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Human emotion recognition in laboratory beagles

Master Thesis

Zagreb 2015

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SAŽETAK RADA:

Ovaj diplomski rad istražio je kako laboratorijski psi pasmine beagle, koji su uzgojeni u uvjetima ograničene interakcije s ljudima, odgovaraju na različite izražene osjećaje na ljudskim licima. Glavno pitanje bilo je koji su mogući utjecaji tipa osjećaja i poznavanja osobe predstavljene na fotografiji, na vizualnu pažnju i otkucaje srca laboratorijskih pasa pasmine beagle. Nakon provođenja eksperimenta pomoću tehnike praćenja pogleda uz simultano mjerenje otkucaja srca, glavni dobiveni zaključci su da poznavanje osobe predstavljene na slici ima važnu ulogu, te da područja oči i usta ljudskog lica najsnažnije privlače pažnju pasa. Bez obzira na razlike u uvjetima odrastanja između laboratorijskih pasa i pasa kućnih ljubimaca, psi su bili sposobni uočiti važne djelove ljudskog lica, što ukazuje na činjenicu da je sposobnost percepcije i prepoznavanja na licima izraženih ljudskih emocija urođena vrsti pas, te postupno usavršavana procesom socijalizacije.

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Master Thesis

HUMAN EMOTION RECOGNITION IN LABORATORY BEAGLES

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ABSTRACT

This thesis has explored the ability of laboratory dogs (breed beagle), which have been raised in conditions of limited interaction with humans, to respond to emotions expressed in human faces. The main addressed question was of possible influences of emotion and familiarity of human faces on both the visual attention and the heart rate of laboratory beagles. After conducting the eye-tracking experiment with simultaneous heart rate measurements, main gained conclusions are that the familiarity of person presented on picture plays an important role, and that the area of eyes and mouth of the human face are the strongest attention attractors. Regardless of the difference in social environment between laboratory beagles and average pet dogs, the beagles were able to direct the attention to the important parts of human face, which suggests that the ability of perception and recognition of human emotions expressed in faces is in the species, and is gradually enhanced through the process of socialization.

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1 Introduction

In the last few decades, the nature of the human–animal interaction has been the subject of numerous scientific studies. The recognition of human emotions by animals, as an important aspect of human-animal interaction, has recently gained a high amount of attention. As the main (and most controllable) mean of human communication, facial expressions of emotions have been an especially interesting subject of research. In order to consider the recognition of human emotions from facial expressions, it is important to address the question in which way the animals understand human emotions. Furthermore, it is of high relevance to know whether such an understanding is influenced by genetic predispositions of a species, the domestication process, ontogenetic factors or a combination of all of them, and if so, by which extent do they each contribute.

1.1 Emotions and facial expressions of emotions

Neurobiologists and psychologists have conceptualized that an emotion is a concerted, generally adaptive, phasic change in multiple physiological systems (including both somatic and neural components) in response to the value of a stimulus (Damasio 1995, Scherer 2000).

There is a distinction between the emotional reaction (the physiological emotional response) and the feeling of the emotion (presumed in some theories to rely on a central representation of this physiological emotional response) (Damasio 1999). An emotional response typically involves concerted changes in a very large number of somatic parameters, including endocrine, visceral, autonomic, and musculoskeletal changes.

In humans, facial expression is one of the most important emotional responses. Humans are highly efficient in communicating emotional states through the stereotypic posturing of facial elements, and the large repertoire of expressions is enabled by elaborated facial musculature. The emotional expressions which are being seen can directly influence the viewer's emotional state, and the appearance of the eyes is used as a particularly salient emotional cue.

1.2 Face recognition

To be able to recognize an emotion shown by a facial expression, the viewer has to have the ability of face recognition as a prerequisite.

The process of face recognition has been an object of interest in various scientific disciplines ever since Darwin's "The Expression of the Emotions in Man and Animals" (Darwin 1872). Cognitive psychologists have been interested in this phenomenon since there is evidence that faces are somehow perceived differently than other patterned objects and may represent a "special" class of stimuli. Cognitive neuroscientists are tackled by evidence that this ability employs discrete neural circuits and represents a specialized brain function. Finally, evolutionary psychologists research the topic because face recognition appears to be a special ability selected through evolutionary pressures and conserved across species (Nelson 2001).

Prior to defining the process of face recognition, it is important to note that there is a distinct separation between the processes of perception and recognition, which was first made on the basis of clinical findings (Lissauer 1890). Perception refers to processes occurring relatively early in time subsequent to the onset of stimulus, which rely on early sensory cortices and achieve processing of the features of the visual image and their configuration. In this sense, it enables performance on tasks that require judgments to be made solely about the visual, geometric properties of stimuli. Recognition, on the other hand, requires additional knowledge that could not be obtained solely from an inspection of the visual features of the stimulus. It requires knowing something about the world, and having a memory. While in its simplest form recognition could operate on the basis of only perceptual information, full-fledged recognition of emotions from facial expressions requires additional knowledge about the link between the expression and many stimuli with which that expression has been associated.

A human face is providing the viewer with configural information necessary for further processing and recognition. There are many types of information a face might convey, including gender, age, identity, emotion, or other socially relevant details. There is evidence to suggest that recognition of most of these classes of attributes can be dissociated (depending on how finely one decides to carve up the categories). The information which the faces provide us with can be separated into two orders of facial configuration. The first-order configuration refers to basic arrangement of a face (eyes are above the nose, the nose is above the mouth etc.) and it is important for discriminating faces from other visual objects. The second-order configuration refers to relative spatial arrangement of facial features with regard to one another, and it is recruited especially when viewing the face right side up (Searcy and Bartlett 1996, Yin 1969, Young *et al*. 1987). Since it's unique in every face (Diamond and

Carey 1986), there is a general agreement that second-order configural cues provide the information needed to discriminate between individuals. In primate social cognition, face recognition is one of the most important social skills, enabling the formation of long-lasting inter-group relationships (Maurer *et al.* 2002, Farah *et al.* 1998). Among humans, it is supported by a variety of neural and cognitive specializations, suggesting that it plays an important role in shaping human societies. Humans are able to recognize and remember many different individuals over a lifetime, often with only mere exposure. For this, they predominantly use holistic processing of a face, meaning it is the second order configuration, and not only the specific features (eg. eyes, nose, mouth) that matter.

As a face-perception related review (Leopold and Rhodes 2010) points out, other non-human primates are also very skillful in face recognition. Chimpanzees are able to recognize both conspecifics and human face identities, and thereby use second-order configuration processing. They also possess a broad repertoire of facial mobility, making expressions especially with lips and eyes, and can interpret other conspecifics' expressions, as well as human expressions, when seen either live or on photographic images.

On the other hand, while monkeys do seem to be able to recognize conspecifics' and in some cases humans' face identity, they seem to use a different strategy to do so. For example, rhesus monkeys process faces as a unique category of visual stimuli using a combination of configural- and holistic processing strategies, but have not evolved a mechanism for representing individual identity as robust as the one in chimpanzees and humans. However, it is certain that all primates have an innate attraction to face-like configurations, and strong preferences for scanning the eyes (Parr 2011).

1.2.1 Recognizing emotion from facial expression

The recognition of emotion from facial expression has been the focus of a large number of psychological studies over the past several decades. Findings from a wide array of neurobiological experiments (lesions, EEG, MEG, PET and fMRI) have provided ample evidence that recognizing facial emotions draws on multiple strategies subserved by a wide array of brain structures. Moreover, a study in 2001 (Calder *et al.* 2001) found that expression and identity information from faces exhibit different statistical regularities from one another, such that principal components for reconstructing emotional expressions were mostly different from the components for reconstructing identity. The dissociation might take place by processing in subsystems that are distinct already at the level of perception (Bruce and

Young 1986), and computational modeling of face perception provides some evidence to support this scheme. There is some evidence that feature-based processing (i.e. based on geometric properties of facial expressions) could be sufficient, in principle, to classify facial expressions into basic emotion categories (Cottrell *et al.* 2001) (coming from computer models that demonstrate such an ability). However, other studies in human subjects indicate that perception of facial emotion requires at least some configural processing of the relations between multiple facial features (Calder *et al.* 2000). The step for processing expressions might be different from processing other facial information because it already requires some recognition. Evidence to support this view comes from the finding that many of the neurological dissociations reported in fact rely on tasks at the level of recognition (that is, the dissociations concern category-specific agnosias rather than impairments in basic perceptual ability). Overall, processing of facial expressions draws in part on relatively specialized routes already at the level of early perception and in part on higher level conceptual knowledge. It is also possible that choice between feature-based processing and configuration-based processing depends on emotion type (for example, for a happy emotion seeing the mouth shaped into a smile suffices, while for precise recognition of negative emotions, more features might be required).

Facial expressions of emotion are grouped into discrete categories, and although there is even evidence for categorical perception of such facial expressions, it is also clear that expressions are typically members of multiple emotion categories, that the boundaries between categories are vague at the level of recognition (Russell and Bullock 1986), and that the categorization of an emotional facial expression depends to some extent on the contextual relation to other expressions with which it may be compared (Russell and Fehr 1987).

Furthermore, some cross-cultural studies in humans have argued that the category of emotion expressed by the face is in fact in the eye (and in the cultural background) of the beholder (Russell 1994). However, the whole answer seems to be that categories can be shaped both by perception and by recognition, depending on the circumstances.

In his review, Adolphs (2002) described two previously mentioned hypotheses on mechanisms of recognizing emotion from faces: a) recognition being purely a part of perception (where the ability to discriminate, categorize and identify emotions is based solely on geometric visual properties of the stimulus (Ullman 1995) and b) recognition via the generation of associated knowledge (meaning that knowledge about the emotion isn't present

in the structure of the stimulus but in the past experiences, and separate neural representations need to come together to be processed as components of knowledge about the same concept (Edelman 1987)). Following these, Adolph's review also adds a third hypothesis of c) recognition via the generation of a simulation (which attempts to generate conceptual knowledge using an inverse mapping that seeks to trigger those states normally antecedent to producing the facial expression). In other words, the third hypothesis assumes that once the observer generates the state s/he's presumed to share with the other person, reproduction of the state could trigger conceptual knowledge. So far, neurological experiments with monkeys (Gallese *et al*. 1996, Gallese and Goldman 1998, Rizzolatti 1996) and humans (Strafella and Paus 2000, Iacoboni *et al*. 1999, Dimberg 1982) have supported the mechanism of recognition via the generation of a simulation. The importance of the third hypothesis is connecting the process of face recognition to the process of emotional contagion, a highly important phenomenon necessary as a predecessor for empathy. If we can demonstrate the ability of facial recognition of emotions, we might be on the way to prove animals indeed can understand human emotions and furthermore might have a way of "empathizing" with those emotions.

1.2.2 Left-side gaze bias theory

When dealing with face expressions, humans significantly prefer viewing the left side of the stimulus (right side of the observed person's face). This phenomenon has by now been confirmed by many neurological, psychological (for example Somppi *et al.* 2014) human as well as animal eye-tracking (Racca *et al.* 2010) studies. Left gaze bias has therefore been defined as the higher probability of first gaze and a higher proportion of viewing time directed at the left hemiface (from the viewer's perspective), when actively exploring face images.

Although for a long time it was argued that human visuospatial attention bias is anyways to the left visual field (Niemeier 2007), and in some cultures a long practiced left-to-right directional scanning bias (most notably, reading) may contribute to this gaze asymmetry (Heath *et al.* 2005), the likely cause of left side bias is the right hemisphere's general advantage in face processing (Burt and Perrett 1997).

To address the question of the origin of left-side bias, a comparative study was done in humans, rhesus monkeys and dogs, where the subjects were presented a normal face image, inverted face image and non-face image (Guo *et al*. 2008). In humans, only adults showed a left-gaze bias for normal face images, while infants seemed to have the same bias for all

stimuli. This led the authors to conclude that the aforementioned bias is an acquired behavior. The bias was not only limited to humans, as laboratory-raised monkeys showed a left-gaze bias towards normal faces of conspecifics and humans, and pet dogs only towards normal human faces, but not monkey or dog faces, nor towards object images. Since all dogs in the study were well socialized to both people and other dogs, the authors argued that the bias towards human faces alone can not be explained simply in terms of lack of exposure to conspecifics, but that it may have a more fundamental phylogenetic origin.

Though the topic of fixation angles might seem very complex to explore, in the recent research on visual fixations in face recognition in humans, it has been stated that two first fixations are actually sufficient to recognize a face. The first fixation (representing the gaze bias) usually lands to the left of the center of nose, while the second on is the center of the nose (preferred landing position) (Hsiao and Cottrell 2008).

1.2.3 Development of emotion recognition in humans

When talking of emotion recognition, an important question comes up: is the mechanism innate or learned through experience? Moreover, could a mechanism similar to the one found in humans be applied in primates in general, as well as in other mammals?

Starting with humans, according to a common sense theory, facial expressions signal specific emotions to people of all ages. The „basic emotion“ theory claims that six (plus one or two) basic emotions (happiness, surprise, anger, disgust, fear, sadness) are universally recognized by all human beings, regardless of their cultural background. However, in his review, Russell (1994) criticized methods used in cross-cultural research (response-format, within-subject design, posed facial expressions etc.), leading to conclusion that although facial expressions and emotion labels are probably associated, the association may vary across cultures. Moreover, it seems that facial expression of a “happy” emotion is the most universally recognized one, while negative emotions are harder to recognize, especially among isolated non-western cultures.

In order to eliminate the effects of culture and the experience gained through social learning, research has in the meantime turned to children, with focus on the question of whether facial expressions are indeed signals which are easily and innately recognized (Widen 2013), or the knowledge comes with the experience. For preverbal children, knowing the meaning of facial signals would have adaptive value (Denham 1998), however, many findings are inconsistent with the aforementioned assumption.

Therefore the second hypothesis arose, suggesting that emotion categories are acquired gradually and change over the course of development. Children seem to lack an innate system of universal categories linked to faces, and interpreted facial expressions more easily in terms of valence (positive or negative), level of arousal etc. (Carroll and Russell 1996, Widen and Russell 2008). Infants younger than 10 months respond emotionally and behaviorally to the valence of facial expressions, but do not interpreted faces in terms of discrete negative emotions (Caron *et al.* 1985). Infants and toddlers beyond 10 months of age can use valence of facial expressions to guide their own behavior in ambivalent situations, but this finding still does not indicate that they recognize or discriminate specific emotions from facial expressions (Klinnert *et al.* 1986). Research investigating whether emotion categories (based on the visual spatial parameters of facial expressions) develop in similar fashion to those that also recruit lexical knowledge of emotion terms concluded that the ability to recognize and label different facial expressions continues to develop well into school years and overall performance improves at each age level. Once again, the „happy" expression was the fastest to be learned, while negative emotion recognition developed over more years, showing that emotion-recognition abilities do not emerge as a coherent package (Vicari *et al.* 2000).

These findings suggest that, though it seems as emotion recognition should be something innate and universal, the ability enhances through experience and relating a certain facial expression with given context. If among their own species the ability to recognize human facial expressions of emotions is learned, it is possible that such a skill could be obtainable even to other animals, if they are given enough exposition to human facial expressions and the contexts when they appear.

1.2.4 Emotion recognition in non-human primates and other mammals

In her review on universals and individuality in facial behavior, Gaspar (2006) states that, when talking of non-human primates, some facial expressions are shared across a broad range of species, while some others are distinctly species-specific and highly stereotyped. Furthermore, as well as with humans, in non-human primates some facial expressions are inborn, while others are learned socially (eg. rhesus monkeys show inborn recognition of facial expression of fear (Sackett 1966).

Primates in general are endowed with a broad range of facial expressions, owing to an elaborate facial musculature when compared to other mammals. The matching-to-sample

experiments so far done on chimpanzees, rhesus macaques and Japanese monkeys show that they all have the ability to recognize and differentiate between different facial expressions of conspecifics (Parr 2003, Parr and Heintz 2009, Kanazawa 1996).

As stated in a review by Tate *et al.* (Tate *et al.* 2006), despite the fact that their facial musculature is less elaborate, experiments with other mammals show that sheep (da Costa *et al.* 2004, Tate *et al.* 2006), cattle (Sandem *et al.* 2006) and dogs (Fox 1970, Lorenz 1963) are able to produce and recognize some facial expressions, especially the expression of fear (and, in the case of dogs, aggression).

When it comes to recognizing human emotions, research with primates shows that chimpanzees can learn to categorize human facial expressions through experience (Parr 2003, Parr *et al.* 1998). On the other hand, an experiment with Japanese macaques (Kanazawa 1996) shows their ability to recognize the „happy“ face as well as their inability to differentiate between „anger/disgust“ and „sad“ facial expression. It is probably owing to the fact that the difference between the last two mentioned expressions lies in the upper parts of the face, which japanese macaques do not use and therefore also do not perceive as important. When related to the previously mentioned hypothesis of recognition via simulation generation mechanism, the macaque study sets the important question whether animals are able to recognize a human emotion even when the configuration of the expression is not typical for their own breed.

1.3 Perception of human faces in dogs

1.3.1 Human-oriented visual attention in dogs

In recent years great attention has been dedicated to dogs' cognitive abilities. This species, which was once considered ethologically “uninteresting”, has recently become subject of scientific inquiry in the field of comparative cognition (Miklósi *et al.* 2004, Miklósi 2007). From the studies of canine social cognition, it emerges that dogs' success as domestic animals and their capacity to become „man's best friend“ are rooted in a wide range of social skills and competencies that allow them to engage in complex communicative, relational and cooperative interactions with humans (Miklósi and Topál 2013).

Overall studies suggest that dogs tend to be better at adjusting their behavior to the owner's demands than other companion animals (Lago *et al.* 1983). This includes their high

ability to coordinate behavior (standing, moving and sitting in synchrony with the owners). Dogs are known as being keen observers of human movements and gestures and in order to be able to understand and make use of human movement and gestures, have to selectively allocate perceptual and cognitive resources to the detection and processing of particular social aspects of the environment - this process is called orienting of attention.

Numerous studies using object-choice tasks employing human-given cues have demonstrated that dogs are experts in following human gestures to find hidden food (Miklósi and Soproni 2006, Reid 2009). Moreover, recent research has shown that dogs' high level of attentiveness towards humans is unique even in the canine family. In a publication by Miklósi and al., an investigation was done to compare interspecific communicative abilities of dogs and wolves which were socialized to humans at comparable levels. It revealed that, though socialized wolves were able to locate hidden food indicated by touching and pointing cues by a familiar human, their performance remained inferior to that of equally socialized dogs (Miklósi *et al.* 2003).

If we want to understand how humans and dogs have managed to achieve such a high level of attention towards humans, we should look beyond the event of domestication, to see why it would be necessary for dogs or wolves to develop a new set of social skills which would enable them to predict and manipulate other agents' behaviors (Schultz and Dunbar 2007). It is obvious that individuals benefit from creating, discovering and taking advantage of others' solutions to ecological challenges. Evolution of such skills has been related to hunting patterns of a species. As we know, the gray wolf is a cooperative hunter, and in order to make a successful hunter, the species had to develop these forms of social behavior. In order to effectively predict other co-hunters' moves, a wolf had to be able to integrate different sensory information automatically through time, which is relevant to understand the basis of social cognition in wolves and their descendants, dogs.

Besides the research done to compare wolf skills with dog skills, the research comparing differently socialized dogs shows there are differences when it comes to their attentiveness towards humans. The Bar Harbor studies (Scott and Fuller 1998) have established four developmental stages in a young dog's life, one of which has been named the “socialization period” and lasts from approximately 2.5 to 9-13 weeks of age. It seems that the socialization period is of critical importance (or at least a „sensitive“ period) for the development of the dog's attention towards humans (Scott 1962). The nature of the whole

experience is what determines a young animal's future social partners and defines the species to which it effectively belongs and gives attention to.

1.3.2 Human face perception in dogs

When dealing with the question of dogs' perception and recognition of the human emotion expressions, the starting point is determining whether dogs are at all able to discriminate face as a special feature among other objects. The question of discrimination, based on visual cues alone, has been approached by a study (Racca *et al.* 2010), where dogs were presented with a human face, a dog face and an inanimate object. The results were positive, extending the group of animals capable of differentiating individual faces based on visual cues alone (ie. beyond humans, some non-human primates, sheep and heifers) to domestic dogs. The same study also dealt with the question of face inversion effect in dogs. The face inversion effect (FIE) is one of the most studied phenomena in face perception research because it has been considered as evidence of specialized brain mechanisms. An inversion response happens when a facial image is inverted, and global processing is disturbed so that faces are harder to recognize as the stimulus has to be processed element by element, like non-face objects (Scott 1962, Tanaka and Farah 1993). Racca et al.'s study suggested that dogs exhibit a non-specific inversion response (towards images of dog and human faces and objects). This would on its own lead to the conclusion that the dogs employ a similar cognitive strategy in processing of dog faces, human faces and common objects; however, a previous study contradicts these findings, as dogs seem to present a different gaze-bias strategy while viewing human faces compared to dog faces and objects (Guo *et al*. 2009) (for further details see subchapter 1.2.2). Another study on human face discrimination by dogs (Huber *et al*. 2013) examined the dog's ability to discriminate the faces of two familiar persons by active choice (approach and touch). The authors found that at least some dogs can discriminate pictures of familiar humans, even if only shown the inner parts of the face, thus providing strong evidence that dogs can discriminate people on basis of visual information from their faces.

Following the confirmation that dogs can distinguish human face as a specific stimuli, the proceeding studies approached questions of dogs' ability to distinguish different facial expressions and the mechanisms (i.e. order of facial recognition) which they might use for it. When presented a two-choice discrimination task with sets of photographs of the owner's

smiling and blank face, the dogs selected the owner's smiling face significantly more often than expected by chance (Nagasawa *et al*. 2011). The results were the same for sets of photographs featuring the same expressions made by strangers, but the dogs were more likely to successfully discriminate the two facial expressions if the owner and the stranger were of same sex. This suggests that dogs can learn to discriminate human smiling faces from blank faces by looking at photographs, but the previous experience plays an important role for the success of learning.

Recognizing smiling from blank faces confirms the ability to discriminate faces according to one single feature (mouth). However, it does not speak of the mechanism generally used for such discrimination. Therefore in 2014 another study (Pitteri *et al*. 2014) examined whether dogs perceive face as a whole or elaborate it through its parts (mouth, eyes etc.). The study concluded that, although the reliance on part-perception may be increased by specific experience, human face discrimination by dogs relies mainly on configural elaboration.

With the technique of eye-tracking being introduced into the field of animal studies, it became possible to further examine the dogs' patterns of visual processing, especially when it comes to two-dimensional images as stimuli. An eye-tracking study (Somppi *et al*. 2012) presented dogs with digital color images of human faces, dog faces, toys, and alphabetic characters, and found that dogs focused their attention on the informative regions of the images without any task-specific pre-training; their gazing behavior depended on the image category, supporting the assumption that they do look at and visually explore 2D images.

A following study by the same research group showed that, when presented images of familiar and unfamiliar upward and inverted human and dog faces, the dogs preferred conspecific faces and showed great interest in the eye area (Somppi *et al*. 2014). Also, familiar faces and eyes gathered more fixations than strangers, leading to a conclusion that dogs are also likely to recognize conspecific and human faces when presented photos.

The past studies give us an important foundation for testing. They confirm that dogs are indeed capable of visual exploration and differentiating of human faces in whole as well as based on distinct parts. To do so, the visual stimuli can also be a 2D image, making the testing setup easier.

Furthermore, the previous studies still leave some open questions to answer. For instance, a little amount of attention has so far been given to the patterns of viewing the stimuli according to familiarity of the presented face. A behavioral study made on topic of dogs' selective attention towards humans (Mongillo *et al*. 2010) has shown that their visual attention changes according to familiarity (preferential attention is given to the owner compared to unfamiliar person). Therefore current study deals not only with recognition of emotions, but also with the impact of familiarity on viewing patterns.

1.4 Research on visual attention – eye-tracking

Although not the only, the eyes are an especially important source of indication of attentional and intentional states. Vision is the primary mode by which members of many gregarious species detect social cues, as well as mediating their goal directed interactions with the environment. Furthermore, when in the role of an observer, many animals use the overt eye movements of others as a proxy for their intentions and as cues towards the location of significant objects (Shepherd 2010).

For scientific observers, it is important to exploit the importance of the eye movement to improve our understanding of mechanisms of social perception - the main question to address this is where do species look for relevant information?

Nowadays technology is allowing us to study how salient environmental cues (e.g. facial expressions) are being used in many different modalities. One of the rising new technologies, the eye-tracking system, allows researchers to access participants' overt visual attention (Duchowski 2007). In previous years, research conducted using this system, has already revealed a great deal about cognitive processes underlying human behavior (Dalton *et al*. 2005, Felmingham *et al*. 2011, Gredebäck *et al*. 2009, Holzman *et al*. 1974, Yarbus *et al*. 1967). Though the use of eye-tracking technology is still preliminary (due to a number of unresolved issues, owing to the fact that it's a technology developed for humans and is only now being expanded for usage with animals), it is already being applied in non-human primates and, recently, in dogs.

The first eye-trackers were built as early as the late 1800s and were technically very difficult to make and also not very comfortable for the participants. These machines had little

in common with today's eye-tracking devices, which rely on infrared reflection and are completely non-invasive.

1.4.1 Measuring the movements of the eye

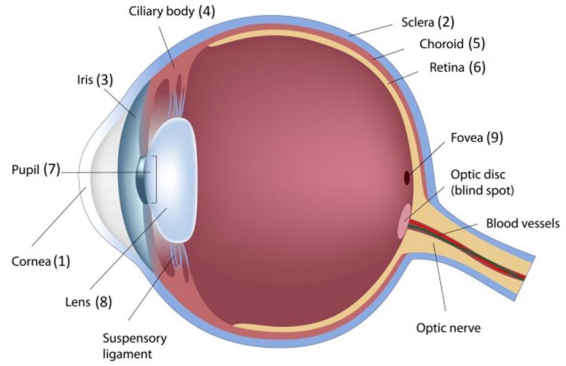


Figure 1 - The anatomical structure of the human eye The eye is built of three layers – the outer, fibrous tunic and two inner tunics: vascular tunic and nervous tunic. Fibrous tunic consists out of cornea (1) and sclera (2), and is a collagen tissue serving to protect the inner components of the eye and maintain its shape. Vascular tunic is the middle vascularized layer which includes the iris (3), ciliary body (4), and choroid (5), with the main purpose of supplying blood to retinal cells. Nervous tunic is the inner sensory layer which includes the retina (6). The retina contains photosensitive rod and cone cells, which transduce the incoming light into electrical signals sent through the optic nerve to the visual cortex for further processing. In the process of vision, the light enters the eye through the pupil (7), the image is then turned upside down in the lens (8) and projected onto the retina at the back of the eyeball. There is a spot on retina called the fovea (9), which is an area extremely abundant with cones compared to the rest of retina.

In order to understand the basic principle of eye-tracking, it is important to shortly describe the structure of the human eye (see Fig. 1), which it was primarily developed for.

The eye movements happen for a simple reason – visual acuity is only in the small area of fovea, which is an area spanning less than 2° of the visual field. Information gathered from foveal nerves is prioritized in processing due to the cortical magnification factor, and as a result about 25% of visual cortex processes the central 2.5° of the visual scene. Therefore to see any picture in detail the eye has to move.

For video-based measurement of the eye movement, there are two important elements: the pupil and cornea (covers the outside of the eye and reflects the light); when tracking the eyes of the participants, having a corneal reflection and a pupillary reflection is a desirable combination. The record is made in infrared, to avoid all natural light reflections and typically illuminate the eye with one (or more) light source. The resulting reflections are called "glint" or "1st Purkinje reflection" (P1) and pupillary reflection (P3) (see Fig .2)

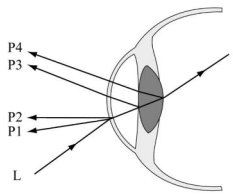


Figure 2 – The scheme of reflections used for eye-tracking

Dominating method for estimating the point of gaze (where someone looks at the stimulus) from an image of the eye is based on pupil and corneal reflection tracking; while it is possible to use pupil-only tracking, corneal reflection offers an additional reference point in the eye image needed to compensate for smaller head movements. The pupil either appears dark in the eye image (mostly, also the method used in this study), or bright, as with some systems (rare). The overall goal of image analysis is to robustly detect the pupil and corneal reflection in order to calculate their geometric centers, which are used in further calculations.

The most reported event in the eye-tracking data does not actually relate to a movement, but to a state where the eye remains still over a period of time - this state is called a fixation and last from tens of milliseconds to several seconds.

When the researcher is specifically interested in gathering data about certain defined regions within the visual stimulus, an area of interest (AOI) is created. AOIs help in answering questions such as did the participant look where expected and what were the properties of his gaze.

1.5 Somatic component of recognition reaction – the heart rate

Most of the previously mentioned studies deal with patterns of dog's gaze and the ability to recognize features of presented photographic images. However, our research had an additional component – emotion recognition. Since we were wondering not only if dogs do recognize emotions, but whether this process somehow also affects their emotional state/excitability, the additional measure of heart rate (BPM, beats per minute) as a response of the autonomous nervous system was taken. The emotions I chose belonged to the set of so-called "basic emotions" (Ekman 1992).

In their review on studying emotions in animals, Adolphs and Anderson point out that, "ever since William James, the somatic component of emotional reactions has received particular attention in emotion theories (e.g., Craig, 2008; Damasio, 2003). These somatic components involve autonomic reactions such as changes in heart rate, blood pressure, breathing, and sweaty palms, as well as changes in the state of internal organs such as the gut. Emotion state is considered pleiotropic, meaning that it has multiple, parallel effects: it influences many different aspects of behavior and also has internal somatic effects, as well as

effects on cognition. For example, responses caused by a fear-like central state not only include defensive behaviors, such as freezing or flight, but also endocrine changes such as increases in stress hormone levels; changes in autonomic function such as increased heart rate and blood pressure" (Anderson and Adolphs 2014).

Many studies so far have shown that heart rate (expressed in number of heart beats in a minute, beats-per-minute, BPM) is a reliable pointer of a stressed (higher HR) or relaxed (lower HR) state in the animal. The mechanism is well known: the autonomous nervous system influences the heart rate, having impact on depolarization of pacemaker cells to the threshold level, conduction velocity and the length of the refractory period. The neurotransmitters norepinephrine and acetylcholine influence the heart rate – while the first mentioned increases the rate of contractions in the heart by shortening the inter-beat intervals, the second one does the opposite. The predomination of either one or the other (also meaning predomination of either sympathetic or parasympathetic nervous system) determines the change in heart rate.

A study on shelter dogs combined measures of heart rate with measures of behavior and saliva cortisol and found a significant relationship, showing that human interaction has an effect upon the behavior, as well as on physiological indicators of animal's state (Bergamasco *et al*. 2010).

Typically, for measuring the heart rate, electrocardiogram (ECG) is used. However, recent studies have shown that using a simple Polar© human heart rate monitor can be sufficiently efficient, and at the same time affects the animal's natural behavior less, thus making the data more authentic (Jonckheer-Sheehy *et al*. 2012).

1.6 Research Predictions and Hypothesis

The question addressed in this thesis is: are the patterns of looking and the amount of given attention to visual stimuli influenced by the familiarity of the presented face and its emotional salience. While the main objective is assessing the pattern of dog's visual attention directed towards humans of different emotions and familiarity, in order to gain more precise insight into their level of excitement in relation to emotions on the screen, heart rate measurements have been used as supporting method.

It would be expected that, according to the type of emotion (or at least the general salience of emotion), there will be a difference in pattern of looking and the amount of given attention (duration of looking, areas being looked at the most). More precisely, we expect the participants' looking to have a longer duration when it comes to positive, rather than negative emotions (since negative emotions are assumed to present a threat or simply unpleasant experience for the participant). We also assume them to dedicate higher amount of attention to the most expressive parts of the face – the eyes and mouth.

Furthermore, we assume that familiarity of the person in the picture can make a difference to the results. Since a familiar person has a higher importance in dogs' lives (the same person who has been training them, rewarding them with food and giving affection), we assume the dogs will spend more time fixating on this face, than on the face of the unfamiliar person.

Also, changes in heart rate are expected to correlate with differences gained with eye-tracking data. We expect the heart rate to be higher when presenting the animal with visual stimuli, than in baseline states without the stimuli. Among those with stimuli, we expect that positive emotions and / or familiar faces will result in a lower heart rate, while negative emotions and/or unfamiliar faces will result in a higher heart rate.

2 Methods and materials

The study was conducted at the Clever Dog Lab NGO, which is a part of the Messerli Research Institute, Veterinary University of Vienna. Procedure was approved by the Ethical Committee for the use of animals at the Veterinary University of Vienna (09/08/97/2012).

2.1 Subjects

Sixteen dogs, all beagles, were trained for the testing (nine neutered males belonging to group 1, three intact males and four intact females belonging to group 2). The dogs belonged to the Clinical Unit of Internal Medicine for Small Animals (IM, group 1) and Clinical Unit of Obstetrics, Gynaecology and Andrology (GA, group 2) of the University of Veterinary Medicine, Vienna, and were purpose-bred at the same university. The IM beagles lived in a group of nine dogs, while GA dogs lived in a group of seven dogs (four females and three males).

The dogs were born at the GA, and were at the age of two months, if males, moved to IM (with the exception of males kept intact, who stayed at the GA department with intact females). They were housed in groups, meaning they had unlimited contact with other beagles, but no contact with dogs of any other breeds (which they did however see through the fence). The housing for both groups consisted of an indoor area where they were fed and could move into in case of bad weather, and outdoor area which enabled them more physical activity. There were short periods of contact with animal keepers (twice a day during feeding and cleaning the) and occasional contact with students (both the IM and GA dogs were used in a practical course on handling patient dogs in veterinary praxis, while GA dogs were additionally taken for walks by the volunteer students approximately 3-5 times a week). However, none of the dogs were socialized in a classical way, meaning they all kept living with their conspecifics, and not with humans, even after the age of 12 weeks.

During the training, eight (all four female together with four male) dogs had to be excluded from the testing for various reasons. Three females were excluded for reasons of entering their periods of oestrus, which significantly slowed down their training processes.

Two dogs were adopted into a family and left the campus of veterinary medicine. With three dogs there were motivational problems, and they could not be trained further.

Table 1 - List of all the dogs used in experiment; Mean(age) = 2.48 Y

Subject's name	Department	Sex	Age (Years)
Manni	Internal Medicine Department	♂ (neutered)	4.3
Fernando	Internal Medicine Department	♂ (neutered)	4.3
Stevie	Internal Medicine Department	♂ (neutered)	3.2
Billy	Internal Medicine Department	♂ (neutered)	3.2
Hektor	Internal Medicine Department	♂ (neutered)	1.2
Ramires	Internal Medicine Department	♂ (neutered)	1.2
Seppi	Gynaecology Department	♂ (intact)	1.2
Hansi	Gynaecology Department	♂ (intact)	1.2

None of the dogs had previously participated in any eye-tracking studies.

2.2 Experimental setup

The experiment was conducted in the eye-tracking testing room of the Clever Dog Lab, Messerli Research Institute, University of Veterinary Medicine in Vienna. The room was divided by a wall-sized projecting screen into the testing part and the eye tracker system operating part (see Fig. 3).

A chin rest apparatus was positioned in the middle of the testing part of the room and directed towards the screen. Placed in front of the chin rest, the eye-tracking camera recorded eye movements of the dog resting on the chin rest. There were also two video cameras (JVC Everio G- GZ MG 750, Yokohama, Japan), one recording the dog's facial expression and body posture, and the other one recording the dog from the back together with projections shown on the screen.

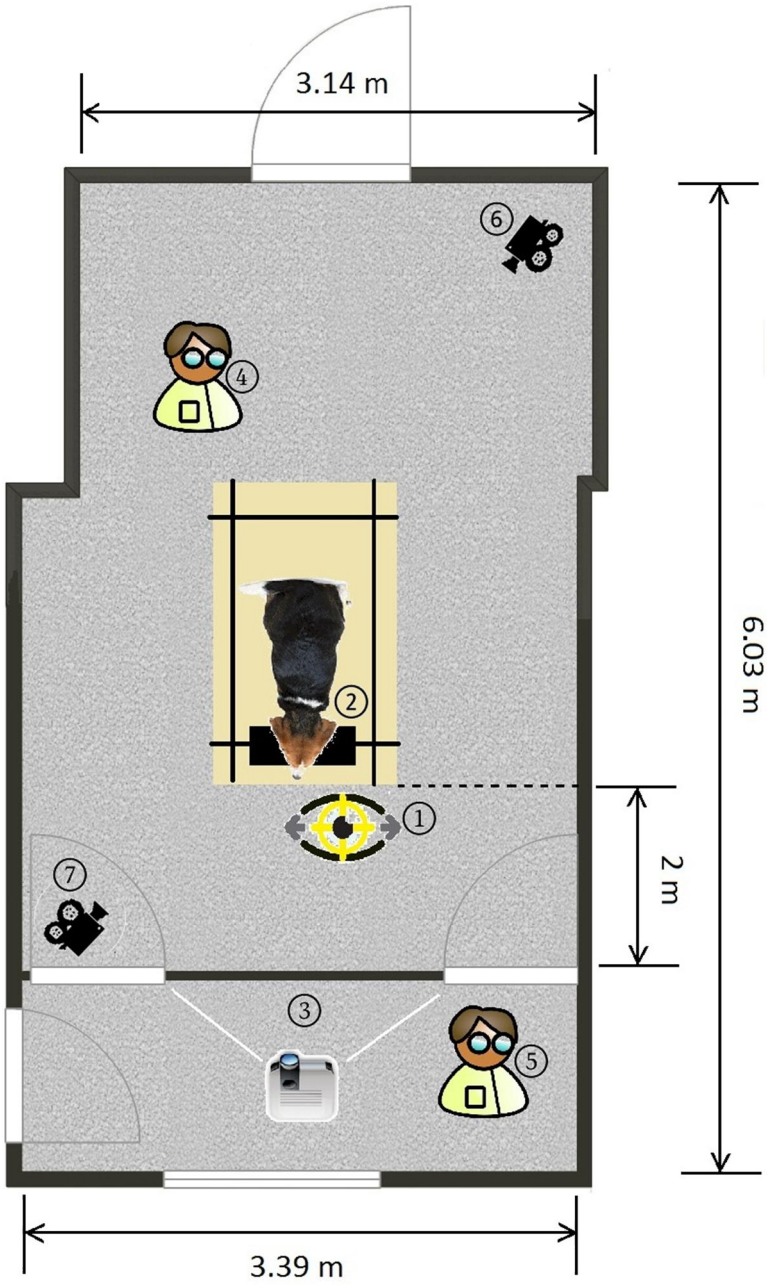


Figure 3. Testing room plan with Experimenters' and Subject's positions
Eye-tracking camera (1), dog positioned inside the chin rest (2), LCD projector and projecting screen (3), Experimenter E1 (4), Experimenter E2 (5), camera recording the back view of the dog (6), camera recording the front view of the dog (7).

2.2.1 Eye-tracking system

Dogs' attentiveness to visual stimuli was measured with the Head Supported version of the eye-tracking device Eyelink 1000 (SR Research Ltd). The device consists of a Core System and a desktop mount camera. The Core System consists of a custom designed high-speed camera connected to a dedicated host computer, which runs on a real-time operating

system, where the host software provides eye sample access with low inter-sample variability, accessed via a set of programming interfaces for multiple operating systems and programming languages. The desktop mount camera is placed just below the display that the participant is looking at. The EyeLink 1000 camera and the infrared illuminator are near the stimulus display. The eye-tracking principle is based on pupil with corneal reflection (CR). The infrared illuminator on the desktop mount camera focuses the light on the participant's eye, and the camera is recording the position of the reflection inside the pupil and on the cornea. The host computer's Eyelink 1000 software uses these reflections to calculate the visual angle of the gaze. The link between the position of the eye and the position of the gazing point on the screen is established by calibration.

The device is operated by Experiment Builder (SR Research Ltd., Mississauga, Canada), a graphically based experiment delivery software package, and Data Viewer (SR Research Ltd., Mississauga, Canada) for extracting measures for further analysis.

2.2.2 Heart rate measuring device

Dog's heart rate was measured with the Polar® RS800CX device (Polar Electro GmbH, Oy, Finland). The system consists of a belt with sensor and transmitter which was placed around the dog's chest (with the electrode area touching the ventral part of the body, where heart beats could be recorded), a watch put on the Experimenter E1's hand, where the heart rate was shown and was being recorded during the testing period, an infrared USB stick and a computer software. In order to increase conductivity between skin and electrodes, ultrasound transmission gel (Geilo GmbH, Ahaus, Germany) was applied on the dog's (previously sprinkled with water pump) skin, as well as on a wet belt.

From the heart rate it is also possible to calculate the heart rate variability (HRV). This measure, simply described as a difference among distances between two heart beats, has previously been found useful to indicate an overall positive, relaxed state (high HRV) or overall negative, stressed state (low HRV) (Malik *et al.* 1996). While the heart rate itself is a measure depending more on physical activity, the HRV is a measure which provides us with more subtle differences, according to mental states of the animals. However, the sensitivity of HRV has so far proven to create many difficulties in analysis (Müller 2014). Since the Polar Belt itself is prone to minor mistakes when recording, before dealing with the data analysis, all the data needed to be filtered and the errors deleted (Marchant-Forde *et al*. 2004,

Jonckheer-Sheehy *et al.* 2012). Unfortunately, it is nearly impossible to be certain of whether an outlier in the data is a mistake or an actual variation in the heart beat. While the slight corrections, whether indeed necessary or not, do not affect the heart rate analysis, they make a great difference (possibly leading to false results) when calculating the HRV. Therefore HRV was not calculated or used for further analysis in the experiment.

To be able to connect changes in heart rate with the actual events during the testing causing them, video materials were obtained by recording the dogs with two cameras, which were both placed in corners of the room, one around 2.0 m in front of the dog and the other one approximately 3.0 m behind the dog (see Fig. 3).

2.3 Stimuli

The dogs were shown images of two distinct human faces showing emotions of different salience.

For this purpose, photographic images of people's faces (dimensions: 800x800 pixels) were made, using a camera (Canon EOS 6D). All the pictures were taken within the same studio-like setup and with the same background color (neutral white). In order to test whether familiarity had any effect on the viewing pattern, one person was familiar (the experimenter E1) and the other one was unfamiliar (randomly chosen dog owner, same person and set of images for all dogs).

Both the familiar and unfamiliar person were required to make four facial expressions: happy, neutral (which were further grouped together as positive), sad and angry (which were further grouped together as negative) (see Fig. 17).

To control if the dog's heart rate responds differently to different emotions, stimuli were arranged in blocks of 4 pictures of the same emotion type (either positive or negative), whereas 2 pictures were of a familiar and 2 of an unfamiliar person. After every block a well-known symbol (▲ or ■) from the training was shown to the dog (after which the dog was rewarded and released for a couple of minutes from the apparatus), in order to keep the subject interested and motivated for further work.

Each block consisted of 4 trials, and was either „positive“ (2 x familiar, 2 x unfamiliar) or „negative“ (2 x familiar, 2 x unfamiliar). A positive block of trials contained photos of happy and neutral face expressions, while a negative block of trials contained photos of angry and sad face expressions. The order of trials within blocks was randomized.

A trial started with an attention trigger (visual and sound attention attraction), lasting for 2s. The attention trigger was an animated graphics interchange format (.gif) file, placed in the center of the screen, and was paired with a high-pitched, attention-attracting sound. There were altogether four triggers with different look, movement pattern and following sound, to avoid the habituation effect. If the dog looked at the screen, the stimulus was shown for the next 5s.

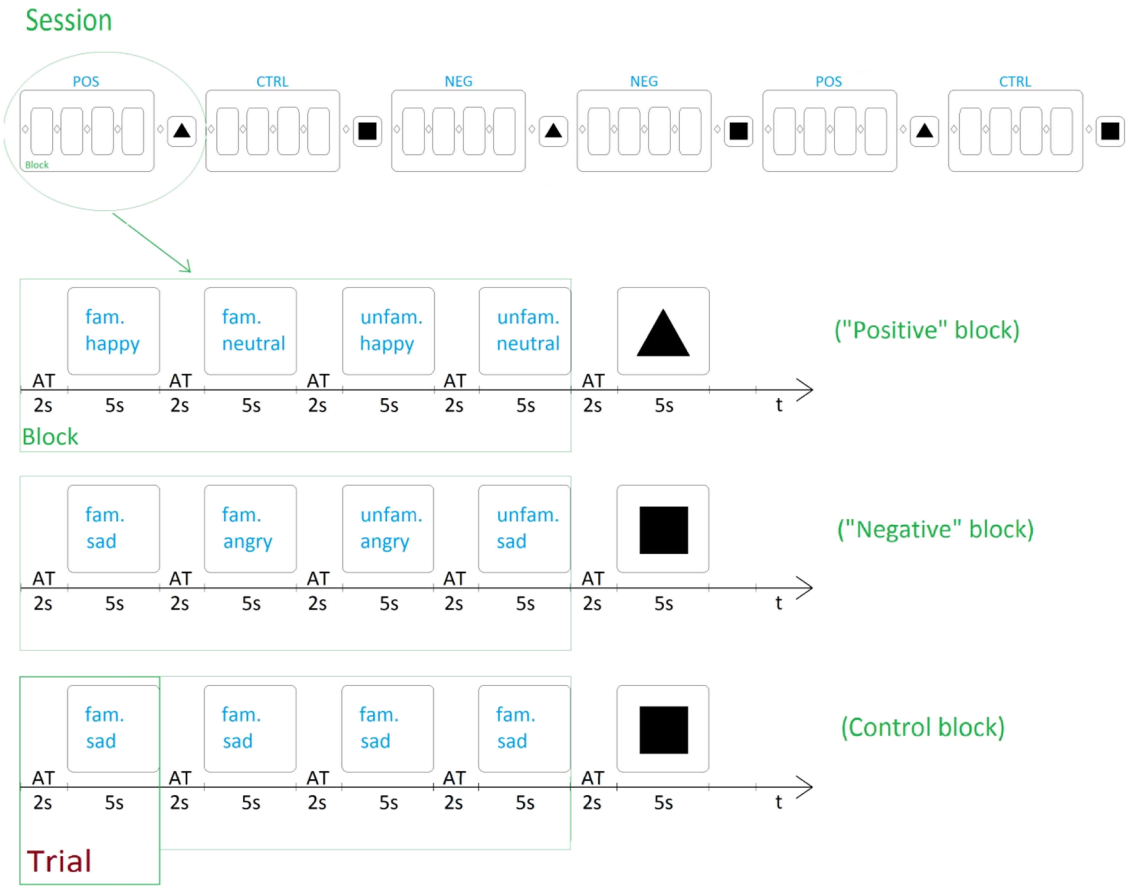


Figure 4. Session, block and trial scheme; AT = attention trigger

All the stimuli were displayed on a screen stretched within a frame, with the projected dimensions of 110 x 80 cm. The distance between the screen and the dog when standing inside the chin rest was 200 cm.

Each session consisted of 4 experimental and 2 control blocks of trials (which means 4x4 + 2x4 = 24 trials per session). The control blocks were randomly inserted between experimental blocks for each session. The control blocks contained 4 identical photos of positive / negative emotions. They were added as a control for heart rate, to see whether there was a difference in bpm between showing pictures of familiar and unfamiliar people.

2.4 Procedure

2.4.1 Training procedure

Before starting the testing, dogs had to be trained. The IMD dogs were usually brought in groups of 3 dogs per training session in morning hours, while the GD dogs were brought in groups of 2 dogs in afternoon hours. Each dog was trained on average twice a week. Although the first training sessions started in March (2013), some significant changes had to be made in order to increase the efficiency of training. Therefore the final training started in August (2013) and lasted for 2 months.

During the training, the dogs were first accustomed to the testing room and clicker-assisted behavior shaping. Following this, the dogs were trained to enter the chin rest apparatus and rest their heads on the chin rest. Once they had started showing behavioral signs of feeling comfortable inside the apparatus (having relaxed body positions, holding their ears up, wagging their tails), we started projecting images on the screen in front of the chin rest. The last stimulus on the screen was always a symbol (▲, ■) with a role of visual signal of release command. Once the dogs were able to spend 30s at the chin rest and stay focused on projections on the screen, they were considered to have had reached the criterion for entering the testing phase.

2.4.2 Testing procedure

Testing lasted 2.5 weeks, and each dog was tested twice a week. There were altogether 5 sessions for each dog, from which we chose the 3 most technically successful ones for further statistical analyses. During the testing, there were always 2 people present in the room, one with the dog (E1) and second one behind the screen (E2).

E1's function was to give a release command to the dog resting on the chin rest after the end of a block (and reward him), and direct the dog back into the chin rest before starting a new block. Also, in case the dog got out of chin rest before the end of a block, E1 would motivate him to get back and finish the block. In order to maintain the dog's focus maximally on the screen and not on the experimenter, E1 was always standing behind the dog. E2's function was to navigate the procedure through the Eye tracker software (including the calibration period) and to ensure that the dog's eye was always visible to the eye-tracking camera (and, in case it wasn't, to warn the E2 to change dog's position in the chin rest).

The (neutered) dogs from IM (group 1) were always brought in pairs. This was done for practical reason, but also because these dogs seemed significantly more comfortable when they were not alone in the room during the experiment. While one of the dogs went through the testing session, the other one was commanded to lie down; after a couple of minutes, the dog would usually fall asleep. After finishing the session, the dogs switched places.

The (intact) dogs from GA (group 2) were always brought alone.

Before starting the testing session, the subject entered the testing room and was then motivated for work by using simple commands such as “sit”, “lay down”, “give paw” etc., for which he was rewarded with food. After this, water and gel were administered on the subject's chest where the heart-rate-measuring belt was to be placed. After fixing the belt on the dog, the dog was asked to stand inside the chin rest apparatus for 30 seconds and walk for 30 seconds, in order to obtain baseline measurements of heart rate. The dog was then commanded back on his place in the chin rest and calibration began with the eye-tracking device.

To navigate the stimuli and eye-movement recording through the testing procedure, using the Experiment Builder software, a half-automatic testing procedure was programmed. This means every session started with calibration, during which, when the dog looked at the desired point, the experimenter would move calibration to the next one. At the end of procedure, the program showed the success of calibration and according to the Experimenter's assessment the calibration was accepted or restarted.

Following a successful calibration, the experimental session started. Normally, the dog would look at an attention trigger and when the camera captured his gaze on the screen, the stimulus was automatically shown for 5 seconds. After that, the program would proceed to the

next trial. The session always consisted of the same, predetermined amount of stimuli (30 pictures and 30 attention triggers) divided in a total of 6 blocks. After the last block finished, the program automatically stopped, with the results being saved.

For the calibration, a 3-point-calibration system was used to attract the dog's attention to three black dots (diameter approximately 2cm) on the screen. For this, E1 made crinkling sounds with a small bag of treats in front of the spot on the screen. Since the dogs ability to focus on screen varied through the sessions, in some cases further attention attraction was needed. In those occasions, the experimenter would position her own face in front of the spot and make the eye contact with the dog in chin rest. After the calibration, the dog was ready for the picture-viewing session. Although in calibration more points mean higher data precision, I opted for a 3-point instead of 5- or 9-point calibration due to the fact that our subjects did not have an attention span long enough to go through a longer calibration procedure, and that a longer calibration could affect the dog in the following session in a negative, de-motivating way.

After each block, as well as after finishing the whole session, the dogs were given the release command (they could move away from the chin rest). At the end of testing, the dogs were, after positive interaction with the experimenter (petting, playing etc.), returned to their enclosure at the campus of the Veterinary University.

2.5 Statistical Analysis

2.5.1 Defining Area of Interest (AOI)

Areas of interest (AOI) define regions in the stimulus that the researcher is specifically interested in gathering data about. The main questions asked are: did the participant look where expected, and what were the properties of their eye movements in the area looked at.

I was interested in two main eye movement events defined within the Area of Interest: dwells and AOI hits.

A dwell, often known as “gaze”, is defined as one visit in the AOI, from entry to exit. It has its own duration, starting point, ending point, dispersion etc. In many ways it is similar to a fixation, but has a larger entity both in space and time.

A hit is the most primitive AOI event, which simply states that for a raw sample or fixation, its coordinate value is inside the AOI. Sometimes for an event to be considered a hit, a certain area has to be looked upon during a minimum amount of time, which tends to reflect the minimum time it takes to cognitively process the given visual information.

For the analysis, each picture was divided into 4 different AOI: Forehead, Eyes, Mouth and (the entire) Face. The areas had different dimensions (in order to frame the face features precisely), but the dimensions for each unique face feature were always the same. Also, there was the fifth defined area, which was everything outside of the face, and was used for testing the gaze bias (see Fig. 16)

2.5.2 Data processing and analysis

Out of five sessions made with each dog, due to great variety in quality of data gained throughout the session, three were post-hoc chosen for further analysis. In each session, we counted the number of "error" trials, and left out the 2 sessions with the highest number of those trials. Our criterion for an "error" was trial having a duration longer than 25000 ms (suspiciously long trial) or shorter than 2500 ms (suspiciously short trial). Since we had video materials showing front view of the subjects during the sessions, we listed possible explanations of trials having suspicious lengths (see Table 2).

Table 2 - „error" trial criteria and reasons for exclusion

Trial duration (ms)	Possible explanation
> 25000	the subject was staring at one spot close to the edge of the screen the subject's eyes were closed the subject got out of the chinrest while the trial was running
< 2500	the eye tracker jumped to the next trial too fast (a repeating technical error)

This left us with 715 trials for 8 dogs (meaning 30 trials per session per dog and one session as an exception with 25 trials). Within the remaining sessions, trials marked as „error" were excluded from further analyses. Statistical analysis was performed using the R 3.1.2 statistical software (Foundation for Statistical Computing, Vienna, Austria).

The analysis was made with the data extracted from the EyeLink® Data Viewer (SR Research Ltd., Mississauga, Canada). From the various reports which the mentioned program offers, we used the Trial report, Interest Area report and Fixation report (see Tab. 3). From the Trial report data, we chose the measures of maximum fixation duration and fixation count. From Interest Area report we used dwell time percentage. Dwell time percentage is the percentage of trial time spent on the current interest area. Since the variations in the number were too high between the dogs, in order to be able to analyze it, we turned the dwell time percentage into a binary measure of dwell probability. If the percentage was higher than 0, it was turned into a 1, marking the event happening. If it was a 0, it meant the dog did not look at that region of interest at all during the trial. I analyzed dwell probability for each of four defined regions of interest (Eyes, Mouth, Forehead and Face) separately, and also made a comparison between them.

From the Fixation report, we used the measures of the between-fixations angle and average fixation duration. Only the angles between first and previous-to-first fixation in each trial were used for the analysis (see chapter 1.2.3). To test the existence of gaze bias, I compared the between-fixations angles according to familiarity and emotion type (both as independent effectors and in combination); furthermore, I compared angles when the first fixation was within the face area to angles when the first fixation was outside of the face area, as well as angles when trials were showing face to angles when trials were showing symbols (▲,■; see chapter 2.3).

Average fixation duration was calculated as a sum of all fixation durations within the face area in one trial divided by the number of fixations in face area per one trial. The fixations out of the face area were excluded from calculation.

Table 3 - The variables chosen for the eye-tracking data analysis

Report Type	Variables extracted	Variables used	Description
Trial report	FIXATION_COUNT	Fixation count	Total number of fixations in the trial
	FIXATION_DURATION_MAX	Maximum fixation duration	Duration of the longest fixation in the trial

Interest Area report	IA_DWELL_TIME_%	Dwell probability	Binary measure of the dwell (1=yes, 0=no) within all regions of interest in the trial
Fixation report	NEXT_FIX_ANGLE	Between-fixations angle	Angle between the horizontal plane and the line connecting the previous and current fixation
	CURRENT_FIX_DURATION	Average Fixation Duration	Sum of all fixation durations within the face area divided by total number of fixations within the face area in the trial

The effects on the aforementioned independent variables were investigated using the Linear Mixed Models (LMM). Specifically, for fixation count, maximal fixation duration and average fixation duration analysis, I used Linear Mixed-effects Model fit by Restricted Maximum Likelihood (REML) (R package "nlme" (Pinheiro *et al*. 2014)); I defined maximum fixation duration and fixation count as independent variables, emotion type (positive and negative) and familiarity as dependent variables and the dog's identity and session as random effects. For dwell probability analysis, I used a Generalized Linear Mixed Model fit by Penalized Quasi-Likelihood (PQL) (R package "MASS", Venables and Ripley 2002); I defined dwell probability as independent variable, emotion type (positive and negative) and familiarity as dependent variables and the dog's identity and session as random effects. For fixation angle analysis, which had characteristics of circular data (expressed in degrees), I used Watson's Two-Sample Test of Homogeneity and Watson's Test for Circular Uniformity (R package "circular", Agostinelli and Lund 2013), with fixation angle as independent variable, and emotion type and familiarity as dependent variables. The circular data was visualised in Oriana 4 circular statistics software (Kovach Computing Services).

Prior to the heart rate analysis, I coded video materials to connect the heart rate to the events during and surrounding the session. During coding, I marked baseline events (dog standing inside the chin rest for 30 s – standing baseline; dog moving around the chin rest for 30 s – walking baseline) before and after the session. Furthermore, I marked the events within the session (trials). The effects on heart rate were investigated using Linear Mixed-effects Model fit by Restricted Maximum Likelihood (REML). Heart rate (BPM) was always defined

as the dependent variable, with dog identity and session as random effects and event type (baselines and within-the-session events) as independent variables.

To gain insight into the dog's general state before and after a session, I first compared heart rate data only within baseline measurements. For the heart rate analysis, I defined baseline order and baseline activity as predictors. Next, I compared the standing baselines to within-session heart rate data. For this I set baseline and within-trial data (emotion type of pictures shown) as predictors. Finally, I compared the within-session heart rate data only, where emotion type and familiarity were defined as predictors.

3 Results

3.1 Eye-tracking data results

When analyzing effects on fixation count, neither emotion type(β=0.10, SE=0.59, t(311)=0.17, p=0.86), familiarity (β=-0.15, SE=0.59, t(311)=-0.26, p=0.80) or the interaction of those two factors (β=0.04, SE=0.84, t(311)=0.05, p=0.96) were shown to be significant. However, mean values showed a bias towards positive familiar pictures (M=7.482 ± 0.43), while negative unfamiliar pictures had the lowest mean value (M=7.172 ± 0.45) (see Fig. 5). Regarding maximum fixation duration, there was a slight positive trend towards negative familiar pictures (M = 2310 ± 121.47) and a negative trend towards positive unfamiliar pictures (M = 2155 ± 139.91) (see Fig. 6), but the effects of emotion type (β=-115.29, SE=160.49, t(311)=-0.72, p=0.47), familiarity (β=-83.59, SE=159.23, t(311)=-0.53, p=0.60) and their interaction (β=71.71, SE=228.49, t(311)=0.31, p=0.75) were statistically not significant. Data values of the average fixation duration were trending similarly to the value of maximum fixation duration, with negative familiar pictures having the highest mean value (M = 1181.83 ± 118.75) and positive unfamiliar pictures having the lowest mean value (M = 881 ± 66.04) (see Fig. 7); however, there were still no significant effects of familiarity (β=-19.93, SE=141.03, t(251)=-0.14, p=0.89), emotion type (β=-146.32, SE=137.17, t(251)=-1.07, p=0.29) or their interaction (β=-128.46, SE=202.66, t(251)=-0.63, p=0.53) (see tables 4, 5 and 6, Supplements)

Regarding the analysis of dwell probability in separate areas of interest, emotion type and familiarity did have significant effects on data (see Fig. 8).

Considering the eyes region, the interaction of familiarity and emotion type had no significant effect on dwell probability (β = 0.27, SE = 0.43, t (357) = 0.63, p = 0.53). However, a main effect of emotion type on dwell probability was found (β = - 0.71, SE = 0.30, t (357) = -2.35, p = 0.02). The positive emotion type had negative effect on dwell probability. When analyzed in a model without the emotion type - familiarity interaction, emotion type had even higher significance (β = -0.57, S.E. = 0.21, t (359) = -2.67, p = 0.0075), whereas familiarity as a single effect did not significantly affect the dwell probability (β = - 0.42, SE=0.30, t (357) = -1.41, p = 0.16). To conclude, the subjects were more likely to look at the eyes for negative than for positive stimuli, while familiarity on its own had no significant effect (see Table 7 and 8, Supplements).

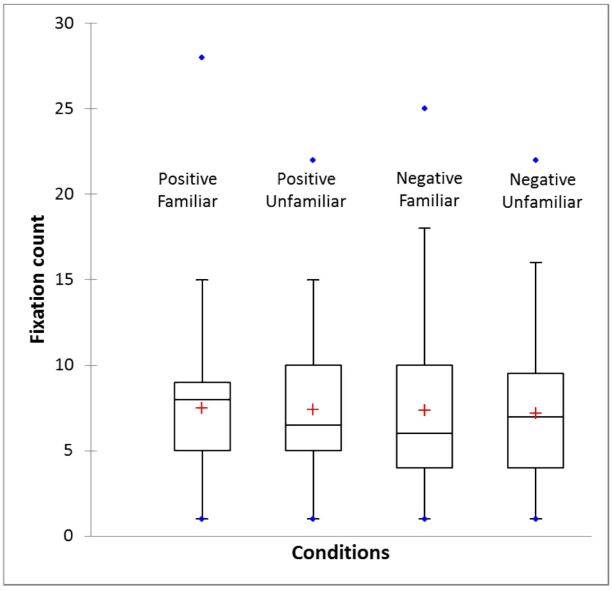


Figure 5 - Fixation Count across four conditions

Boxplots display means (marked with a cross), medians (the middle line within the box), inter-quartile ranges and ranges with blue dots as outliers

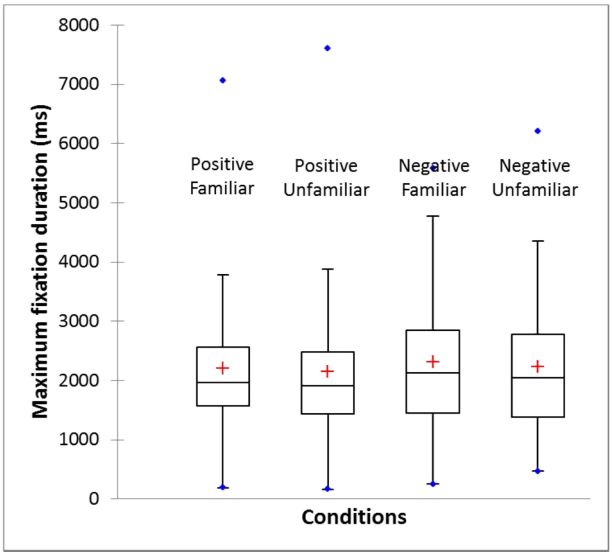


Figure 6 - Maximum Fixation Duration across four conditions

Boxplots display means (marked with a cross), medians (the middle line within the box), inter-quartile ranges and ranges with blue dots as outliers

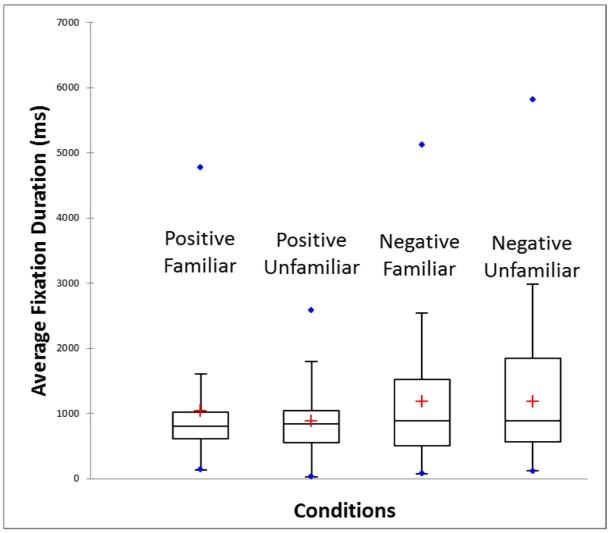


Figure 7 - Average Fixation Duration across four conditions
Boxplots display means (marked with a cross), medians (the middle line within the box), inter-quartile ranges and ranges with blue dots as outliers

Considering the mouth region, in the model with familiarity and emotion type in interaction, a significant effect of familiarity on dwell probability was found (β = - 0.88, S.E. = 0.31, t (357) = - 2.88, p = 0.0042). The unfamiliar face was significantly less likely to be looked at. Emotion type (β = - 0.30, SE = 0.29, t (357) = - 1.04, p = 0.30) and interaction between emotion type and familiarity (β = 0.56, SE = 0.43, t (357) = 1.30, p = 0.19) did not affect the dwell probability significantly. When analyzed without the familiarity – emotion type interaction factor, familiarity remained a significant effect (β = - 0.60, SE = 0.214, t (357) = - 2.81, p = 0.0052). We could conclude that the subjects were more likely to look at mouth for familiar compared to unfamiliar stimuli (see Table 9 and 10, Supplements).

Considering the forehead region, the interaction of the emotion type and familiarity had a near to significant effect on dwell probability (β = - 0.91, SE = 0.48, t (357) = - 1.91, p = 0.06). The subjects were less likely to look at the negative than the positive stimulus, but only for unfamiliar faces (see Table 11, Supplements). Familiarity on its own (β = - 0.31, SE = 0.32, t (357) = - 0.97, p = 0.33) and emotion type on its own (β = 0.06, SE = 0.31, t (357) = 0.19, p = 0.85) had no significant effects on dwell probability.

Considering the face region, emotion type and familiarity in interaction did not have a significant effects on dwell probability (see Table 12, Supplements) (β = 1.08, SE = 0.64, t (357) = 1.69, p = 0.09), therefore emotion type and familiarity were subsequently analyzed without the interaction factor. In following analysis, only the main effect of familiarity on dwell probability was found significant (β = - 0.84, S.E. = 0.30, t (358) = - 2.78, p = 0.0058). The subjects were less likely to look at unfamiliar face. Emotion type on its own had no significant effect on dwell probability (β = - 0.39, SE = 0.29, t (358) = - 1.32, p = 0.19) in face area. (Table 13, Supplements).

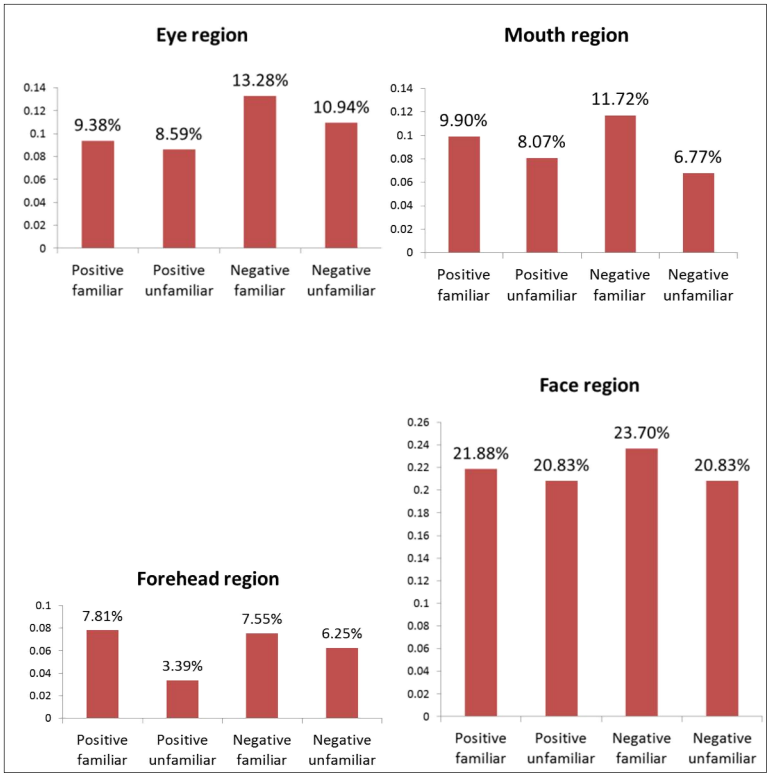


Figure 8 – Probability of looking according to conditions in four regions of interest

In comparison of dwell probability between different areas of interest, face was excluded, since it includes all three aforementioned regions and therefore logically has the highest dwell probability. There was significant difference between forehead and eye region (β = - 0.89, S.E. = 0.16, t (743) = - 5.53, p < 0.001). Though both regions were roughly the same size, the subjects were more likely to look at eye region than at forehead region. Furthermore, there was a near to significant difference when comparing the eye and mouth region (β = - 0.24, SE = 0.15, t (743) = - 1.65, p = 0.10), as the subjects were less likely to look at the mouth region compared to the eye region. The comparison of forehead and mouth

region revealed that the subjects were significantly more likely to look at the mouth region (β = - 0.89, SE = 0.16, t (743) = - 5.53, p < 0.001) (see Fig. 9; see Table 14, Supplements).

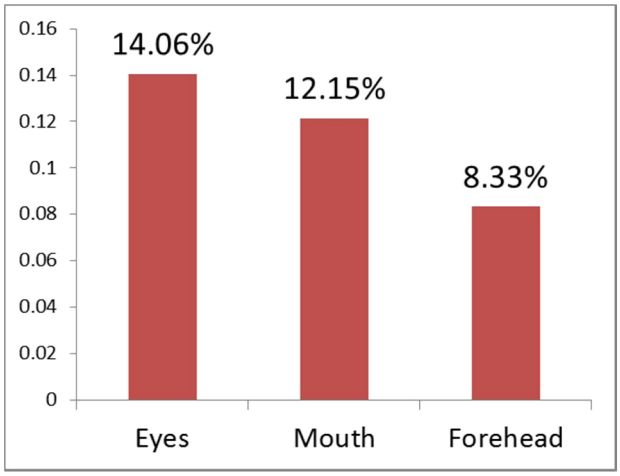


Figure 9 – Total dwell probability across three different regions of interest

3.1.1 Gaze bias analysis

When comparing between-fixations angles of familiar (M = 256.337° ± 138.934°) and unfamiliar (M = 212.341° ± 56.005°) faces, there was no significant difference (N = 245, test statistic = 0.03, critical value = 0.15, for α = 0.1) (see Fig. 10). Furthermore, when comparing between-fixations angles of positive (M = 16.751° ± 154.328°) and negative emotion types (M = 218.76° ± 33.975°), there was also no significant difference (N = 245, test statistic = 0.12, critical value = 0.15, for α = 0.1) (see Fig. 11; Table 16, Supplements).

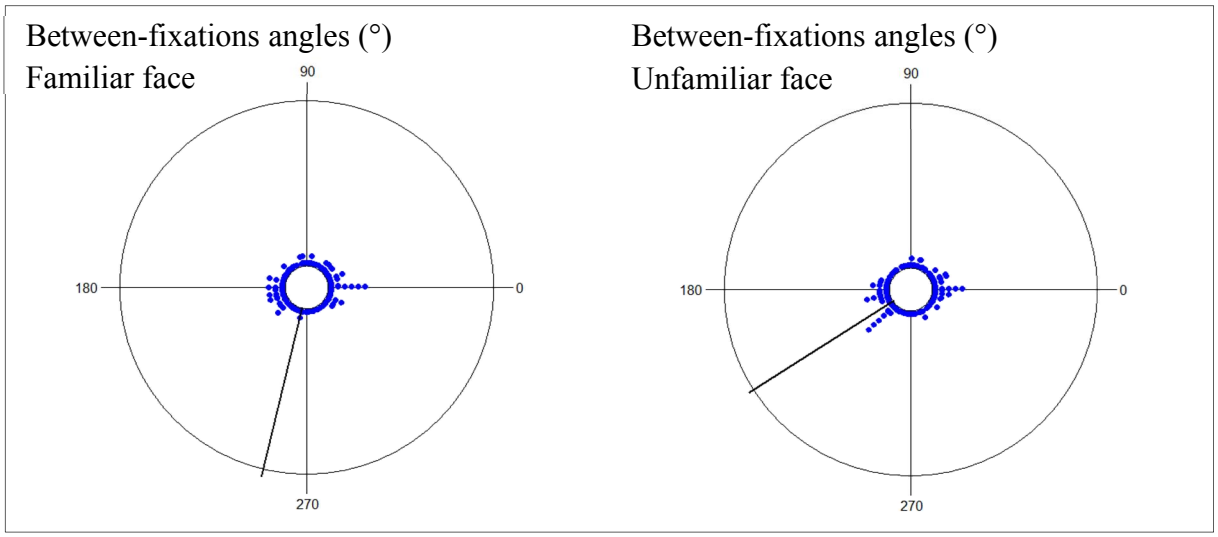


Figure 10 – Between-fixation angles for familiar and unfamiliar face; blue central dots represent raw data, while black arrows represent the mean value

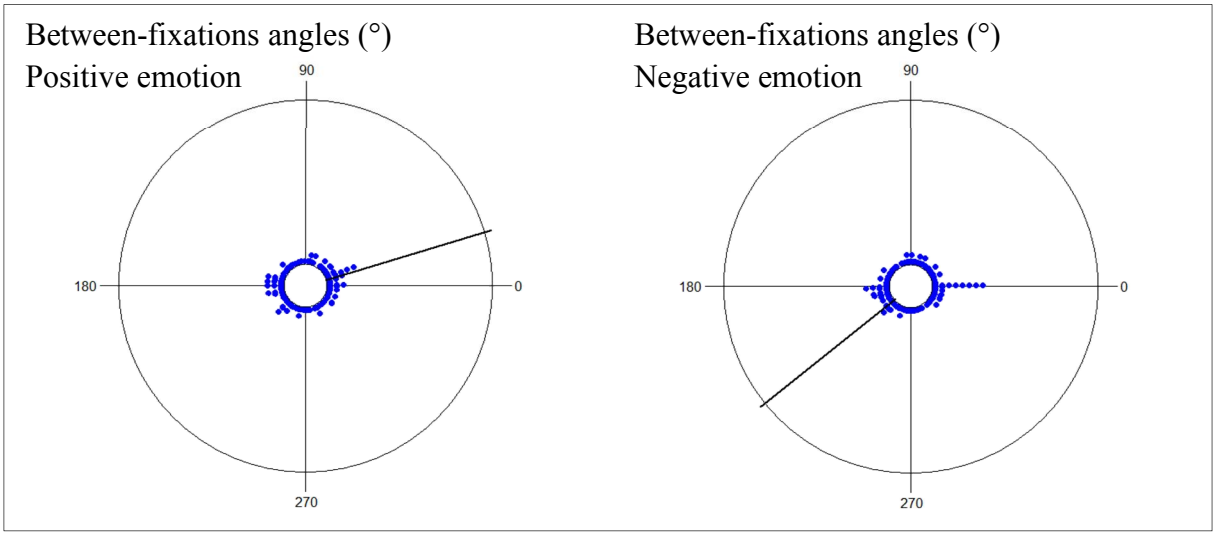


Figure 11 - Between-fixation angles for positive and negative emotion type; blue central dots represent raw data, while black arrows represent the mean value

However, results of Watson's Test for Circular Uniformity for fixation angles of face area (M=301.743° ± 99.563°) showed a significant bias (N = 245, test statistic = 1.15, critical value = 0.19, for α = 0.05). The same test for the area around the face (M = 164.664° ± 65.881°) showed no significant bias (N = 245, test statistic = 0.14, critical value = 0.15, for α = 0.1). Interestingly, the angle values for the face area did not have a tendency to the left side of visual area, but to the right side (see Fig. 12).

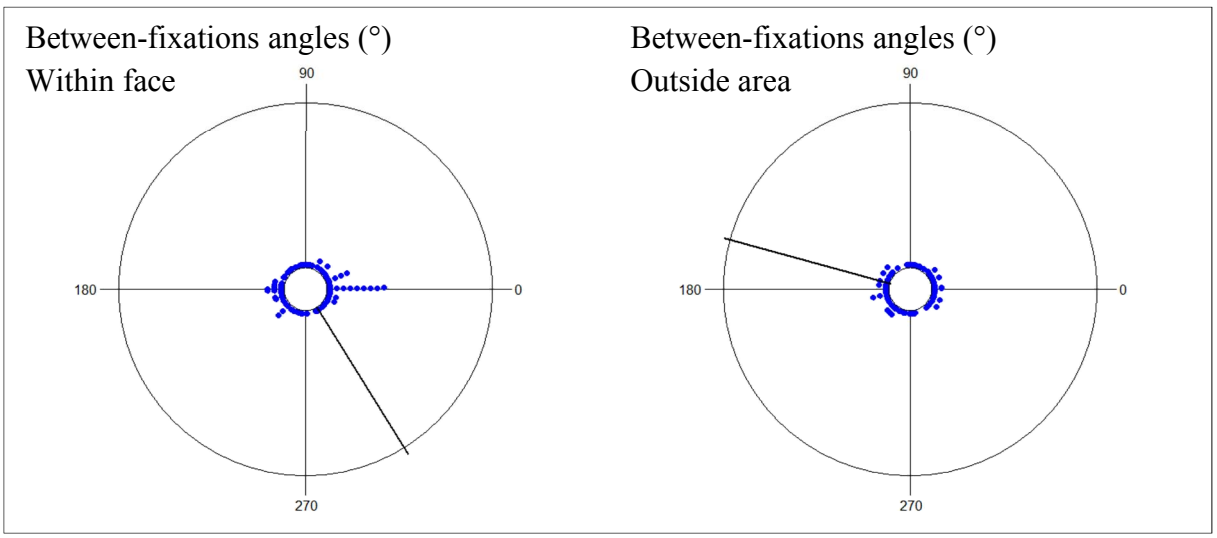


Figure 12 - Fixation angles within and outside of face region; blue central dots represent raw data, while black arrow represents the mean value

3.2 Heart rate data results

When comparing data only within baseline measurements, with baseline order and baseline activity as effectors, heart rate was significantly more likely to be higher for walking than standing ($\beta = 24.15$, S.E. = 1.02, $t(5703) = 23.61$, $p < 0.0001$), while both second baselines (standing and walking) had significantly lower heart rates than first baselines ($\beta = -6.33$, S.E. = 1.14, $t(5703)=23.605$, $p < 0.0001$). The interaction of the effectors wasn't significant ($\beta=-0.214$, SE = 1.48, $t(5703) = -0.144$, $p=0.89$) (See Fig. 13; Table 18, Supplements).

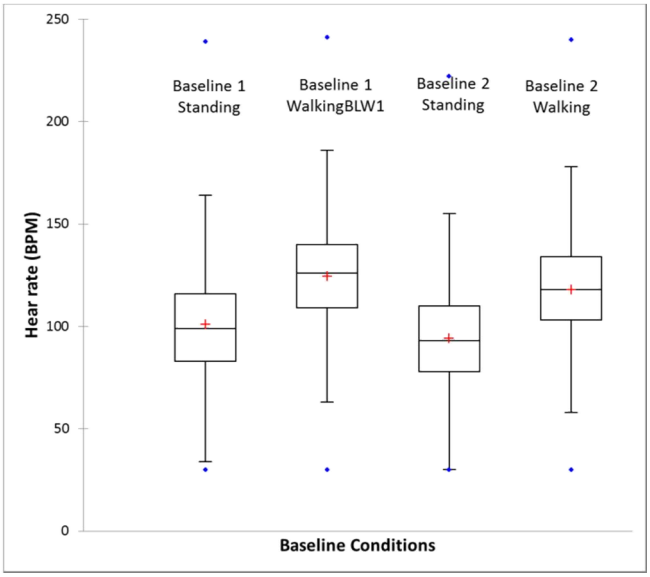


Figure 13 - Heart rate (BPM) across different baseline conditions
Boxplots display means (marked with a cross), medians (the middle line within the box), inter-quartile ranges and ranges with blue dots as outliers

When comparing the standing baselines to within-session conditions, both the first baseline (before the eye-tracking session) and the second baseline (after the eye-tracking session) differed from all 4 emotions, with first one being significantly higher ($\beta = 3.51$, S.E. = 0.92, $t(12218) = 3.804$, $p = 0.0001$) and second one significantly lower ($\beta = -2.49$, S.E. = 0.97, $t(12218) = -2.568$, $p = 0.01$) (See Fig.14; Table 19, Supplements).

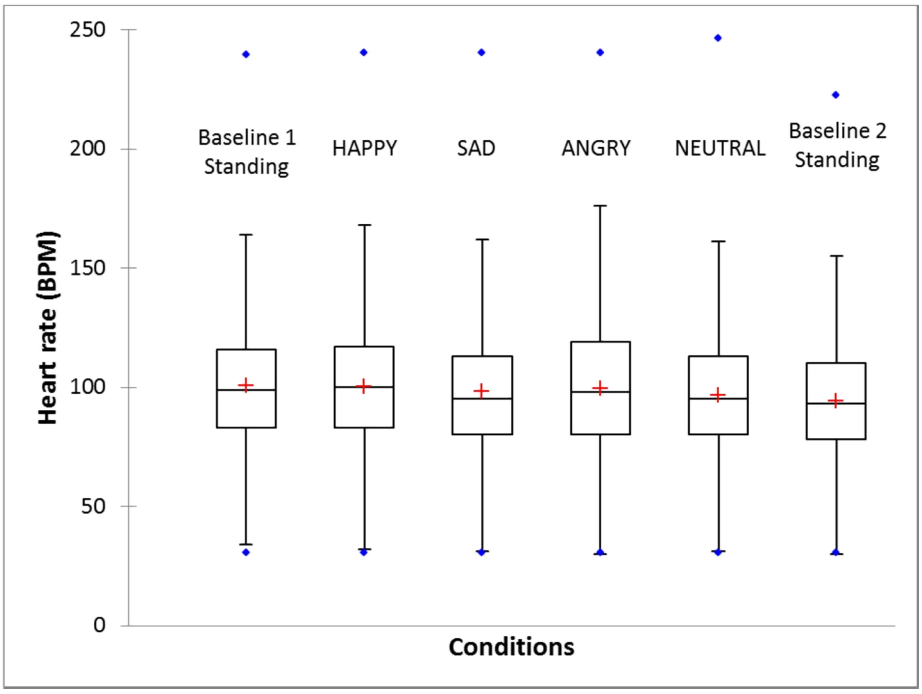


Figure 14 - Heart rate (BPM) across different standing conditions (baselines and emotions)
Boxplots display means (marked with a cross), medians (the middle line within the box), inter-quartile ranges and ranges with blue dots as outliers

When analyzing the differences between within-session conditions, in the interaction model, all effectors were highly significant (see Fig. 15), with the interaction of emotion type and familiarity having the highest significant effect on heart rate (β = -4.31, S.E. = 1.13, t (9871) = -3.828, p = 0.0001). For familiar faces, the heart rate was higher for positive (M = 99.61 ± 0.60) than for negative stimuli (M = 97.66 ± 0.64), while for unfamiliar faces a reversed pattern occurred (M_{UNPOS}= 97.69 ± 0.53; M_{UNNEG} = 99.84 ± 0.61). (Table 20, Supplements). Once the interaction was removed from the model, only familiarity had a significant effect (β = 1.31, SE = 0.55, t (9872) = 2.39, p = 0.02), with the heart rate being higher for the unfamiliar face. Emotion type as a single factor had no significant effect on heart rate (β = 2.827, S.E. = 0.799, t (9871) = 3.536, p = 0.26).

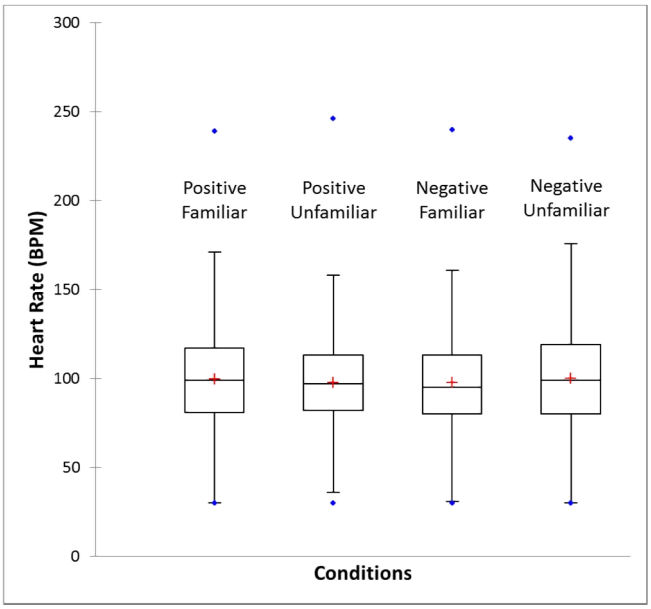


Figure 15 - Heart rate (BPM) across within-session conditions

Boxplots display means (marked with a cross), medians (the middle line within the box), inter-quartile ranges and ranges with blue dots as outliers

4 Discussion

4.1 General results discussion

The analysis of Trial Report and part of Fixation Report data (fixation count, maximum fixation duration and average fixation duration) showed that neither familiarity nor emotion type, with or without the interaction factor, played a significant role in affecting the variables. The means of duration-related values (maximum fixation duration and average fixation duration) for interaction of familiarity and emotion type seemed to indicate a general bias in duration towards negative familiar faces, and against positive unfamiliar faces. Looking only at mean values of emotion types, the duration appears to be longer in cases of negative emotions; looking at mean values of different familiarity, familiar faces were looked at longer than the unfamiliar ones.

The mean values of fixation count show a tendency to look at more points within positive familiar face, while the negative unfamiliar face is defined by the lowest mean value.

When put together, these data are directing us towards the assumption that familiar faces were in general more interesting than the unfamiliar ones, while the emotions themselves may not play such an important role. It might be that the subjects were more comfortable to look at the familiar face because it belonged to the experimenter E1, and therefore was related to a predictable, positive outcome. The unfamiliar face was a new experience with no predictable outcome, and was probably either not interesting, or maybe even frightening to look at.

However, making strong conclusions regarding the aforementioned set of data should be avoided, since the only issue we can discuss are mean values and possible trends in data.

The results of the analysis of separate regions of interest by dwell probability, on the other hand, showed significance of familiarity and emotion type, both in cases when interacting and on their own. Both eyes and mouth were most looked at in case of familiar faces expressing negative emotions. In case of eyes, the (negative) emotion was a stronger effector, while in case of mouth, familiar face attracted more dwells into the defined interest area. The forehead had a highest dwell probability for combination of positive emotion and familiar face, and the whole face was in general more looked at if familiar, the latter going along with previously discussed results of general trial data.

Further comparison among three different areas of interest established a hierarchy in dwell probability: eyes ≥ mouth > forehead. This agrees with the starting prediction that eyes, as a universal attention attractor, would be the most looked at part of the face. Furthermore, it goes along with findings of a recent research on configural processing of faces in dogs (Pitteri *et al*. 2014), which confirmed that dogs can discriminate isolated internal features of a human face, with the eyes being most salient region for human face processing. However, in a recent publication regarding emotion recognition in dogs (Müller *et al.* 2015), there was no difference in learning to discriminate facial expressions shown in the mouth or the eye region. The comparison of the mouth and eye area in our experiment has also shown only trends, thus firm conclusions on possible differences between mouth and eye perception are not possible. What is certain is only that both are significantly more interesting than the forehead. This could be explained by the fact that forehead as a sole feature does not have the same attention attracting property, especially since it is positioned right above the eyes (who draw most of the attention) and the eyebrows (who were in this experiment also defined as a part of the eye area of interest).

The analysis of between-fixation angles failed to allow any certain conclusion regarding the gaze bias. The circular data was too dispersed, and though the mean values sometimes did fall onto the left side of visual area, it was not an established pattern. The only significant difference, the one between the first fixations falling within the face area and the ones falling outside of the face area, showed a bias to the right side in case of face area, therefore being completely the opposite to our expectations.

When it comes to heart rate data, the results showed that, throughout the entire testing procedure, the dogs had the highest heart rates during walking occasions before the beginning of session and after the session (walking baselines). This was somewhat expected, since the heart rate is directly influenced by physical activity, and can be taken as a general confirmation that the heart rate measuring device worked well. It seemed that before every session the dogs were in a state of expectation/excitement, since the heart rates were the highest during both walking and standing baselines before the session. Heart rates declined throughout the session, to end up at lowest point at second standing baseline, probably owing to decrease of interest for the session or / and due to relaxation after the session had been completed. The positive familiar faces were followed by a higher heart rate than the negative familiar faces, which could be explained by the fact that a positive emotion on the familiar face might have served as a strong predictor of positive future event, while a negative emotion

on the familiar face had (also during the training) no real consequence for the dog. On the other hand, negative unfamiliar faces were followed by a higher heart rate than the positive unfamiliar faces, which might be due to those stimuli being generally an unpleasant experience for the dogs. The separate analysis of emotion type and familiarity showed the only significant effector to be the familiarity, which agrees with the conclusions of the fixation count, maximum fixation duration and average fixation duration analysis.

4.2 Methodological limitations

There are a few reasons that might explain why the results of the analysis for the fixation count, maximum fixation duration and average fixation duration, as well as for the gaze bias analysis, were not significant.

First of all, the conditions of testing were not always easy to control. From the start on, the dogs were difficult to train (since they had no training experience whatsoever before this experiment). Their ability to focus was of a shorter duration than what would be expected from an average pet dog. They were easily distracted by many factors: the noises coming from the hall in front of the testing room, the smell of dog food coming from the container in the room, the noises made by Experimenter 2 behind the projecting screen etc. Additionally, Experimenter 1, who always had to be in the room with them and make sure they're working properly, was a slight distraction herself, being the same person they saw on the screen. Some dogs in some sessions performed better than the others, but in almost every session it happened that the dog at some point got out of the chin rest apparatus during the trials, and then had to be commanded to come back. This has certainly influenced the quality of data gained and the durations measured by the eye-tracking device. Finally, with some dogs it was difficult to determine how much time they spent actually looking at details of the presented stimuli, and how much time they spent simply staring at the screen and expecting release command.

The process of calibration often took more than a minute or two (which would have been the ideal time) to be completed. For the reasons of maintaining the participants' attention, it is indeed universally recommended to keep the calibration as short as possible (Nyström and Holmqvist 2011). Though we attempted to maximally speed up the procedure, the previously discussed problem of dogs' attentive abilities combined with the sensitivity of the eye-tracking system often resulted in a need to repeat the calibration process, significantly shortening the participant’s attention span.

The number of our participants was lower than first expected. In the beginning of training, we had sixteen dogs to work with, but as the training progressed, the number was for various reasons lowered to eight dogs. A greater number perhaps would have given the data a better distribution and would have made the effectors more significant.

Also, if we look at the heart rate in general, the numbers did not change drastically throughout different session conditions, and emotion-wise, it's hard to claim in which way exactly the emotion salience seen on screen had affected the dogs' own state, or whether it affected it at all. For this kind of measurement, we would have had to use further calculations of heart rate variability, as a second step in analysis. The set of measures, on which heart rate variability relies, would produce more precise results, possibly with a greater distinction between various emotional states. However, besides the aforementioned problem of correcting for outliers (see chapter 1.5), another requirement for the heart rate variability measure would be a longer trial time. To keep the dogs' attention at a high level, our trials had to be short, which consequentially made them unsuitable.

4.3 On the influence of familiarity and emotions on face recognition

Regarding the familiarity bias in general, it has been confirmed that dogs' interspecific attention depends on many factors, including the nature of the dog-human relationship (Mongillo *et al*. 2010). During the training phase of the current experiment, the dogs established a very close bond with the E1. The E1 had the role of the main trainer, and also took them for walks (from the clinical departments to the testing room and back), gave them food rewards, and before and after each training spent time playing with the dogs and giving them affection. Therefore we can speculate that familiar, E1's face had a significantly higher value for the dogs.

Furthermore, we argue that the specific conditions of these dogs' upbringing made the familiarity an even more important factor in their visual attention patterns. As already stated, the laboratory beagles used in current study were raised by the dog keepers at the university, and were in a regular contact only with familiar faces through their whole lives. They did have occasional contacts with new people, but these are still difficult to compare with the contacts that pet dogs have with strangers during everyday walks and multiple other social events their owners expose them to.

If we look further into their past lives, these dogs were socialized in a different way than the pet dogs are. The usual phase where the dog would start living with humans, and

direct its attention primarily to humans, and only secondary to other dogs, is missing in their experience. If the conditions of the socialization were different, perhaps the results would show the emotional salience having an equally strong effect on looking patterns.

However, despite their different upbringing and being surrounded primarily by conspecifics, these dogs did show a tendency to look at familiar faces, as well as to look at features of the face (eyes and mouth) which were in previous research history established as most salient when talking of emotional expressions. Some parts in their learning experience were missing, but even through a very limited contact with the caretakers, the dogs were able to establish a typical hierarchy of facial features (eyes ≥ mouth > forehead) to focus their attention to. This indicates that the ability to recognize and perceive human facial expressions is already innate in the species, and has probably been, if not developed, then at least highly strengthened by the process of domestication. Further socialization in mainly heterospecific surrounding and experience in learning contexts related to facial expressions may serve to enhance the recognition ability.

4.2 Perspectives

This experiment provided some insight into the laboratory dogs' visual processing patterns of human emotions. However, many issues still remained open and should be further investigated.

The first and most interesting step to be made would be comparing the present results with the results of the same study conducted with pet dogs. The mentioned project, which is nearly completed, will provide valuable insights into the differences and similarities of dogs' visual processing patterns. Furthermore, it might help us to better understand the importance of early experiences with humans in dogs' lives regarding not only face recognition, but also the general attention state towards humans.

When continuing the research, the next step to consider is exploring the reversibility in development of emotion recognition. Knowing whether the dogs' visual attention is predetermined by early experience and remains the same throughout the life, or it has a certain plasticity and can change depending on the environmental conditions and demands, would be useful not only in behavioral studies, but also for applied purposes such as resocialization of shelter dogs. Therefore, conducting a follow up study with the same

laboratory beagles, after they have been adopted into families, could provide valuable answers.

A few technical improvements to be considered in future studies are: a) accelerating the training process and b) making the testing setup as natural as possible for the dogs. An exemplary step towards a more relaxed testing situation might be using a different kind of eye tracking equipment. There have already been successful eye tracking studies conducted with a head-mounted eye tracking device. In this study, one of the most common problems was the decline of the dogs' general interest for the stimuli after having to stand still at the same place for more than half of a minute. Using a head mounted device would enable the dog to move more freely around the room, which might make the whole testing experience more relaxed as well as more interactive for the dog.

5 Conclusions

This thesis has addressed the question of possible influences of emotion and familiarity of human faces on both the visual attention and the heart rate of laboratory beagles.

After conducting an eye-tracking experiment with simultaneous heart rate measurements, we are a step closer to understanding the patterns of human face processing in dogs.

The hypothesis was that the patterns of looking and the amount of given attention to visual stimuli are influenced by the familiarity of the presented face and its emotional salience. Although the data did not provide a clear answer on the effect of emotional salience of stimuli on the gaze duration measurements, familiarity seems to play an important role; the subjects spent more time and more attention on pictures of the familiar face.

Regarding the specific areas of face, this experiment confirmed the importance of the eyes as the universal attention attractor, especially in negative or threatening situations. Following the eye area findings, the data fit previous findings of dogs' ability to focus on the mouth.

Our heart rate data did not follow any specific pattern regarding different emotion types. Opposite to our assumption, the condition before the actual testing was more exciting for the dog than the actual testing session. However, the differences between the conditions within the session match our conclusions from the eye-tracking data, confirming the importance of familiarity as a factor in visual attention given to human faces.

Despite the fact that the laboratory beagles had a different socialization period than the pet dogs have, they were still able to direct their attention to the most salient parts of human face. This finding indicates that the preference for face area which we perceive and define as important for face expression recognition is innate in the species, and is gradually enhanced through the process of socialization.

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7 Supplements

Table 4 - Effects of familiarity and emotion type on Fixation Count

	Fixation count				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Unfam	0.150	0.586	311	-0.256	0.798
Pos	0.103	0.591	311	0.175	0.861
Unfam * Pos	0.042	0.842	311	0.051	0.960

Table 5 - Effects of familiarity and emotion type on Maximum Fixation Duration

	Maximum Fixation Duration				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Unfam	-83.595	159.227	311	-0.525	0.600
Pos	-115.290	160.492	311	-0.718	0.473
Unfam * Pos	71.708	228.490	311	0.314	0.754

Table 6 - Effects of familiarity and emotion type on Average Fixation Duration

	Average Fixation Duration				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Unfam	-19.926	141.027	251	-0.141	0.888
Pos	-146.315	137.170	251	-1.067	0.287
Unfam * Pos	-128.463	202.663	251	-0.634	0.527

Table 7 - Effects of familiarity and emotion type on dwell likelihood at EYES region of interest

	Dwell (binary) - EYES				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Unfam	-0.418	0.296	357	-1.411	0.159
Pos	**-0.706**	**0.300**	**357**	**-2.351**	**0.019**
Unfam*Pos	0.269	0.426	357	0.630	0.529

Table 8 - Effect of emotion type on dwell likelihood at EYES region of interest

	Dwell (binary) - EYES				
Emotype	F	S.E.	dF	t-value	p-value
Pos	**-0.570**	**0.212**	**359**	**-2.687**	**0.0075**

Table 9 - Effects of familiarity and emotion type on dwell likelihood at MOUTH region of interest

	Dwell (binary) - MOUTH				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Unfam	**-0.883**	**0.306**	**357**	**-2.880**	**0.0042**
Pos	-0.304	0.291	357	-1.043	0.2975
Unfam*Pos	0.559	0.429	357	1.301	0.1941

Table 10 - Effect of familiarity on dwell likelihood at MOUTH region of interest

	Dwell (binary) - MOUTH				
Fam	F	S.E.	dF	t-value	p-value
Unfam	**-0.601**	**0.214**	**359**	**-2.814**	**0.0052**

Table 11 - Effects of familiarity and emotion type on dwell likelihood at FOREHEAD region of interest

	Dwell (binary) - FOREHEAD				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Unfam	-0.307	0.317	357	-0.967	0.3341
Pos	0.058	0.308	357	0.189	0.8504
Unfam*Pos	**-0.912**	**0.478**	**357**	**-1.910**	**0.057**

Table 12 - Effects of familiarity and emotion type on dwell likelihood at FACE region of interest

	Dwell (binary) - FACE				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Unfam	**-1.475**	**0.507**	**357**	**-2.910**	**0.0038**
Pos	**-1.082**	**0.522**	**357**	**-2.072**	**0.039**
Unfam*Pos	**1.082**	**0.641**	**357**	**1.687**	**0.0925**

Table 13 - Effects of familiarity and emotion type (independently) on dwell likelihood at FACE region of interest

	Dwell (binary) - FACE				
Fam + EmoType	F	S.E.	dF	t-value	p-value
Unfam	**-0.838**	**0.302**	**358**	**-2.777**	**0.0058**
Pos	-0.387	0.293	358	-1.324	0.1863

Table 14 - Comparisons of dwell likelihood at different regions of interest

	Dwell (binary) - comparisons				
ROI	F	S.E.	dF	t-value	p-value
Fore. vs. Eyes	**-0.894**	**0.162**	**743**	**-5.529**	**<0.001**
Fore. vs. Mouth	**-0.894**	**0.162**	**743**	**-5.529**	**<0.001**
Mouth vs. Eyes	**-0.245**	**0.148**	**743**	**-1.654**	**0.0986**

Table 15 - Mean and standard error of duration-related eye-tracking data

Condition	Fixation Count Mean ± S.E.	Maximum Fixation Duration Mean ± S.E.	Average Fixation Duration Mean ± S.E.
Familiar Positive	7.482 ± 0.43	2207 ± 116.77	1033.9 ± 96.59
Familiar Negative	7.337 ± 0.51	2310 ± 121.47	1181.83 ± 118.75
Unfamiliar Positive	7.4 ± 0.48	2155 ± 139.91	881 ± 66.04
Unfamiliar Negative	7.172 ± 0.45	2232 ± 123.87	1177.9 ± 119.57

Table 16 - Mean and standard error of fixation angles

Condition	Fixation angle Mean ± SE
Familiar	256.337° ± 138.934°
Unfamiliar	212.341° ± 56.005°
Positive	16.751° ± 154.328°
Negative	218.76° ± 33.975°
Within the face region	301.743° ± 99.563°
Outside the face region	164.664° ± 65.881°

Table 17 – Mean and standard error of heart rate (BPM) over different conditions

Condition	HR Mean ± S.E.
BL1 (standing)	100.8 ± 0.84
BL1 (walking)	124.4 ± 0.75
BL2 (standing)	93.98 ± 0.81
BL2 (walking)	117.7 ± 0.72
BLS (overall)	97.59 ± 0.59
BLW (overall)	121.2 ± 0.52
Familiar Positive	99.61 ± 0.60
Familiar Negative	97.66 ± 0.64
Unfamiliar Positive	97.69 ± 0.53
Unfamiliar Negative	99.84 ± 0.61

Table 18 - Comparing baseline order and activity effect within baseline heart rates

	Heart rate (BPM)				
BL (no) * act	F	S.E.	dF	t-value	p-value
BL2	**-6.330**	**1.144**	**5703**	**-5.532**	**<0.0001**
Walk	**24.145**	**1.023**	**5703**	**23.605**	**<0.0001**
BL2 * Walk	-0.214	1.483	5703	-0.144	0.8854

Table 19 - Comparing condition effect (standing conditions only) on heart rate

	Heart rate (BPM)				
Condition	F	S.E.	dF	t-value	p-value
BL1	**3.508**	**0.922**	**12218**	**3.804**	**0.0001**
BL2	**-2.486**	**0.968**	**12218**	**-2.568**	**0.0102**
Happy	0.568	0.739	12218	0.768	0.4423
Neutral	0.309	0.775	12218	0.399	0.6898
Sad	-0.596	0.8	12218	-0.744	0.4568

Table 20 - Effects of familiarity and emotion type on heart rate

	Heart rate (BPM)				
Fam * EmoType	F	S.E.	dF	t-value	p-value
Pos	2.827	0.799	9871	3.536	4e-04
Unfam	3.644	0.82	9871	4.444	0e+00
Pos * Unfam	-4.307	1.125	9871	-3.828	1e-04



Figure 16 - Example of trial image with marked AOIs and visible fixation points (blue circle size is proportional to fixation length)



Figure 17 – Face picture trials presented to dogs, from right to left: happy, neutral, sad and angry emotion (top: familiar face, bottom: unfamiliar face)



Figure 18 - A subject standing in the chinrest apparatus (author: Anjuli Barber)

Dania Randi - *Curriculum vitae*

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2011 - 2015 – Master Study of Zoology, Experimental Biology

2008 – 2011 – Bachelor Study of Biology

2004 – 2008 – Gymnasium "Andrija Mohorovičić", Rijeka

1996 – 2004 – Elementary school "Osnovna škola Dr. Andrije Mohorovičića", Matulji

1990 – Born in Rijeka, Croatia

Practical experience:

2014 – The European Conference on Behavioural Biology in Prague
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Research Assistant (6 months) at Clever Dog Lab, Messerli Research Institute, University of Veterinary Medicine in Vienna

2013 – 3rd CompCog Conference in Vienna
Helper

2012 – Research and Educational Project "Dinara 2012"
Volunteer research helper

2011 – International Research and Educational Project "Hvar 2011"
Volunteer research helper

2010 – 15th International Bat Research Conference in Prague
Poster Presenter

Research and Educational Project "Zrmanja 2010"
Volunteer research helper

2009 – Research and Educational Project "Kornati 2009"
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Other qualifications

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