the animal rather than leaving the animal out of the design iterations until the prototype must be tested. Another very important difference is, that in the previously mentioned cases the animal was part of a study wherein there was no consideration for the physical and psychological needs of the animal.

There are a few examples of research where animals utilize a technological medium in order to communicate to human subjects. Sue Savage-Rumbaugh [21] has studied Kanzi, a bonobo, who interacts with her via a specialized keyboard with symbols on the buttons. Marine mammal behavioral biologist Denise Herzing has been studying a group of wild Atlantic spotted dolphins and has collaborated with a research team at Georgia Tech on a wearable human-to-dolphin communication device called Cetacean Hearing and Telemetry (CHAT) [22]. Even though this research already considers the needs and cognitive capabilities of animals, the aim of these studies is to find out more about the nature of language, which is outside the scope of AWI and ACI and of this study.

Now ACI and AWI are somewhat positioned in a broader scope, we will review the many different studies within the field. A classic example and first venture into ACI is Rover@Home by Resner [23], who created an application that enables people to clicker train their dogs over the Internet. While enabling an interaction between a human and a canine through an online medium is already a big step, the quality of the interaction is assymetrical in the sense that the dog merely follows orders and is not capable of actually controlling the application. Training a dog over the Internet supports human needs, but not necessarily those of the canine.

The Canine Amusement and Training (CAT) project [24] is a tool created to allow the canine to join the human in electronic gaming, while simultaneously aiming to motivate the human to spend more time with their canine in a responsible way. It goes a step further than Rover@Home by aiming to serve the needs of both the canine as well as the human, but it is still in a very early stage of development. Furthermore, the dog is still dependent on the human to initiate gameplay.

One method used to stimulate both the human and the animal to participate in interaction is through technologically mediated gameplay during which the animal is considered full user of the game. The game Pig Chase [25] is an example of an interface that allows the animal to participate as fully recognized user through means of embodied play. Pig Chase is part of The Playing with Pigs project, which is a collaboration of the Utrecht School of Arts, Wageningen University and Wageningen UR Livestock Research. The game in this case is a large touch screen set up in a pig stable, where pigs can follow small lights with their snout. Once the pig catches a small light by pressing its snout against the touchscreen, it explodes into a burst of light, which is something the makers assert pigs enjoy and thus serves as a reward and stimulation. The small light is controlled by a human using a tablet or smartphone. The makers intended the game to be playable in 2013, but the game has not appeared on the market thus far.

Metazoa Ludens by Tan et al. [26] is one of the few studies where an interface has actually been built, tested and used. The researchers promote a new type of media interaction called Metazoa Ludens. The interface allows human users to interact and play with their hamster remotely via Internet through a mixed-reality-based game system. In the game, the human user has the role of a floating avatar that is hunted by a big hamster. In the installation, the hamster is placed on a flexible floor and presented food inside a tube attached to an arm that it chases so as to catch and collect the food. The hamsters were allowed to play Metazoa Ludens for an hour on weekdays during a period of 6 weeks. The conclusion, after the mean body condition scoring (BCS) was compared between measurements taken before and after 6 weeks, is that the hamsters were healthier and more fit after 6 weeks of playing Metazoa Ludens. Next to observing physical developments, a seperate study, using the method of Duncan, was carried out to measure the motivation of the hamster to play Metazoa Ludens. Results show that over time the hamster's preference to play Metazoa Ludens increased, allowing researchers to conclude the hamsters liked playing the game.

Another succesful venture into technologically mediated human-animal interaction is Cat Cat Revolution (CCR) [27], a digital game of cat and mouse that can be played on a tablet. The game allows cats to participate in play through a species-appropriate interface acquired by applying HCI principles to pets and by using the element of chasing an object, a natural behaviour of cats. Human participants in the study indicated that CCR was experienced as a fun and mutually beneficial play experience. The researchers conclude that their findings suggest implications for future human-pet gaming systems, despite the asymmetrical ability of humans and pets to share or coordinate interaction.

Closely related to the study described in this paper is Paw-tracker [28], an interface that utilizes Internet technologies and a combination of sensor-based dog-created content with social media. It enables human users to track their pets' activities and share the gathered information with friends. The concept behind this research is that the human user will know what his/her pet is up to, while they are away from the house. Even though the research concerns itself with the issue of dogs being alone at home, it does not directly provide support or a solution for a home alone dog, if anxious.

The research performed by Mankoff (who herself is a canine) et al. [29] does aim to support the home alone dog. The study addresses the issue of canines being left home alone by their owners (or through the perspective of the canine, the pack) and aims to solve this issue by providing the home alone dog with information about a pack member's extended pack interactions. This is done through the development of a Pack Activity Watch System: Allowing Broad Interspecies Love In Telecommunication with Internet-Enabled Sociability (PAWSABILITIES). The human is notified when the dog is bored (lying down) and can initiate play remotely by activating a machine that throws a ball. Whether PAWSABILITIES has the desired effect during a period of isolation undergone by a canine is not investigated. However the study did result in a lot of interesting finding on how canines perceive and what their (cognitive and physical) capabilities are in relation to technology.

Research is not only directed at creating applications, such as games, but also at exploring the applicability of existing Human Computer Interaction (HCI) models to ACI and AWI and discovering new guidelines and methodologies.

K.L. Overall & D. Dyer [30] have described enrichment strategies for laboratory animals with an emphasis on behavioural enrichment. They state that many of the responses of dogs to enrichment and welfare situations likely revolve around social interaction, referring to Campbell et al. [31], who found that dogs will not initiate exercise unless they have the stimulation of a human or of other playful dogs.

Hirskyj-Douglas & Read [32] take into account the possible difference in sensory information intake and processing in humans and canines, by performing a study that uses an HCI user-centric approach to aid development of species appropriate audio and visual stimuli.

Although quite a number of studies have been mentioned in this paper and undoubtedly more studies will exist within the area of AWI and ACI that have not been mentioned here, the field of ACI is still in its infancy. Applications such as games, are still very basic and co-designing with animals is still a bit of a struggle. Next to that ACI cannot make use of surveys and other evaluation methods the way these are used in many HCI studies, since animals cannot write nor talk. Thus new ways of evaluation must be designed and used. However, the first steps into exploring the opportunities of this field are being taken. And the fields of AWI and ACI will continue to grow, offering valuable insights into the cognitive abilities of animals and possibly ourselves.

3. Preliminary Study

3.1 Overview

In order to design and evaluate the application to be used in the study and the means of measuring the psychological state of the canine subjected to the study, an informal preliminary study was performed consisting of both literary and emperical research.

The preliminary study considering the application explores the design of different applications that possibly prevent the canine from getting stressed when isolated from the human owner. These applications were explored informally and assessed according to both the (hypothesized) reaction of the canine subjects, the feasibility of the application within the time limits of this research, the practicality of the application within a home environment and the suitability towards the aim of the research.

The preliminary study in which we examined means of measuring the psychological state of the canine consists of setting up and evaluating a cortisol measurement test (ELISA). The study focuses on finding suitable methods of collecting, storing and measuring cortisol in canines and will not be described in detail in this paper.

3.2 Application Design Process

At the beginning of the design process the issue was described andand possible solutions were constructed within the aims of ACI and AWI to be analyzed and evaluated (Figure 1).

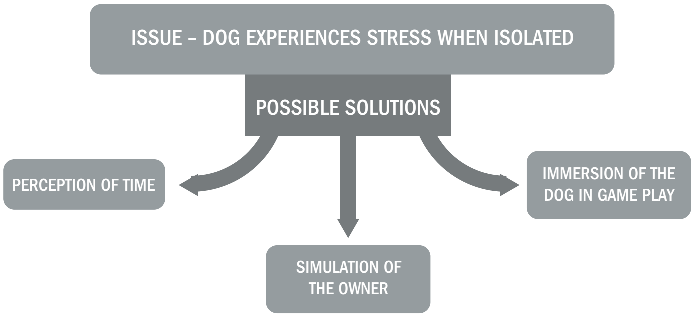

Figure 1. Diagram showing possible solutions to stress caused by isolation in dogs

Perception of time

A solution to lower the amount of stress experienced by the canine might be handing the canine a digital device that works like a clock. Studies [33, 34] investigating stress in humans caused by waiting (for a service) showed that the amount of stress could be lowered by announcing the amount of time the human had to wait.

It is doubtful, however, whether providing real time information on the amount of time left in separation would really aid the canine, seeing as we do not know whether canines can be taught to watch a clock and associate its state with the amount of time that has passed and is still to come. It is unknown whether canines have perception of time, despite a study by Rehn and Keeling [2] on the effect of time left alone on dog welfare showing that dogs performed more intense greeting behaviour towards their owners as well as a higher frequency of physical activity and attentive behaviour when the owner returned after 2 hours of separation. While the study is not able to distinguish whether the dogs were aware of the length of time they were separated or not, it does confirm that dogs are affected by the duration of time spent home alone.

A digital application that could appeal to this sense of time is a timer that shows the dog real time information on how much time is spend in separation and how much time is left until the owner returns. The application is similar to the traffic lights in the Netherlands used for bikers. (Figure 2) A circle of green LEDs indicates whether a person is allowed to cross the road on his or her bike. The number of lit LEDs indicates the amount of time passed while waiting for the traffic light to turn green.

Teaching a dog to associate the owner coming home with the amount of LEDS lit in the device (or possible a specific sound or scent) means the return of the owner is viewed as a reward. Using the owner as a reward after waiting might only enlarge the separation issue, because the absence of the owner associated with negative emotions might be emphasized if the return of the owner is associated with relief of the negative emotion.

If the device would not worsen the separation anxiety of the canine, it would possibly only make the waiting for the owner to return more bearable rather than providing the dog with another (more positive) activity that allows it to act independently from the owner allowing for a more significant change in the animal's welfare.

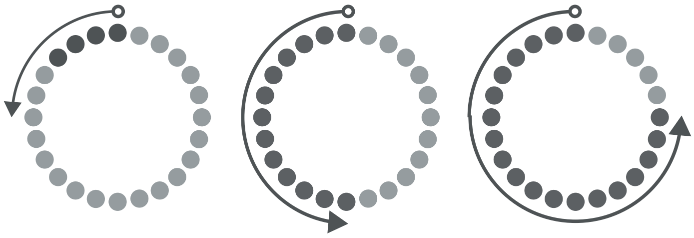

Figure 2. Amount of time passed indicated by LEDs

Simulation of the owner

There are various applications for battling isolation in humans. Examples of simulating either human or pet presence are online avatars and chatterbots, telepresence or robotic and virtual companions. Previously named examples include AIBO () and PARO (). Though these pets do not perform the entirity of behaviour performed by an actual dog or in case of PARO a seal, they evoke emotions similar to emotions evoked by real pets.

Simulating presence aids to reduce loneliness and negative emotions in humans, but could also work for canines, who, like humans, are very social in nature. The question is then: what to simulate? Research by Vestrum [5] shows that home alone dogs are not significanty affected by the presence of another dog, when their owner is away. Thus simulating another dog would probably not have an effect, but simulating human presence might prove beneficial for the home alone dog. Research by Coppola, Grandin & Enns [7] investigating whether human contact reduces stress for shelter dogs shows that shelter dogs interacting with humans had lower cortisol levels than those dogs that did not interact with humans. Simulating human presence for home alone dogs might battle stress caused by separation from the owner. Simply stated, to lower the amount of stress experienced by the canine after the owner has left the house, the owner has to be simulated, so that, in the perception of the dog, the owner is never gone.

There are several drawbacks however. Firstly, virtual and online simulations would prove to be difficult to build for canines, partly due to the qualities of their senses (see Canine sensory perception). Moreover, there is a possibility that the simulation would fall into the uncanny valley [35], causing the dog to be possibly even more stressed compared to being home alone. The uncanny valley refers to to the dip in a graph of the comfort level of humans as robotic subjects (companions) move toward a human likeness described in a function of a subject's aesthetic acceptability. The robotic companions build for humans are often not human, but animals or abstract representations (e.g. chatterbots). This is because humans are very good at recognizing other humans. A robot that would look human, but does not behave accordingly, falls into the uncanny valley, leaving the human feeling uneasy and possibly even afraid of the robotic companion.

An identical situation could appear if we were to simulate the owner of the canine, who knows his owner better than we do. Next to that the canine might make use of cues that we as humans might not identify. It would be hard to escape the uncanny valley. If the simulation of the owner would fall into the uncanny valley, we would only strenghen the negative experience of the dog while separated from its (real) owner. On the other hand, if the simulation would work too well, the dog might not be able to distinguish the difference between the real owner and the robotic simulation, which in turn could lead to a weakened bond between the human owner and the canine, due to the canine forming a bond with the robotic simulation. Hypothetically speaking the possible confusion could even result in behavioural issues.

Apart from these issues, simulating the human owner would allow the dog to become more independent from the human owner. However, this independence only works for the owner, who does not have to worry about his dog being alone. In the perception of the dog, the owner would always be home and the dog would still be dependent on the owner. We would only create the illusion of the owner being present, and in fact lie to the dog about the real owners whereabouts.

We mainly discussed simulating the entire owner rather then simulating parts of the owner. Simulating parts of the owner include situations such as leaving a pair of boots that contain the smell of the owner, so the dog smells something familiar and does not get stressed. This technique is often used to ensure the dog does not get anxious when the owner leaves the house. Another example is using the owner's voice to soothe the dog. Many owners have tried using a telephone or webcam conversation to connect with their dogs, once physically seperated. Often the canine gets excited, but also somewhat confused. They can hear the voice of their owner, but other sensory cues, such as sight and smell are not provided.

From the preliminary tests we have conducted with the prototype, we can state that dogs do not seem to get very confused when they hear their owner's voice through a speaker, even when the owner is not in the room. The initial confusion of hearing the owner's voice from a speaker relinguishes within a few minutes after which no confusion is observed. When the owner is in the room with the dog and the speaker plays the voice of the owner, the dog will initially look at the owner, as if the owner is speaking. However, after the speaker has played the owner's voice several times, the dog will refrain from looking at the owner and look at the speaker instead. If the owner is not in the room, the dog will directly move towards the speaker.

Immersion of the dog in gameplay

The study of play has gained significance only recently in the scientific community. In previous decades play was not viewed as a serious subject, partially because play by itself does not seem to have any particular function. It does not provide food or shelter and even though the notion exists of play as a means to learn skills needed to succeed later in life, during work there is no time for something as inefficient as play. Play is performed purely for its own sake. In his TEDTalk: “Play is more than just fun” [36] Stuart Brown talks about the importance of play and how it might actually have various important functions for the individual immersing in it. Deprevation of play might lead to disfunctional individuals incapable of performing what is considered normal social and adaptive behaviour and sometimes might even lead to a state of depression.

Another speaker at TEDTalks is Mihaly Czikszentmihalyi, who talks about Flow [37]. He describes flow as the (creative) moment when a person is completely immersed in an activity for its own sake. Once in this state a person is highly focused at the activity at hand and does not consider other events or feelings (such as hunger or fatigue) important. The state of flow is expressed as the amount of challenge presented by the activity and the amount of skill acquired by the subject immersing in the activity. Defined like this the notion of play and flow seem to highly overlap and describe a state wherein the individual experiences a positive emotion whilst completely immersed in the current activity.

In the introduction section of this paper we shortly mentioned games played by humans that could possibly battle social isolation. We suggest that the immersive quality of play (or gaming) could provide a solution to social isolation in canines as well and subsequently provide a solution to separation anxiety. The canine will be focused on an activity and as a result be distracted from the notion of being seperated. An example can be given from personal experience. Gino, a 6 year old Mallinois/Bordercollie hybrid usually gets upset when I leave the house, even if there are other people still in the room with him. One day my friend staying with Gino decided to try and distract him with his favourite game: hide and seek. He hid Gino's toy in the room and initiated the game. Within minutes Gino's attention was fully focussed on the game, whereas normally he would sit in front of the door and whine. This leaves us to conclude that there is at the very least a possibility that a game could immerse the dog in play and lower the stress response caused by (social) isolation.

This study is not the first study that explores the benefits of gameplay on animals. Research mentioned in the Scientific Context Section of this paper include Metazoa Ludens [26] and Playing with Pigs [25]. Although Playing with Pigs had a disparate aim in comparison to this study, namely to explore the bond between humans and the pigs they eat, the idea of using games to provide the animal with an activity is similar. Metazoa Ludens shows that playing games has a positive influence on hamsters living with humans. Possibly a game for dogs could evoke an identical response.

In order to succesfully design a game for dogs, the game must adhere to a couple of requirements. (Figure 3) First it must provide suitable stimuli to a canine's sensory perception. Furthermore the game has to provide the dog with a satisfactory challenge to keep the dog immersed. The game should not be too challenging either, for the dog might give up on trying to play the game and fail to become immersed in the activity. Also, because we do not want the dog to be reliant on the human owner, the game has to work independently from the owner, meaning that the owner does not interfere with the game.

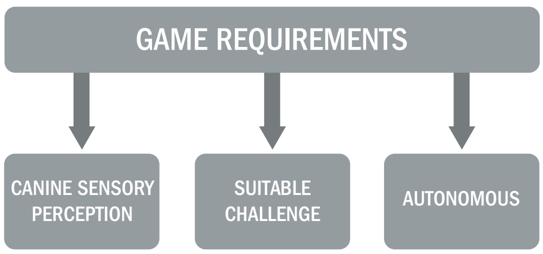

Figure 3. Diagram showing initial game requirements

Canine sensory perception

Canines have a different sensory perception than that of humans. In order to succesfully design an application for dogs, we have to be aware of these differences and react to them in our designs accordingly. Note that the sense of taste is not discussed in this paper. Canine taste functions similarly to human taste, but apart from a reward in the form of treats, does not play a mayor role in the prototype of the digital interactive game.

Visual cues

Visual signals in a digital interactive game could involve the use of lights (LEDs) or a screen. In many video recordings of canines interacting with their owners via Skype, the dogs did not respond to the visual image of their owners on screen, but to their voices [38]. During one of the informal tests the subject did not seem interested in a static picture of the owner being shown nor in a silent live recording of the owner, yet the voice of the owner through a speaker resulted in the canine becoming excited. The dog owners I spoke to, that had tried to Skype with their dog, stated that the dog mainly seemed interested in audio cues rather then the image on the screen. The display of video material of the owner is for some reason not convincing (enough) to establish meaningful form of interaction with dogs.

Next to this, canines do not view colour the way humans do either. Unlike humans, who have trichromatic color perception, canines have dichromatic color perception [39], meaning that they have difficulty differentiating middle to long wavelengths of light (green, yellow, orange and red). If we were to use (physically) coloured objects (such as coloured blocks or LEDs) this would be something to take in account.

Olfactory cues

It is well known that dogs are much more sensitive when it comes to odour than humans. Existing methods to battle seperation anxiety and/or negative emotions in canines during isolation include leaving objects containing the scent of the owner or using scented oils to calm the canine, such as Bach Rescue. Note that there is no scientific proof of the workings of these treatments.

Odour however is very difficult to control (digitally or electronically), because of its properties such as: the concentration (pervasiveness), intensity (perceived strength of odour sensation), hedonic tone (pleasantness), duration (time within which the odour is still smelled) and the frequency with which the scent is being introduced to the subject.

Next to that, the addition of scent in the interactive game would be superfluous in the sense that the environment the canine is in will already contain the scent of the owner. Releasing an identical or similar scent to that of the owner might either not affect the psychological state of the canine positively. The canine will strongly smell the presence of the owner, but other sensory input will contradict this stimulus, because the owner is not present. A calming scent could be used every time the owner is away from the house, but this might result in the dog associating the scent with having to be alone. Also there might be a threshold that needs to be breached in order for the dog to start feeling comfortable, that could possibly not be breached by using odour to calm the dog. Calming scents are often used to relax dogs during anxious situations, but often do not work by themselves. Due to time limitations and the difficulty of controlling scent technologically (and digitally) no emperical study was performed to test the assumptions mentioned.

Haptic cues

Earlier in this paper a study by S. P. Lee [6] was described wherein a chicken was placed in a haptic harnass, allowing it to be petted remotely by a human being. What worked for chickens in this study might work for canines as well, considering the fact that lots of dogs like to be petted. However, in order to achieve the same workings as the Human-Poultry Internet research, a haptic harnass would have to be worn by the dogs. Not all dogs are used to wearing a harnass and some might even try to get rid of wearing it, which influences the results, because it would cause stress to build up in some dogs.

Furthermore, the aim of the Human-Poultry study is to create an interdepence between animal and human, while in this study we want the animal to be autonomous from the human. The haptic stimulation provided to the dog would have to come from a software program and in case of a harnass, the dog would not be able to only voluntarily participate in the interaction with the haptic stimulation, which would undermine the aims stated in ACI and AWI.

Audio cues

Similar to the sensitivity of the olfactory system of canines, the auditory system of canines is very well developed. Dogs are able to hear a spectrum from 40 Hz to ultrasound up to 60 kHz. [40] Moreover they can locate the source of a sound far better than humans, partially because they have the ability to rotate the ears; a property of the canine auditory system that differs per breed, depending on whether the ears are standing upright or whether they are hanging. In the wild, canines use these auditory capabilities to locate and hunt prey, while domestic dogs are often kept for guarding purposes.

Next to literary research I had noticed that both Gino, my own dog (a Mallinois shepherd) and Kai, the dog of my parents (a crossbreed shepherd) reacted very strongly to certain sounds, such as rustling sounds (often associated with small prey, such as mice) or the sound of a plastic bag (often associated with treats). When I reproduced a rustling sound for an extended period of time (about 20 minutes) the interest of Kai in trying to locate the sound did not seem to decrease over time. It appeared as though all his attention was focused on tracking down the location of the sound.

Suitable challenge

Apart from taking into account the sensory capabilities of a canine, the cognitive and physical capabilities should also be considered. The game should appeal to actions and/or behaviours that dogs are known to exhibit. We cannot, for instance, expect a dog to know or easily learn how to type or understand and speak Dutch.

Brian Hare [41] founder of the Duke Canine Cognition Centre (DCCC) has investigated dog psychology and found that dogs have very well developed socio-cognitive skills. They can engage in complex communicative interaction with humans [42] and are able to comprehend behavioural cues from human experimenters [42 – 45]. The situation that we will simulate during this study will not involve the presence of humans however and will require other cognitive abilities more closely linked to problem solving.

In his books: The Intelligence of Dogs [46] & How dogs think [47], Stanley Core attempts to shed a light on dog psychology and cognition by looking at the differences between different breeds of dogs. Border Collies rank the highest on intelligence, based on the number of iterations needed to understand new commands. Core does state that different types of intelligence are present in dogs: Adaptive and instinctive intelligence (learning and problem-solving ability), which are specific to the individual animal. And working or obedience intelligence, which is breed dependent.
Because different breeds tend to have specific character traits (such as intelligence) Brian Hare set up Dognition, a web-based testing service [48] where dog owners can play science-based games with their dogs that as a result provides a dog profile report on the

personality type of their dog. Different personality types show different preferences towards types of games.

Knowing not all dogs work exactly the same way, we are aware that the game designed might not have the same effect on all individual dogs, even if they are capable of performing the same actions (such as using their paws). This is because individuals differ in cognitive capabilities, but also in preferences. The Animal Hospital of North Asheville [49] describes a set of play styles and actions that are observed during dog play with playtypes ranging from chasers to wrestlers and actions including tugging and body slamming. These play types however are only observed in groups of dogs (and humans) interacting with eachother. Some dogs are known to engage in self play which often involves tossing an object around.

A few forms of play exist aiming to stimulate the dog to play by itself, such as the tethertug [50] that appeals to the play action of tugging. An elastic pole with a rope attached to it allows dogs to play tug outside. The tethertug can only be used outside however and most dogs are often kept inside the house when the owner leaves. Other forms of games include hiding treats in a so called sniffing rug (often DIY made by dog owners), or in a plastic bottle that has small holes, so the treats fall out of the bottle when it is rolled over the floor. Next to that there is the Kong [51], a hollow, rubber object in which food can be placed (in the form of treats, but also foods that can be smeared). It is questionable whether a dog that experiences anxiety during isolation would initiate play with these toys.

The development of interactive artefacts for dogs that are mentally stimulating has recently gained interest of many dog owners. Artefacts developed by Nina Ottoson [52] are designed to mentally stimulate the dog by providing different puzzles containing a treat. By solving the puzzle, the dog receives a treat. The puzzles require the presence of a human however for some of the puzzles consist of loose parts that the dog could swallow.

There are also games that address the hunting behaviour of dogs, such as hide and seek with objects and/or humans and playing fetch. These forms of play require a human to be present in order to initiate play however, which will not be the case when the dog is isolated. There are a few digital interactive devices that have automated the action of throwing the ball, so the dog can play fetch by itself, such as GoDogGo [53] and iFetch [54]. Most of these games are only played when the human is at home, due to human concerns such as fear of possibly damaging furniture. Moreover these automated games have not been tested on whether they provide stress-relieving gameplay for dogs, once these dogs are home alone.

Autonomy

As stated before, we want to develop a game that can be played by dog without human interference, which means the game must work autonomously. In the introduction section of his paper we mentioned research by by Aslaksen & Aukrust [4], who concluded that dogs do not initiate play when (home) alone. When designing the game, we must make sure the game initiates play in order for the dog to immerse in gameplay.

Automation of existing games (such as fetch) seems to have the potential of immersing a dog in gameplay that is intuitive and experienced as fun, while also being autonomous. Keeping practicalities in mind, such as space and the possibility of damaging furniture we chose to create a digital interactive game that exploits the concept of hide and seek using sound. The next section will describe the workings of the digital interactive game.

4. The Digital Interactive Game

The digital interactive game designed for this experiment consists of 2 speakers, a dispenser and 2 buttons designed specifically for canines (Figure 4).

Figure 4. Picture displaying game set up

The rules of the game are very simple and provide direct feedback in order to aid the dog in understanding how the game is played (Figure 5). The game is played as follows:

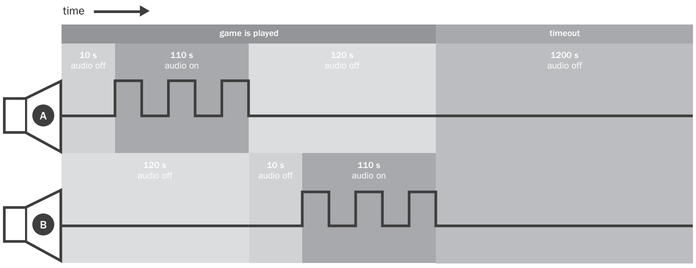

Figure 5. Diagram showing the workings of the game throughout the passage of time.

1. Audio (the owner's voice) is emitted (randomly) from one of the 2 speakers (in this case speaker A) and repeated over a period of 2 minutes. Within this timeframe the audio is repeated 12 times.

2. Within the timeframe of 2 minutes, the dog can press the button connected to the speaker emitting the sound (the correct button) or the button that is not connected to the speaker (the incorrect button).

3. The software will verify that the button pressed by the dog is indeed connected to the speaker emitting the sound (the correct button) or is not the speaker emitting the sound (the incorrect button).

   Depending on whether the correct button was hit or not, a signal is send to the dispenser, which in turn will dispense a treat. Simultaneously the speaker (speaker A in this case) will stop emitting audio and the next speaker (speaker B in this case) will start emitting audio (repeating step 1 and 2).

4. After either the correct button is pressed or the timeframe (of 120 seconds) has passed, the software will quit the game and run a counter for 20 minutes (timeout) before emitting a sound again repeating the game.

Technical specifications

The digital interactive game was built using the visual programming language Max MSP, an Arduino microcontroller and an audio mixer (MOTU) to drive the speakers. The Arduino receives input from a microswitch that detects pressure on the surface of the button and reacts to this input by operating a food dispenser. The food dispenser consists of a servo, to which a metal lever was attached. Under the right angle, the metal lever touches the capacative sensor of the dispenser, causing the dispenser to dispense treats. The program code (the so-called MaxMSP patch) can be found in Appendix A.

5. Experimental Methodology

In order to assess the psychological state of the canine during the experiment cortisol samples analyzed with an enzyme-linked immunosorbent assay (ELISA) test and quantified ethogram complimented by qualitative observations were applied.

5.1 Salivary Cortisol Measurements

Cortisol concentrations

Cortisol tests are often used in order to indicate the amount of stress experienced by an animal [55 – 59]. Although the ELISA test is used to study cortisol in canines frequently, a preliminary test was performed to determine whether the cortisol concentrations [60] of the samples taken from dogs would fall within the detectable range of the ELISA test. We confirmed that the cortisol concentrations in the preliminary test samples were detectable within the cortisol concentration calibration range of 0,4 to 1,7 nm/mg.

Cortisol can be measured through different means, such as excretion, blood and hair. For this test the use of saliva [61] to provide samples containing cortisol was chosen, because differences in cortisol concentration can be measured in saliva within a period of a few hours, whereas cortisol conserved in hair is only detectable over longer periods of time. Next to that the amount of cortisol conserved in a hair differs per hair depending on the colour of the hair (light or dark). Furthermore, saliva can be collected at any moment in time, whereas excretion would have to appear during every test within the set timeframe, which is unlikely (and unfavourable) to happen within a domestic setting. Taking blood samples is rather intrusive and might have a strong effect on the psychological state of the dog, which could possibly alter the cortisol results and additionally would be uncomfortable for the dog.

Cortisol sample collection

Cortisol samples were obtained twice daily from each subject at the moment of departure and return of the owner, ending the subject's isolation. This was done due to the circadian nature of cortisol concentrations inside the body, causing cortisol concentrations inside the body to fluctuate throughout time. The obtained samples were stored for a maximum of 4 weeks (the amount of time needed to obtain all cortisol samples during the experiment) in -18°C degrees and transported to the laboratory.

The cortisol was collected from the subject's saliva, which was obtained from the subject by placing a dental roll (Nobadent) between the cheek and the jawline of the dog's mouth. This way the dog could not chew on the dental roll or swallow it. The dental roll remained in position for 1 minute before being taken out and placed in a 10 ml syringe.

Once the dental roll was placed inside the 10 ml syringe 2 ml of phosphate buffered saline (PBS) was added to dilute the sample. This was done to allow the saliva to travel through the dental roll, once pressure was added to the dental roll by the syringe. The solution was pressed into a labeled testtube, which was then sealed and stored before being transported to the laboratory.

Enzyme-linked immunosorbent assay (ELISA)

The ELISA test used in this study uses competitive binding (Figure 6), which means that an unlabelled antibody is incubated in the presence of its antigen. The bound antibody-antigen complexes are in an antigen-coated well (1 well for each sample) and washed, so any unbound antibody is removed. The more antigen available in the sample, the more antibody-antigen complexes are formed and fewer unbound antibodies remain available to bind to the antigen in the well, hence the name competition. A secondary antibody, specific to the antibody in the well, is added and coupled to an enzyme. After this, a substrate is added and the remaining enzymes elicit a chromogenic signal. This chromogenic signal (absorbance) is then read by a microplate reader, which outputs optical units (the absorption is determined at 450 nm).

For the ELISA test used in this study, the chromogenic signal is yellow. Simply stated, the more yellow the reaction product in the well, the higher the measured optical unit (absorbance) and the lower the cortisol concentration, thus the lower the amount of stress experienced by the dog.

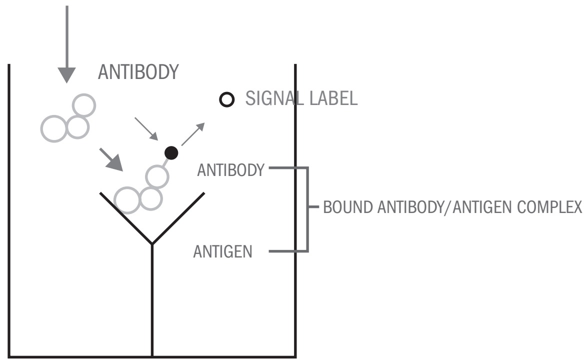

Figure 6. Diagram demonstrating the workings of competitive ELISA. Note that the antibodies are presented symbolically, and do not represent the actual structure.

5.2 Video Data and Analysis

In addition to cortisol analysis, video data was recorded during the period wherein the dog is isolated. Cortisol concentrations give an objective indication of the amount of stress experienced by the canine during the test. However, the measurement of cortisol concentration does not discriminate between positive (excitedness) and negative (anxiety) arousal. In order to add context to the cortisol concentration measurements, video data of the dog's behaviour is recorded and (subjectively) analyzed.

This video data is quantified through a focal animal sampling ethogram that was also used by Elisabetta Scaglia et al. to analyse home alone dogs [62] and was modified to incorporate interactions with the digital interactive game. The ethogram was created for each first half hour from every hour of video recording. All occurences of specified actions (Figure 7) of one individual are recorded during a predetermined sample period (the entire time in which the animal is isolated) where the length of the period and the amount of time the animal is in view are taken into account. In addition audio data was recorded and noted down.

Qualitative notes and observations were made and taken into acount in addition to the quantified ethogram data. This was done to ensure a certain amount of context was attributed to the observed behaviours so as to better interprete the behaviours exhibited by the subjects.

5.3 Set-up

Subjects were tested for a period of 10 days (weekdays) divided into 2 conditions: stimulated (5 days) and unstimulated (5 days). During the stimulated condition the subject was isolated for a set amount of time and accompanied by the digital interactive game. In the unstimulated condition the dog was isolated for an identical set amount of time without the digital interactive game being present.

The subjects are divided into 2 groups. These groups differ from one another in the order of conditions (stimulated and unstimulated) the subject is subjected to. The first group of subjects is first subjected to the stimulated condition and after that, to the unstimulated condition. The second group of subjects is first subjected to the unstimulated condition and following that the stimulated condition.

The amount of time (in hours) a subject was isolated per day differs per subject and will be discussed in more detail in the Results section of this paper.

6. Results

6.1 Subjects

For the study 3 subjects were measured in their domestic situation. Other animals (such as cats and others dogs) that would normally accompny the subject were excluded from the space wherein the subject was isolated to ensure that the other animals could not interfere between the interaction of the subject with the game.

The subjects all lived in the same area of the Netherlands (the province of Groningen), to ensure the testing could occur simultaneously for 2 subjects. Because cortisol samples had to be obtained at set times throughout the test, the distance needing to be traveled between the subjects had to be less than a 30 minute drive.

Figure 8 and 9 show the amount of time the subject was in isolation and the times at which the cortisol samples were taken.

Subject A

Name: Isa
Breed: White Swiss Shepherd
Age: 6
Gender: Female
Domestic situation: Detached home
Living with other animals: 2 cats

Subject B

Name: Tommie
Breed: English Springer Spaniel
Age: 5
Gender: Male (neutered)
Domestic situation: Detached home
Living with other animals: no

Subject C

Name: Rosie
Breed: Australian Shepherd
Age: 5
Gender: Female
Domestic situation: Detached home
Living with other animals: 1 dog (Friesian Stabyhound)

Figure 7. Behavioural categories and their definition

Action		Description
No Video	NV	Not visible in video (during these periods, activities, such as vocalisation, chewing and scratching are identified through sound recordings).
Sound Game	SG	Sound emitted through speakers by the game.
Barking	BA	Creating (multiple) short-lasting, loud sound(s) using the mouth.
Whining	WH	Creating a high pitched sound, often with the mouth closed.
Howling	HO	Creating a long-lasting sound, using the mouth.
In Video	IV	Dog is visible in the video.
Exploratory Game	EXG	Motor activity directed toward (parts/aspects of) the interactive game, including sniffing and (gentle) oral examination, such as licking.
Exploratory Dispenser	EXD	Motor activity directed specifically towards the dispenser, such as licking or biting, in order to reach the treats.
Dispenser Off	EXDO	Dispenser is taken off its position.
Play Game	PLG	Any behaviour directed towards the interactive game that is in line with the rules of the game, such as (trying to) push(ing) a button, eating the treats, listening to the speakers.
Play	PL	Any vigorous or galloping gaited behaviour directed towards a toy (that is not the interactive game) including chewing, biting, shaking from side to side, scratching or batting with the paw, chasing, rolling balls and tossing using the mouth. Destruction is not part of this category.
Locomotion	LO	Walking or running around without exploring the environment (pacing).
Oriented to Environment	OE	Sitting, standing, or lying down (the head does not rest on the ground or paws) with obvious orientation to the physical (or social) environment, including sniffing, close visual inspection, distant visual inspection (vigilance or scanning)
Grooming	GR	Action of cleaning of the body surface by licking, nibbling, picking, rubbing, scratching, and so on directed towards the animal's body (self-grooming).
Yawning	YA	Inhaling a lot of air, while the mouth is open
Passive Behaviour	PA	Lying down with the head on the ground without any obvious orientation toward the physical (or social) environment (sleeping or resting).
Exploratory	EX	Motor activity directed toward physical aspects of the environment (that are not the interactive game), including sniffing and (gentle) oral examination, such as licking.
Lip Licking	LL	Licking the lips with the (tip of) the tongue.

Period	Condition	Subject
A1 (21-07 t/m 25-07)	Stimulated	Subject A (Isa)
A2 (28-07 t/m 01-08)	Unstimulated	Subject A (Isa)
B1 (21-07 t/m 25-07)	Unstimulated	Subject B (Tommie)
B2 (28-07 t/m 01-08)	Stimulated	Subject B (Tommie)
C1 (04-08 t/m 08-08)	Unstimulated	Subject C (Rosie)
C2 (11-08 t/m 15-08)	Stimulated	Subject C (Rosie)

Figure 8. Table showing subject testing periods

Amount of time isolated (in hours per day)	Time of isolation	Subject
3	10:30 to 13:30	Subject A
2	11:10 to 13:10	Subject B
1	20:00 to 21:00	Subject C

Figure 9. Table showing the amount of time subjects were isolated

6.1 Salivary Cortisol Analysis

The ELISA analysis was performed on a duo set of calibration samples (Figure 10) of which the mean was calculated and the 60 cortisol samples obtained from the subjects during the experiment.

The optical units (absorbance) resulting from the ELISA analysis are usually converted to cortisol concentrations (ng/ml) by plotting a standard curve (Figure 11 and 12) using the mean absorbance obtained from each calibration sample (of which the cortisol concentration is known). Rather than using the cortisol concentration values, the decision was made to use the optical units (absorbance) in our data analysis. This is because converting the optical units to cortisol concentrations creates noise. Besides that, we are interested in the difference in the values measured during the stimulated condition and the unstimulated condition. Therefore using optical units to do our calculations will suffice.

	Cortisol Concentration (ng/ml)	Mean Calibration Optical Units (nm)
Cal0	0,0	2,39
Cal1	0,1	2,33
Cal2	0,4	2,26
Cal3	1,7	1,92
Cal4	7,0	1,26
Cal5	30,0	0,71
low	0,3	2,36
high	1,9	1,96

Figure 10. Known cortisol concentration and the mean calibrated optical units

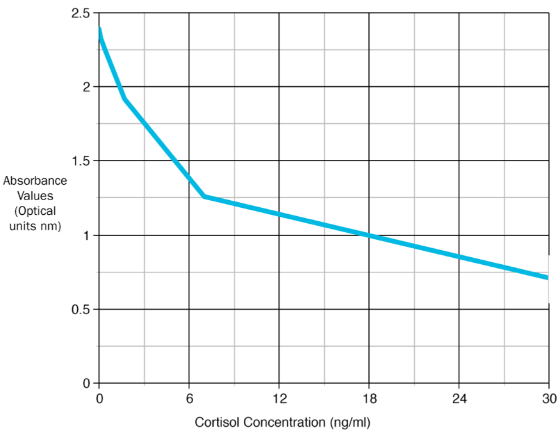

Figure 11. Standard curve plotted using the mean absorbance (optical units) obtained from the calibration samples.

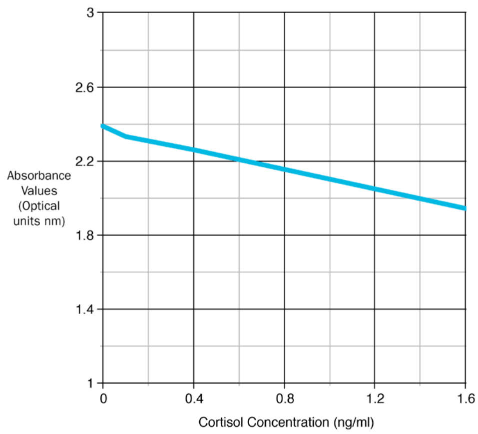

Figure 12. Standard curve plotted using the mean absorbance (optical units) obtained from the calibration samples 0.0 to 1.7.

The resulting absorbance (in nm) from the ELISA test were analyzed using a two tailed unequal unpaired sample variance T-test. Absorbance values were measured for samples taken just before the departure of the owner T_d and for samples taken just after the return of the owner T_r. The absorbance values of T_d and T_r do not differ greatly from each other due to the relatively short amount of time between taking samples. A comparison was made per individual subject between the measured conditions (unstimulated and stimulated) (Figure 13).

No comparisons were made between subjects. This is due to the fact that cortisol concentrations are known to possibly differ greatly between individuals and because cortisol concentrations fluctuate throughout the day, following a circadian rhythm. Only comparisons within the individual subjects are made.

	Subject A		Subject B		Subject C	
	Unstimulated	Stimulated	Unstimulated	Stimulated	Unstimulated	Stimulated
N	10	10	10	10	10	10
MIN	2,30	2,26	2,18	2,32	2,31	2,34
MAX	2,39	2,37	2,37	2,41	2,39	2,42
MEAN	2,34	2,32	2,30	2,38	2,36	2,39
SD	0,02	0,04	0,06	0,03	0,02	0,02
MN(U)-MN(S)	0,02		-0,08		-0,03	
T-TEST P	**0,26**		**0,003**		**0,01**	

Figure 13. The data used are not the calculated cortisol concentrations, but the absorbance values (in nm). The higher the absorbance value, (the lower the cortisol concentration and) the lower the amount of stress experienced by the dog.

No significant difference ($p > 0,05$) was found comparing the absorbance values during the unstimulated condition (2,34) and the stimulated condition (2,32) for subject A.

Comparing the absorbance values of the unstimulated condition (2,30) and the stimulated condition (2,38) for subject B resulted in a significant difference ($p = 0,003$). The absorbance values of the stimulated condition were higher than the values of the unstimulated condition. This means that subject B had lower cortisol levels during the stimulated condition, which correlates with a lower amount of stress.

A comparison of the absorbance values during the unstimulated condition (2,36) and the stimulated condition (2,39) of subject C also resulted in a significant difference ($p = 0,01$).

Although T_d and T_r values do not differ greatly, the conditions (stimulated and unstimulated) were also compared per T_d sample per subject (Table 4) and per T_r sample per subject (Figure 14 and 15). This is to ensure that the results mentioned previously were not greatly affected by the circadian nature of cortisol concentrations in the body.

	Subject A		Subject B		Subject C	
	Unstimulated	Stimulated	Unstimulated	Stimulated	Unstimulated	Stimulated
N	5	5	5	5	5	5
MIN	2,30	2,26	2,28	2,34	2,35	2,34
MAX	2,39	2,37	2,37	2,41	2,39	2,42
MEAN	2,35	2,33	2,33	2,39	2,37	2,39
SD	0,03	0,05	0,04	0,03	0,02	0,03
MN(U)-MN(S)	0,01		-0,05		-0,02	
T-TEST P	**0,65**		**0,03**		**0,30**	

Figure 14. The unstimulated condition is compared to the stimulated condition per T_d sample per subject.

No significant results (p > 0,05) were found for subject A and subject C when comparing the unstimulated condition to the stimulated condition. Significant result (p = 0,03) was found for subject B. Both subject B and C had higher absorbance values during stimulation, which correlates with a lower amount of stress during stimulation.

	Subject A		Subject B		Subject C	
	Unstimulated	Stimulated	Unstimulated	Stimulated	Unstimulated	Stimulated
N	5	5	5	5	5	5
MIN	2,32	2,26	2,18	2,32	2,31	2,37
MAX	2,36	2,35	2,34	2,40	2,38	2,40
MEAN	2,34	2,32	2,26	2,37	2,35	2,39
SD	0,02	0,04	0,06	0,03	0,03	0,01
MN(U)-MN(S)	0,02		-0,10		-0,04	
T-TEST P	**0,25**		**0,02**		**0,02**	

Figure 15. The unstimulated condition is compared to the stimulated condition per T_r sample per subject.

Comparing the unstimulated condition to the stimulated condition for the T_r samples showed no significant results (P > 0,05) for subject A. Significant results were found for both subject B (p = 0,02) and subject C (p = 0,02) when comparing the mean values of the unstimulated condition with the stimulated condition. Both results indicate that the subject experienced less stress during the stimulated condition compared to the unstimulated condition.

6.2 Video Data and Analysis

Video data was gathered for each of the subjects for each day of testing during which ethograms (Figure 7) were set up using the focal animal sampling method within a predetermined sample period of 30 minutes of each whole hour of video recorded. The ethograms provide more insight into the behaviour and the psychological state of the canine during testing in addition to the cortisol measurements taken. All actions of the subject were noted down using tally to keep score. These scores were added for each specified behaviour to present the total amount of occurence of a specific behavioural action within the sample period(s) of 30 minutes.

Due to the fact that subject A was measured for a longer period of time (3 hours, resulting in 3 sample periods of 30 minutes) compared to subject B (2 hours, resulting in 2 sample periods of 30 minutes) and C (1 hour, resulting in 1 sample period of 30 minutes per recorded video) and due to some variation of length in video recordings within the video data recorded per subject, the scores (tally) were converted to percentage of behaviour performed over the duration of the sample period.

Furthermore the amount of time the subject was visible in the video was noted. The behaviours performed within the range of vision from the video were calculated within the period of time the subject was visible in the video. The recorded audio, which could also be observed when the subject was out of view is calculated within the entire sample period (also when the dog is out of view). Figure 11 shows the mean percentage of actions observed in the video recordings from subject A for the stimulated condition and the unstimulated condition and the difference in occurence of these actions.

Mean	Stimulated	Unstimulated	Difference
BA	3,15	0,14	-3,01
WH	0,93	0	-0,93
HO	0,37	0,14	-0,23
IV	4,37	81,7	77,33
LO	36,93	1,54	-35,39
OE	26,65	15,46	-11,19
GR	0	6,95	6,95
YA	0	0,10	0,10
PA	0	78,52	78,52
EX	0	0,29	0,29
LL	0	0	0

Figure 16. The mean percentages of actions observed in the video data recorded during the stimulated condition and the unstimulated condition for subject A.

From the data obtained from subject A we can see that she showed slightly more barking, whining and howling behaviour during the stimulated period compared to the unstimulated period. All 3 vocalisation are associated with stress [63], however barking is also associated with guarding behaviour. Subject A is known to show guarding behaviour in a domestic setting and during one of the video recordings of the stimulated condition people passed by the door, causing her to start barking.

The IV (In Video) values indicate that subject A was barily observed during the stimulated condition. She was not in proximity of the digital interactive game (to which the camera was aimed). Based on the observations made during the unstimulated period, subject A was most likely performing passive behaviour at a location outside the scope of the camera. In order to video record her during the unstimulated condition, we chose to place the camera in a location that the subject would frequent more often. This resulted in the IV variable having a value of 81,70 % for the next period of testing.

What can also be noted is that subject A seems to be in locomotion (LO) and oriented to the environment (OE) more in the stimulated condition. However if we take in account that she was observed much less during the stimulated condition than during the unstimulated condition, we can conclude that the difference in the amount of LO during the stimulated and unstimulated condition is not significant and therefore most likely happened by chance. The same accounts for the variable OE.

The variable passive behaviour (PA) is observed strikingly more often during the unstimulated condition compared to the stimulated condition. This does not mean it is certain that subject A was performing more passive behaviour during the unstimulated condition, due to the fact that she might have performed identical behaviour during the stimulated condition that has not been recorded on video.

Based on observations made during the unstimulated condition we state that subject A is performing very little to no stress-associated behaviour when isolated. Although we have observed slightly more locomotion and orientation to the environment (OE) during the stimulated condition of subject A, we believe the data might be inconclusive due to the limited amount of behaviours measured within the view of the video recording.

Mean	Stimulated	Unstimulated	Difference
BA	0	23,41	23,41
WH	0	31,14	31,14
HO	0	3,82	3,82
IV	54,63	70,50	15,87
LO	33,78	16,32	-17,46
OE	41,03	88,18	47,15
GR	2,54	0,96	-1,58
YA	1,05	0,24	-0,81
PA	43,08	1,37	-41,71
EX	4,41	1,59	-2,82
LL	4,93	3,17	-1,76

Figure 17. The mean percentages of actions observed in the video data recorded during the stimulated condition and the unstimulated condition for subject B.

The amount of barking, whining and howling behaviour of subject B is remarkably lower during the stimulated condition compared to the unstimulated condition. During the recordings of the unstimulated condition we observed that subject B performed a pattern in his behaviour. He would walk a set route throughout the room, stopping at about 3 to 4 different locations to perform OE (orientation to the environment). Subject B would not perform any vocalizations until the 20th minute of the recording after which he started whining. Within about 2 minutes after the whining would commence, he would start barking and at times perform howling behaviour as well. Once the vocalizations started, these behaviours (BA, WH & HO) would continue to be displayed only to be interspersed with a few minutes of silence before the vocalizations would be continued. Subject B did perform the behaviour of locomotion (LO) on a set route during the stimulated condition, but did not engage in any vocalizations. We also noted that he often walks the same route in the presence of humans.

Subject B was more often in view during the unstimulated condition than the stimulated condition and was much more oriented to the environment. He performed more locomotion, grooming, yawning and lip licking behaviour during the stimulated condition. Locomotion is sometimes associated with stress, especially if the locomotion happens in a pattern or set route. In this case this behaviour was also exhibited in the presence of humans, which could either mean that the behaviour performed is just in his repetoir, which means he is not experiencing stress, or it could indicate that subject B is also stressed when humans are around. Frequent grooming and yawning are also associated with stress, but in this case the occurence of grooming and yawning is not considered as an indicator of stress, because the behaviours were not displayed for considerable amounts of time. Lip licking is seen as a pacifying behaviour, often used to pacify an opponent, but often is also associated with the dog being tense and stressed [63]. Sometimes the dog will yawn after licking its lips to relieve stress tension. In the case of subject B, lip licking (LL) is performed slightly more during the stimulated condition.

Subject B shows slightly more exploratory behaviour during the stimulated condition than during the unstimulated condition. Exploratory behaviour is often associated with a sense of safety. If the dog is very anxious, it will not feel safe enough to explore the environment, whereas when the dog is in a more positive psychological state it is more inclined to explore its environment. Another striking difference between the stimulated and the unstimulated condition is the amount of passive behaviour (PA) recorded. During stimulation, subject B slept considerably more than during the unstimulated condition. The general association of passive behaviour (sleeping) is that an anxious dog will remain alert (OE) to the environment whereas a calm dog will be more likely to fall asleep.

This data suggests that subject B shows more stress-associated behaviour during isolation and less stress-associated behaviour during the stimulated condition compared to the unstimulated condition.

Mean	Stimulated	Unstimulated	Difference
BA	0	6,60	6,60
WH	0	24,31	24,31
HO	0	0	0
IV	90,85	38,61	-52,24
LO	9,53	62,66	53,13
OE	7,12	85,82	78,70
GR	0	0	0
YA	0	0,23	0,23
PA	0	0	0
EX	11,09	5,30	-5,79
LL	0	0	0

Figure 17. The mean percentages of actions observed in the video data recorded during the stimulated condition and the unstimulated condition for subject C.

Subject C did not perform any howling behaviour during the video recording. The amount of barking and whining is considerably less during the stimulated condition compared to the unstimulated condition.

Subject C was much more often in view of the video (IV) during the stimulated condition than during the unstimulated condition, meaning that she was in proximity of the game about 90% of the time.

Subject C performed a considerable larger amount of locomotion (LO) and orientation to the environment (OE) during the unstimulated condition compared to the stimulated condition. During the unstimulated condition she paced back and forth throughout the room continuously. The pacing was sometimes interspersed with moments where she would often stand frozen in front of the door with raised ears. If she would then continue to move, the start of the locomotion was often accompanied by whining.

Observation data shows that Subject C performed more stress-associated behaviours during the unstimulated condition compared to the stimulated condition, where little to no stress-associated behaviour was shown.

Digital interactive game interaction

In addition to behaviours observed in both conditions (stimulated and unstimulated), behaviour involving the digital interactive game was noted during the stimulated condition and analyzed identically to the visual behaviour recorded in both conditions (Figure 18).

For subject A we can state that the game made a sound (SG) 50% of the time recorded. This is quite a large amount and can be attributed to the fact that on one of the test days recorded, the game malfunctioned and played a sound nearly the entire time.

The mean percentages of behaviours towards the game show that subject A performed explorative behaviour towards the game about 13% of the time recorded. She did not play the game, however. This could possibly be due to the fact that subject A was not taught to play the game before testing occured. Next to that, she did not follow any training courses (such as agility classes, flyball or obedience training) at the occurence of the testing. She did know basic commands, but had never worked with buttons prior to the testing.

Not knowing how to play the game might have resulted in a loss of interest in the digital interactive game.

The game made a sound 9,81% of the recorded time in case of Subject B, which means that the game initiated play by starting a sound about 2 times within the timespan of the ethogram (30 minutes). Subject B showed slightly more interest in the game compared to subject A and also performed explorative behaviour towards the dispenser by sniffing it. He did not play the game, probably because of similar circumstances as described for subject A. Subject B does know basic commands, but at the time of testing was not involved in any agility, obedience or flyball training. He also had not been taught to press a button previously. Both subject A and B showed a lot of interest in the game in the presence of humans.

The sound played by the game (SG) was more often played during the recording of subject C, this is because on the last testing day we adjusted some of the game settings to match the willingness of subject C to play the game. The standard setting for the sound to be played by the game is a duration of 2 minutes after which the game is silent for 20 minutes. In case of day 5 (of testing under the stimulated condition) we adjusted the setting to a duration of 5 minutes for the sound to play, followed by 5 minutes in which the game is silent.

The amount of time subject C is in view of the camera (and thus in proximity of the game) is 91% percent. In that amount of time she showed interest in the dispenser (EXD) and even managed to displace the dispenser (EXDO) so as to reach the treats inside. Often subject C performed this behaviour after an attempt to play the game, while it was not running (no sound was made). This behaviour lead to the adjustment of the game settings on the last day of testing.

Furthermore she showed more interest in the game than subject A and B and is the only dog who managed to play the game. Subject C knows basic commands, but (at the time of testing) was also engaged in agility, obedience and doggy dance training. Next to that she had worked with a button before.

An observation made outside the video recording is that subject C kept on showing interest in the game even if the humans had returned after isolation. In fact, if the video recording was played on a laptop in the presence of subject C and the game,she would respond to the audio (sound made by the game) in the recording by pressing the game buttons.

	Subject A	Subject B	Subject C
SG	50,74	9,81	20,23
IV	3,63	54,63	90,85
EXG	12,83	14,49	15,88
EXD	0	1,59	32,93
EXDO	0	0	30,66
PLG	0	0	6,66

Figure 18. The mean percentages of actions involving the digital interactive game, observed in the video data recorded during the stimulated condition for all subjects.

6.3 Summary

The cortisol data (absorbance in nm) shows that for subject A the absorbance value during the unstimulated condition was insignificantly ($p > 0,05$) higher compared to the absorbance value during the stimulated condition. The same can be stated for the comparison between conditions (stimulated and unstimulated) using only the T_d samples and for the comparison using only the T_r samples. The ethogram data (derived from the video recordings) and qualitative observations show that subject A performed little to no stress-associated behaviours during the sample periods observed in the stimulated condition. She did not show a lot of interest in the digital interactive game, but also did not show stress-associated behaviours during the unstimulated condition.

Subject B showed significantly higher absorbance values during the stimulated condition compared to the unstimulated condition in all analysed cases (the entire sample set, the sample set T_d and the sample set T_r). The ethogram data and qualitative observations show that subject B showed some interest in the digital interactive game. He performed a lot of stress-associated behaviours during the unstimulated condition compared to much less stress-associated behaviour during the stimulated condition.

Subject C showed significantly higher absorption values during the stimulated condition compared to the unstimulated condition for the comparison of the entire sample set and the sample set T_r. The ethogram data and qualitative observations show that she performed a reasonable amount of stress-associated behaviour during the unstimulated condition, whereas she performed no stress-associated behaviour during the stimulated condition and showed a great amount of interest in the dispenser and the game.

7. Discussion

This experiment was set up to explore the question: ***is it possible to improve a canine's psychological state during isolation at home, using the presence of a digital interactive game that can be played by the canine without human interference?***

Since cortisol concentrations can greatly differ among individuals and since the moment of obtaining T_d and T_r samples differed per subject, comparisons were only made within the individual subject and not between subjects. Furthermore, we can only formulate answers within the context of the individual subject rather than generalize the results over the population of dogs, due to the fairly small sample size of this study.

From the obtained results we can conclude that for subject A the presence of a digital interactive game that can be played without human interference does not improve nor diminish the psychological state of the subject. We base this conclusion on the fact that absorbance levels measured were (insignificantly) higher during the unstimulated condition compared to the stimulated condition and passive behaviour during the unstimulated condition was frequently performed. Subject A does not appear to experience stress when isolated from the human owners, but instead performs frequent passive behaviour (sleep) while isolated, which is associated with being calm (and therefore not stressed). This association is based on a comparison with identical behaviour performed by subject A in the presence of humans. We can argue that a dog that is not stressed when isolated will also not be in need of improving its psychological state and that a neutral psychological state during isolation will show less improvement if improved compared to a negative psychological state that is improved. Note that with improved psychological state we mean that the dog is no longer in an anxious (negative) state and possibly even in a happy (better than neutral) state of mind.

From the obtained results for subject B we conclude that the presence of a digital interactive game that can be played without human interference does improve the psychological state of the subject. In order to rule out habituation the conditions (stimulated and unstimulated) were interchanged between subjects. Although, due to the limited sample size, habituation might have occured, we argue that the possibility of habituation having occured exactly in the period between the two conditions (vocalisation during the unstimulated condition and no vocalisation during the stimulated condition) is more unlikely than the digital interactive game having a positive effect on the psychological state of subject B. He appears to experience stress when isolated from the human owners and experiences less stress when accompanied by the digital interactive game, as observed in the video recordings. We base this conclusion on the frequent vocalisations performed by subject B at set intervals during the unstimulated condition compared to no vocalisations during the stimulated condition. According to A. Miklosi [6] the longer the period of silence in between the moments of barking, the more anxiety experienced by the canine. Additionally we base our conclusions on the increased amount of passive behaviour during the stimulated condition compared to the unstimulated condition and on the significant difference in absorbance values measured during the stimulated condition (2,38) and the unstimulated condition (2,30).

The results of subject C lead us to conclude that the presence of a digital interactive game that can be played without human interference does improve the psychological state of the subject. A significant difference in absorbance values was measured during the stimulated condition (2,39) and the unstimulated condition (2,36). Next to that subject C appears to have experienced a reasonable amount of stress when isolated from the human owner (unstimulated condition), whereas she appeared to experience no stress during the stimulated condition. This is based on the ethogram data that shows a reasonable amount of stress-associated behaviours during the unstimulated condition compared to no stress-associated behaviours during the stimulated condition and and qualitative observations. Furthermore subject C showed a lot of interest in playing the digital interactive game even outside the context of the experiment.

There are quite some limitations that could have influenced the results of this explorative study. Firstly, the sample size of this study was fairly small. And the sample group was heterogeneous, disabling us from generalizing any conlusions over the breed of dogs or even the population. The study would be greatly improved if the sample size is enlarged, and the sample group more homogeneous, which would result in a larger data base and would allow for validated generalizations. That being said, however, this pilot study does suggest that a pattern could be found in a larger sample group.

Secondly, the experiment was conducted during the months of July and August in which the summer holiday is celebrated by many Dutch people. This means that dog owners participating in the study often did not leave their house for long periods of time, which they would have if they did not have holidays and would go to work. This resulted in the periods of isolation being relatively short, causing the cortisol concentrations in the samples taken before departure and after return to differ only slightly. Next to that the short periods of isolation do not resemble the common daily situation wherein dogs are often isolated for much longer periods of time. However it could be possible that the effects measured in this study would only be enlarged if conducted over a longer sample period. Apart from shorter sample periods it was also more difficult to find participants willing to leave (and return to) their house at a set time during a period of 10 days. This would be easier if participants had somewhere to be in those set times (such as work).

Furthermore, this study has shown that the game is not suitable for every type of dog. A dog that is not stressed or bored when isolated, who does not have the urge to be active or to be mentally challenged will not find itself attracted to engaging in gameplay with the digital interactive game. A dog that is in need of mental stimulation and known to be active however might experience a lot of benefits from being able and allowed to play the game during isolation. Dogs with these personality traits often descended from certain breeds such as Border Collies, Australian shepherds, Mallinois and Dutch shepherds. It might be interesting to test the interaction of dogs of these breeds with the digital interactive game.

Dogs with these traits are often the dogs that develop separation anxiety issues. The digital interactive game could not only be used to treat separation anxiety, but possibly also be used as a method to raise and train these types of dogs in order to prevent the development of separation anxiety related issues. We would like to note that our attempt to improve the canine's psychological state through gameplay mediated by a digital interactive game is an attempt to improve the quality of life experienced by the canine during isolation. It is not meant to enable a lengthening of the isolation period.

Another improvement that could prove to be a good addition to this study would be to train the subjects into using the game. In this case 2 out of 3 subjects had never worked with a button before, which made the threshold to start interacting with the game higher. Subject C did know how to operate a button and was also more inclined to perform the action of pressing the button. In this study the dogs were not trained due to the limited amount of time in which to obtain the results. A study that could be conducted over a longer timeframe could incorporate training subjects how to play the game, ensuring that every subject is familiar with the game.

In this test we decided to not use any treats during the unstimulated condition, whereas treats were used to reward the subject during the stimulated condition. One could argue that the presence of the treats themselves could have altered the psychological state of the subject and that treats should have also been dispensed during the unstimulated period. The treats were observed as part of the entire digital interactive game and thus, if the treats had an effect of the psychological state of the subject, it is an effect that results from the presence of the entire game. For future research deconstructing the game elements and testing them individually would provide valuable insights as to which game component has a certain effect.

One could argue that training a dog to play the game and subsequently having it play the game to ensure a positive state of mind is in fact a method of changing behaviours known as shaping. Some might argue that shaping a dog's behaviour would be in conflict with the aims described in ACI, since we are training the dog to perform specific behaviours that it might not have developed by itself. We would like to clarify however that ACI aims to influence the development of interactive technology to improve an animal's life expectancy and quality, by facilitating the fulfilment of their psysiological and psychological needs; under which technology that provides entertainment is consistent with this aim. [13] The behaviour performed in order to play the game is partially based on the intuitive behaviour of the dog (namely listening for sounds and locating them) and the behaviour that is needed to operate the game is easy to learn for many dogs. We would like to compare teaching a dog to listen to the sound and press a button to teaching a human how to use a mouse or a keyboard. Also we believe the digital interactive game has the potential to foster the relationship between humans and dogs by connecting the human and the dog through the training that needs to be undertaken to play the game; human and dog can play the game together, and by providing the dog with a means of entertainment that is not dependent on the human.

8. Future Work

Future work based on this study could include performing this test, using the digital interactive game on a larger, more homogeneous sample group. Including more cameras to capture the subject's behaviours would drastically improve the data set needed for the ethograms.

Also, the digital interactive game could be further developed to provide better tailored entertainment for dogs. The digital interactive game as it is at the moment, has the option to become to become a more complex game involving more speakers and buttons. The system could be designed in such a way that the program guides a dog throughout different levels, starting with a very simple interaction (e.g. hearing sound from only 1 available speaker and pressing the button to get a treat) to build up to more complex interactions (e.g. several speakers with buttons during which a sequence must first be completed in order to obtain a treat) in order to keep up with a dog's learning curve.

The option to include a button for the dog to initiate play by pressing the button was included in the game, but not utilized during this study. The game with 2 buttons was already quite challenging for our untrained subjects and adding another button would most likely only cause confusion at this point in time.

Also, the speakers used for this digital interactive game were rather large and heavy. The buttons used were wired, which meant that the wires had to be taped to the ground to ensure the safety of the dog and to ensure that the button would not be damaged. A future improvement could be to incorporate the button within a speaker (or the other way around) and make these wireless, so the objects could also be hidden in the domestic environment, possibly making the game more fun and more intuitive for dogs.

In conclusion, there is still a lot of work to be done in order to provide canines with a means of entertainment that enables them to become less dependent on their human owners, while simultaneously creating a more healthy connection between them. The evidence of this study suggests that accomplishing this is certainly possible.

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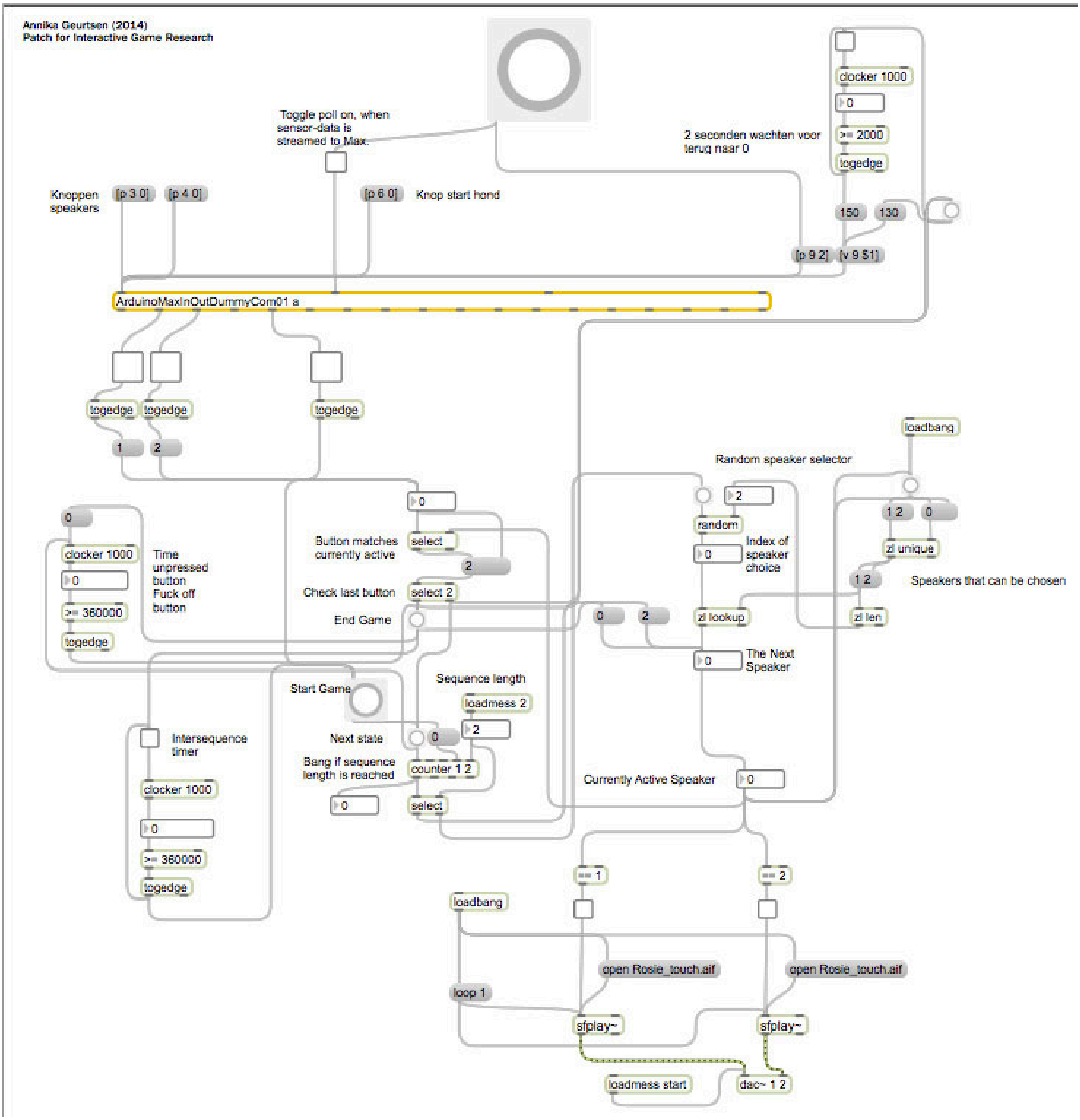
10. Appendix A



written in MAX MSP consists of several parts:

· An Arduino-MAX MSP module that enables communication between MAX MSP and the Arduino about whether the buttons are pressed or not and to which position to move the servo.

· A random generator that produces a random number (1 or 2) to determine which speaker should emit the sound.

· A controller that checks whether the button pressed by the dog matches the currently active speaker (the speaker emitting a sound). If the pressed button matches the currently active speaker, a signal is send to the timeout timer and the random generator.

· A timer that controls the amount of time the speaker emits the sound. The timer is set to 2 minutes, to ensure the dog does not get annoyed or driven crazy by the sound emitted by the speaker.

· A timeout timer that controls the amount of time the game is set on timeout. This timer is set to 20 minutes, to ensure the game does not continuously initiate gameplay during the period of testing.

· Audio controll containing objects to open and loop recorded .aiff files (to be emitted by the speaker).