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Potential application of thermography (IRT) in animal production and for animal welfare. A case report of working dogs

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Abstract

Introduction. The authors describe the thermography technique in animal production and in veterinary medicine applications. The thermographic technique lends itself to countless applications in biology, thanks to its characteristics of versatility, lack of invasiveness and high sensitivity. Probably the major limitation to most important aspects for its application in the animal lies in the ease of use and in its extreme sensitivity.

Materials and methods. This review provides an overview of the possible applications of the technique of thermo visual inspection, but it is clear that every phenomenon connected to temperature variations can be identified with this technique. Then the operator has to identify the best experimental context to obtain as much information as possible, concerning the physiopathological problems considered. Furthermore, we reported an experimental study about the thermography (IRT) as a noninvasive technique to assess the state of wellbeing in working dogs.

Results. The first results showed the relationship between superficial temperatures and scores obtained by the animal during the behavioral test. This result suggests an interesting application of infrared thermography (IRT) to measure the state of wellbeing of animals in a noninvasive way.

Key words
- infrared
- skin temperature
- animal welfare

INTRODUCTION

Over the years, various laws with regard to living conditions and management, "adaptation" and "welfare" of animals held in captivity have been introduced. In detail, we have the last laboratory animals European Directive (2010/63/UE) on the protection and housing of animals utilized for scientific purposes [1]. Furthermore, we have the last European Food Safe Authority (EFSA) EU Annual Welfare Strategy 2012-2015 together with World Organization for Animal Health (OIE).

Within the survey methods that allow objective and scientific evaluation of the conditions of animal welfare, for some time a few research centers [2] have begun to examine the possibility of using non-invasive methods to monitor any conditions of stress. The main advantage of using non-invasive methods is to avoid any interference between the observation and the "spontaneous" behavior of the animal. Among these non-invasive methods, such as open field and maze test, tonic immobility and emergence test, there is thermography [7]. Infrared thermography (IRT) or thermo vision is a technique for measuring remotely the temperature of objects and to represent it through images. These usually are represented in false color scales, in which different colors correspond to a specific temperatures and not to the "true" color of the object *(Figure 1)*. The use is widespread from agricultural to engineering fields [4, 5].

Animal thermography applies mainly to the identification of inflammation, to the determination of stress, or to the evaluation of diseases that lead to ther-

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mal changes. The ease of use, high thermal resolution (few centimes of celsius degree depending on detector used), and very non-invasive opportunities of use, have recently made thermography a technique widely used as a diagnostic tool. Since the data observed, *i.e*. the temperature (or we shall say the radiation emitted by objects), refers to the external part of the animal (skin, hair, feathers or fur). The identification of superficial inflammation is not a meaningful diagnosis, but must be interpreted in the contest of physical phenomena and physiological determinants; they are somehow related to disease, or physical condition of the animal.

THERMOGRAPHY TECHNIQUE IN ANIMAL PRODUCTION

When using IRT on living animals it is important to note that the water concentration in the skin makes very high emissivity values (between 0.95 and 0.98). Then, the presence of reflected radiation has little effect on a correct reading of images. Otherwise, in the thermal image the presence of metal object or of a particular keratin materials (scales, bones, nails, etc.), mixes the energy reflected with the signal emitted by the area being examined, providing an incorrect perceptions of temperature and thermal anomalies *(Figure 2)*.

In the case of measurements of animal skin-temperature, their correct evaluation is facilitated both because living subjects are several degrees over environmental temperature and because surrounding materials have, in general, lower emissivity values. In these conditions, easy to get in laboratory, any noise signal such as little variations in environmental temperature, or far source of IR radiation, can be considered as not influencing the actual temperature of the animal skin.

Also, in the field of veterinary applications, thermographic inspection techniques can be divided into passive and active, but with different meanings than in the typical non-destructive testing used on different, non-living materials. In passive IRT, temperature is measured on bodies considered as not influenced by the temperature of its surroundings. Active thermography (or functional imaging applications in the case of the human) [6], takes into account the temperature reached by the body through an external source of heating or cooling, and can evaluated and measured after its return to normal conditions. The development of dynamic sequences of thermal images with special algorithms, allows obtaining information that the individual image could not show using passive thermography.

Furthermore, we want to stress the fact that non-contact measurements avoid any local alterations of heat exchanges mechanism between skin, its surrounding and body core by the vessels. It frees the subjects from any physical and psychological constrictions.

Each animal species presents unique technical challenges, due to the species-specific differences (size, presence of fur, behavioral characteristics, housing, etc.), that can affect the success of the measures and not allow the definition of a standard operating technique used in all cases. Often only the experience and knowledge of the species in the analysis, allow to identify the best solutions and to adapt the method to specific needs.

THERMOGRAPHIC IMAGES READING

Features of the thermographic technique is to show the results in form of digital images, namely in form of a heat radiant map, as amended as needed with image processing programs. Thermal images are always represented in the grayscale, corresponding to different radiation intensities from different points of the object. Images in "false colors" obtained by associating different color with each level of a given gray. The goal is to better highlight certain phenomena related to the real aspect of the animal picture.

It is not possible, to diagnosticate a specific disease by a color thermographic image, but it is only possible to visualize the presence of a "thermal anomaly" that can be properly connected to the physiological phenomenon in the context of a more general history of the animal disease state. The purpose of the survey through thermography is precisely to optimize the conditions and put in evidence some examples of these anomalies.

For example, *Figure 3* shows the thermography of a rabbit. On the right the scale of correspondence colors-temperatures, different colors are associated to the respective temperature. The background is black because it is considered out of scale, *i.e.* a temperature lower than those reported in the false scale of colours. The rabbit fur shows a temperature slightly higher than the surrounding environment, reflecting its excellent thermal insulation, but still allowing for thermal exchanges. Nose, ears and eyes, where naked skin is present, are the only areas where it is possible to read correctly the temperature of the animal. Nevertheless, the presence of moisture at the nose makes the area cooler than the other two. Generally speaking, evaporation from naked skin is one of the most important ways for thermoregulation in furred animals [7]; in this respect, see also the cooler nose of the dog in *Figure 1*. Anatomical details of the ear and the eye are detectable due to the different blood supply.

VETERINARY MEDICINE APPLICATIONS

Biomedical application of infrared thermography in veterinary medicine is relatively recent. IRT is considered a non-invasive imaging method because it causes no damage to either the patient or operator, since, as we have seen, it does not use any radioactive substances, ultrasound or penetrating radiation, nor it does need any surgical access to the body.

Thermography provides information on the location of pathological and physiological temperature variations, but for the general difficulty of heat diffusion through the fat and bone tissues, it do not give any anatomical details about deeper structures and organs and finally it is unable to provide information on the etiology of the diseases. It may, however, provide a dynamic, real time image of the thermic changes over time [8]. Diseases for which thermography is particularly useful are those that lead to alterations of the normal control of body temperature, such as changes in the microcirculation, inflammation, trauma, metabolism and efficiency of the thermoregulatory systems. It is a technique with considerable potential, especially where there are physical and mathematical models of thermal processes in the body. It is also very useful in monitoring the response to certain therapies without interfering with them. To date, studies have primarily been conducted in the field of farm and lab animals [9] and horses [10, 11]; Hurnik, Webster and De Boer studied as early as 1984, how they could use thermography to detect estrus in cows, considering the increase of temperature in the perianal region [12].

An important aspect of this technology, which has a strong impact on welfare, is its preventive nature: it is able to discover changes that have not caused clinical signs, yet, in apparently healthy subjects. For example, thermographic inspection can spot the presence of a greater blood flow in subclinical inflammation or in presence of atrophy (areas with greatly reduced circulation), before it becomes clinically evident [13]. This feature is very useful in case of inflammation of the feet in cattle and horses, where lameness is often associated with only one problem, but is due to a combination of contributing factors and creates side effects such as asymmetries and fatigues in some muscles, that can be identified with the help of thermography.

With regard to dairy cows *(Figure 4)*, the thermographic technique has proved to be particularly useful in the early detection of foot diseases [14] and mastitis [15-17], allowing early intervention and improved animal welfare, as well as reducing the negative economic impact of these conditions for the farmer.

Thermography can be useful in poor performance syndrome of sporting horses *(Figure 5)*; thermographic videos recorded during exercise allow the clinician to visualize the heating of the different muscle areas and monitor the proper vascularization of tissues, as well as to identify abnormal responses due, for example, to diseases.

Particularly interesting is the possibility of using the thermal camera to monitor the progress of the skin temperature of animals during transportation and to monitor the adaptation to a condition considered very stressful. Since the late eighties, Schaefer and Bench studied the stress of cattle and pigs during transportation [18-20]: in case of stress catecholamine and cortisol increase their blood concentration, resulting in a metabolic and vasomotory response (usually an increase in core temperature and peripheral vasoconstriction), that can be detected by thermography [21]. The use of a camera inside a transport truck *(Figure 6)* is not simple and requires the overcoming some logistical problems, such as, for example, finding a safe position for the equipment. The availability of electric power during the entire duration of filming is also an issue and, last but not least, the presence of strong vibrations due to transportation, must be taken into consideration.

THERMOGRAPHY AS A NON-INVASIVE TECHNIQUE TO ASSESS THE STATE OF WELLBEING IN WORKING DOGS (CASE REPORT)

Context

In this section, the authors present a trial concerning the use of IRT technique in working dogs in order to show its use in furred animals. The social importance and the multiple functions of the dog to search for drugs are widely recognized and the preparation of these tasks requires a high level of professional skills. Fundamental aspects are the behavioral characteristics and the ability of these animals, which must be chosen very carefully, especially in the view of the social importance of this work. One of the priorities is to develop a process for evaluating the dog's attitude and trainability/learning ability, even at an early age. The goal is to provide the applying institutions some assessment protocols that are objective, repeatable and meaningful. In addition, the application to the subject of protocols of early attitude evaluation could lead to optimize the use of resources and to an enhancement of the percentage of success in training; this could avoid longer evaluation processes, which leads to the exclusion of a higher number of dogs. Behavioral tests are a common approach to study the attitude and reactivity of an animal and the application of these methods makes it possible to evaluate the response of various parties to different kind of environmental stimuli and to analyze them. Behavioral traits are considered quantitative traits with variable heritability. In the study of behavioral variation, the detection and quantification of neurotransmitters, important in determining the characteristics of reactivity of subjects studied, is generally carried out with HPLC (High-Performance Liquid Chromatography), which can be regarded as one of the most effective techniques for the detection and quantification of organic compounds. In particular, some neurotransmitters are relatable to the manifestation of stress and their evaluation in plasma and platelet allowed obtaining significant results in previous work [22]. At present, researches were made to verify the applicability of the technique in the assessment of thermal comfort and temperament in working dogs.

Aim of the research

The present experiment was conducted to verify if thermography could be used for the assessment of the state of wellbeing in the working dog, in relation to the behavioral and physiological characteristics of the subject, taking in account the ambient working conditions. In the present preliminary study, we would like to test that thermography is taken into consideration as a possible tool to detect the values of skin temperature in a continuous manner, during behavioral tests, without interfering with the behavior of the animal.

Materials and methods

The measurements were carried out at the *Centro Allevamento e Addestramento della Guardia di Finanza in Castiglione del Lago (Pg - Italy)* during two separate tests: the first was held before the dogs were exposed to the training course in the autumn of 2007, and the second in the spring of 2008, after six months of training. The temperature and relative humidity of the trial's period were 13.7 and 58% in autumn 2007 and 8.8 °C and 78% in spring 2008.

20 dogs, including 18 German Shepherds and 2 Labrador Retrievers, 9 females and 11 males, aged between 12 and 24 months, were submitted to a ther-

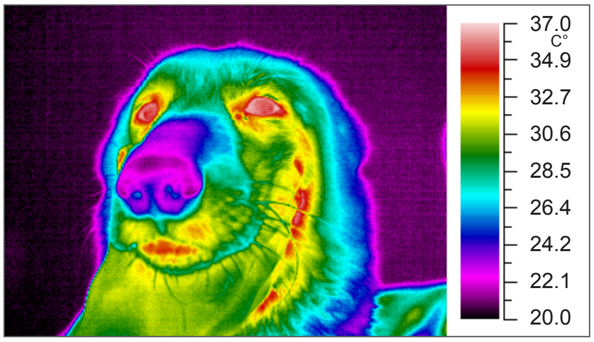

Figure 1
Thermographic image of dog, eyes are in general the reference points used to measure the core temperature. Also the cooling system of the nose is well put in evidence. (Redaelli, 2008)

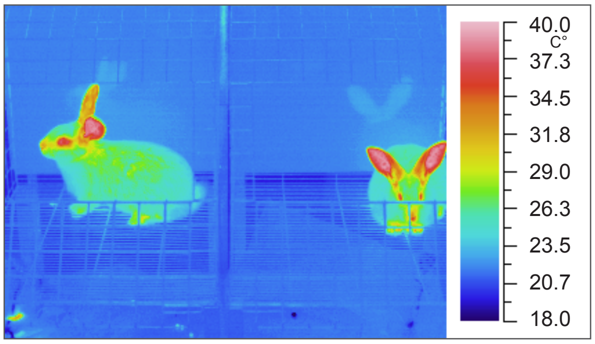

Figure 2
The images of the two rabbits partially visible in the background are artifacts due to low emissivity of the metal wire of the cage. (Redaelli, 2008)

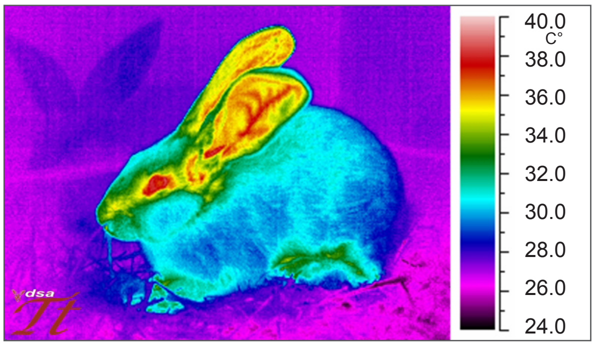

Figure 3
Thermographic image of a rabbit. (Redaelli, 2007)

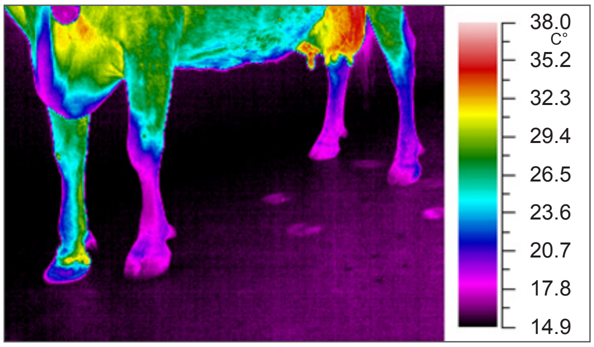

Figure 4
Thermography of a cow: inflammation of the right forelimb is evident in green-yellow. (Redaelli, 2008)

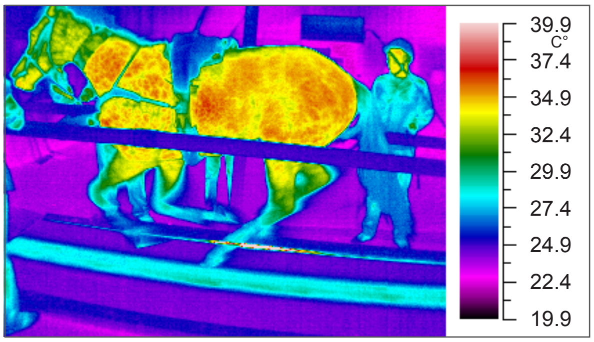

Figure 5
Thermographic images of a horse during treadmill testing. (Redaelli, 2009)

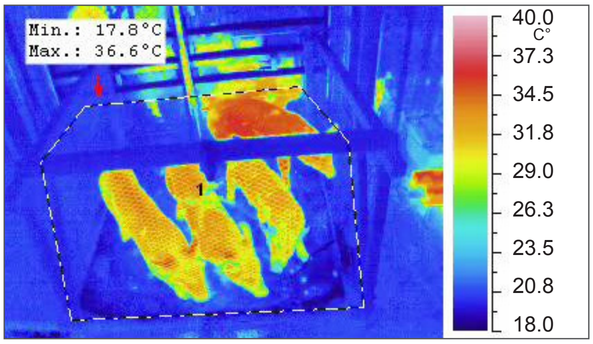

Figure 6
Thermographic image of piglets during transportation. (Redaelli, 2009)

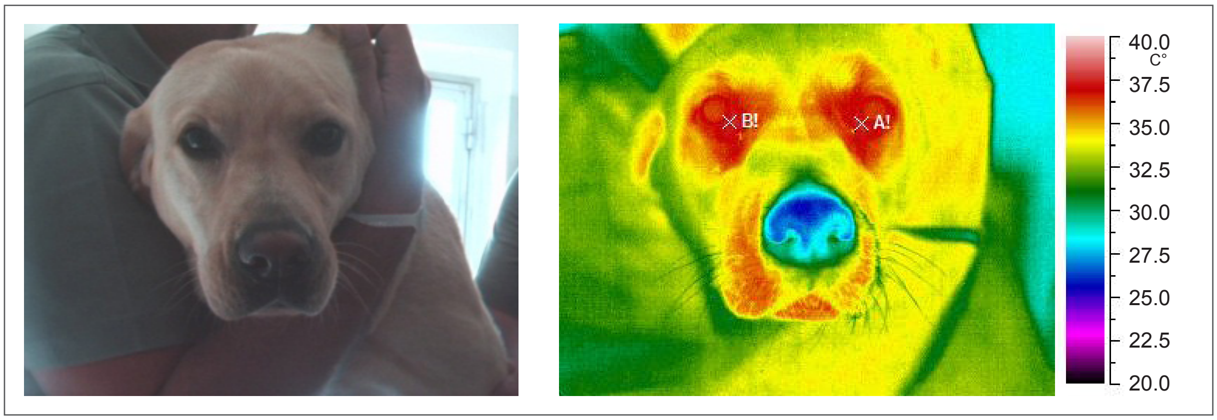

Figure 7
Thermography example of a subject taken during blood sampling. (Redaelli, 2010)

mographic survey and at the same time, the dogs were blood sampled to evaluate the concentration of circulating catecholamine. Plasma samples were analyzed by the High-Performance Liquid Chromatography method to evaluate adrenaline, noradrenaline, L-3, 4-dihydroxyphenylalanine, homovanillic acid (HVA), 3-methoxy-4-hydroxyphenylglycol acid (MHPG), 5-hydroxyindole acetic acid (5-HIAA), and 5-hydroxytryptamine (5-HT) levels. 5-HTand 5-HIAAwere also analyzed from platelets, in collaboration with the Department of Pharmacology, Chemotherapy and Toxicology, Faculty of Medicine and Surgery in Milan University.

After 5 minutes, the same animals were tested for the evaluation of their "natural behavioral attitudes", modified from Svartberg [23]. All the subjects were born, reared, housed, and trained in the same facility and followed the same training sessions. Dogs' behavioral reactivity was scored according to a standardized working dogs test to evaluate natural dog attitudes. The shooting distance is varied according to the type of test performed (the animals were free to move in accordance with the tests carried out). The thermographic surveys were not carried out outdoors, but indoor facilities were chosen, for a better standardization of the testing conditions, and a specific attention was paid to the area around the eyes, the ear and the mouth of the animals.

Results

Figure 7 shows an image example of thermographs realized in correspondence of the area around the eyes, at the same time of blood sampling; in particular, for each investigated area (eyes, ears and mouth) the maximum temperature value detected has been exported.

In order to assess the effect of the gender, the detection area (ear, eye, mouth), the test (first or second) value of the temperature, a general linear mixed model has been used, in which the dog by gender has been considered as a random effect. The differences between the levels of the explanatory variables were significant only for gender (difference of 0.6 °C ± 0.2 °C), but there were no significant differences between the tests and between the areas. For each behavioral test performed was then made a thermography-video from which it was possible to extract the maximum temperatures recorded around the eyes, the ear and the mouth of the animals.

The analysis was carried out considering training, breed, and sex as independent variables. From a behavioral point of, significant differences were recorded before and after training in "sociability", "playfulness", "predatory instinct", and "aggressiveness" scores. Lower levels of platelet 5-HT and 5-HIAA were found after training. Plasma L-3, 4-dihydroxyphenylalanine levels differed between sexes, with males showing higher concentrations.

From a behavioral point of view, significant differences were recorded before and after training in "sociability", "playfulness", "predatory instinct", and "aggressiveness" scores.

Working perspective

It was actually possible to make the thermography video during the behavioral tests, no interaction was needed between the thermographer and the animals, thus confirming the non-invasiveness of the developed system, as shown also in other species. In addition to behavioral information of the subjects, it also provides information on the variation of skin temperature during the test, both in the same dog, and in different animals, as shown in rats. With regard to temperature measurements made during the blood sampling, the difference found between the sexes could be linked to differences in concentration of certain neurotransmitters (in particular the L-dopa plasma) detected between individuals of different gender. Further investigation is needed to confirm the results and to better assess the complex structure of the relationship between behavior and neurotransmitters. In this direction, the relations between measured temperatures and scores obtained from the animals during the behavioral test, allow us to hypothesize for an effective use of thermography as a noninvasive technique to measure objectively the state of well-being.

CONCLUSIONS

Thanks to its characteristics of versatility, lack of invasiveness and high sensitivity, thermography lends itself to countless applications in biology [24]. Probably the major limitation to its application in the animal and biological field lies in the ease of use and in its extreme sensitivity. In fact, a thermal image of an animal presents very often thermal anomalies not directly related to its physio-pathological state, but due to various causes, such as environmental conditions or those of measurement, or to individual variability.

This article provides an overview of possible applications of the technique of visual inspection of heat, but it is clear that every phenomenon connected to temperature variations can be identified with this thermography. Thus, the operator has to identify the best experimental context to obtain as much information as possible concerning the physiopathological problems to be studied. Further, the first results of the use of thermography as a non-invasive technique to assess the state of welfare in working dogs showed that IRT could be used to measure objectively the welfare of animals.

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Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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