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Heat traces at crime scenes - A forensic study

Abstract

Every person who moves around a place of action, i.e. also a crime scene of a criminal offence, leaves traces of heat there. On the one hand, body heat is transferred to objects by sitting, lying, walking, standing or grasping objects. On the other hand, the use of technical equipment such as washbasins with hot water supply, the use of coffee machines, cookers, lamps, firearms, motor vehicles or other objects leads to the heating of objects. Such traces of heat can be measured and documented by thermal imaging cameras, since heated objects emit infrared radiation that can be detected by such cameras, measured in temperatures and converted into image signals. They give the observer a visual impression of which objects at a location are warm or cold. The great advantage of heat traces is that they largely provide information about their time of origin and thus allow conclusions to be drawn about when certain actions occurred at the crime scene, and possibly also how many people were acting there. Their greatest disadvantage is their high volatility, as they can only be detected for a few minutes up to half a day, depending on the circumstances. The work with heat traces is not yet used in criminalistic crime scene work and is also far from being fully explored. The author has endeavoured to shed some light on the subject in a series of heat trace experiments, some of which will be presented here. It could be worthwhile to deal with this type of trace scientifically and practically in the coming years, as its peculiarities can enrich the current standard repertoire of crime scene traces and thus the solving of crimes. The author hopes that this paper will provide an impetus for further research.

1. Heat residues of human activity and their measurement

The French forensic scientist Edmond Locard established as early as the beginning of the 20th century that every human action leaves traces behind (Locard's rule). If you sit down on an armchair, you leave fibres of your trousers on the seat and, depending on the seat covering, you also pick up material from the armchair along with the trouser fabric. Touching an object with the bare hand causes finger and palm prints and when walking through a room, the person leaves behind skin flakes and hair or material containing dna when speaking, sneezing or coughing. Depending on the type of trace, the person concerned has little influence on whether or not they leave these substances behind and can only protect themselves against the laying of such traces to a limited extent.

A physical phenomenon that has received little attention so far, but to which Locard's rule can certainly be applied, are so-called thermal traces. This refers to heat residues that every person leaves behind, on the one hand through their body heat and on the other through the operation of technical equipment. Thermal traces have a big disadvantage, but also a very big advantage, which cannot be observed or hardly observed with other traces. Thermal traces are quickly volatile. Depending on the duration and intensity of the heat exposure, they weaken more or less quickly, so that the search for and securing of such traces at the crime scene requires urgency. Their considerable advantage, however, is that - unlike most other crime scene traces - they provide information about when they were laid, so that, in the best case, one can trace processes that occurred at the crime scene back to their time of causation and thus gain clarity about when and, if necessary, in what order certain processes took place. Thermal imaging cameras are an instrument for searching for and securing evidence.

Physically fundamental for the detection of thermal traces is the fact that people transfer heat to the respective surfaces of the touched objects when walking, standing, sitting, lying down, but also when touching objects. Heat transfer from one object to another takes place in three ways: Conduction, convection and radiation. In conduction, two objects touch each other directly and the heat from one object is transferred to the other. In this process, nature provides for the establishment of a thermal equilibrium. The objects approach each other in temperature as time progresses. The warmer object thus becomes colder and the colder object warmer at different temperatures. Heat conduction as a sub-case of heat transfer is the normal case in the transfer of body heat. When you sit on a chair, the seat feels warm after a while, while the buttocks are cooled down a little by the colder chair. In convection, mass is heated at a certain point, the heated parts of the mass move towards the colder parts and heat them in turn. This is the case, for example, when a pot of water is placed on a cooker. Although only the part of the water closest to the bottom of the pot is heated, the heated molecules move towards the colder ones in the upper part of the water mass and heat them up. Finally, the third sub-case of heat transfer is radiation. Here, electromagnetic rays are sent from one object to another. Although the objects do not touch each other, the rays that are sent from the heat-emitting object are converted into heat by the other object. Imagine the relationship between the sun and the earth. The sun sends its rays to the earth, where they are absorbed and converted into heat energy.

If we now convert these theoretical findings of thermodynamics to the events at a crime scene, thermo traces are also created here by the transfer of body heat and by the operation of technical equipment by human hands. Thus, the sexual killer, who has become acquainted with his victim, may sit down with him for a coffee before committing the crime, and then surprisingly proceed to the act of violence and the killing. Both he and the victim leave traces of heat on their seats. The victim will previously leave a heat signature in the form of his body silhouette in the bed where he has spent the night. The coffee machine used to brew the coffee still shows traces of heat hours after it has been used, as do the coffee cups used, and when the perpetrator washes his hands in the bathroom after his crime to clean himself of his victim's blood, he heats up the tap as well as the sink by using the hot water supply. These objects still show heat radiation over a longer period of time, which allows a conclusion to be drawn about what happened and when it happened.

Detection and documentation of such thermal traces is possible with thermal imaging cameras. The work of such cameras is based on the reception of infrared radiation emanating from the heat of an object. Electromagnetic radiation of different wavelengths emanates from every object. Only in a very narrow range are these rays visible to the human eye and ensure that surfaces and shapes are perceived. The majority of the rays are not visible. Infrared rays are in a wave range that cannot be perceived by humans, but can be perceived by an infrared thermometer in a thermal imaging camera. When measuring temperature without contact with such a camera, a lens focuses the radiated energy. A detector converts the radiated energy into an electrical signal, which is translated by the camera into a multi-coloured image. The camera measures all objects in the area to which it is directed and displays them in different colours depending on their heat value. Even objects that are subjectively perceived as cold still emit infrared radiation. The [1]temperatures of these objects only have to be above absolute zero of -273.15 degrees Celsius. [2]

2. Heat radiation as crime scene evidence

What do such thermal traces have to do with the prosecution of crimes? In order to answer this question, a few scenarios will be briefly presented here, on the basis of which it will become clear which heat residues of perpetrators and victims can be expected at crime scenes and which information these traces may possibly provide about the occurrence of the crime. Basically, a distinction is to be made between traces that were produced directly by body heat and those that were produced by the use of technical equipment by a person.

Thermal traces caused by body heat

Footprints

The detection of footprints or shoe prints can, in the best case, make the walking distance of a person traceable, so that it can be determined where a person moved along the crime scene. If necessary, escape routes can also be traced. However, the chance of finding heat traces caused by unshoed or shod feet depends on the emergency services reaching the scene of the crime very quickly, as footprints evaporate very quickly due to the short exposure time to the ground. This is even more true for shoe tracks than for tracks of bare or stockinged feet, as shoes have a heat-insulating effect and thus give off even less heat energy to the ground than bare feet.

Seat tracks

Especially at crime scenes where relationship crimes have occurred, it does not seem unlikely that perpetrators, victims and witnesses to the crime have sat down to sit down before the crime. Buttocks and thighs then leave heat on the seating surfaces. The detection of traces of sitting by infrared radiation allows conclusions to be drawn on the one hand about the time of origin of these traces and on the other hand about the number of people who were at the crime scene. It should be noted, however, whether heat traces on several seating surfaces have approximately the same intensity, as otherwise false conclusions could be drawn with regard to the number of people present. If, in the course of the event, a person moves from one seating area to another, traces of heat are produced on two areas, which could erroneously lead to the assumption that there were two persons present. Here it has to be checked whether the seating surfaces possibly show a different heat intensity, as the surface used earlier will already have cooled down compared to the one used later and thus will show a weaker heat signature than the one used last.

However, seat marks can also play a role in finding incriminated motor vehicles that have been abandoned only shortly before they were found. In this case, it is also possible to determine how long ago the vehicle was used and, above all, how many people were sitting in it.

Lying tracks

Lying traces can also play a role in relationship crimes. The effect of body heat over a whole night is extensive and intense. Under certain circumstances, the heated surface is also protected from rapid cooling by bed covers or similar, so that measurable traces can be expected here for longer than, for example, on walking and sitting surfaces. Thus, at a crime scene

[1] Fäßler, Andrea (2012), p. 11 f.

[2] InfrarotTec Systems. FLIR Distribution (n.d.), p. 7.

where a homicide or another serious violent or sexual offence has occurred, it could be determined whether of two existing beds possibly both show a strong warming and thus it can be assumed that two persons have spent the night in the beds, which in turn speaks for a great social proximity of these persons.

Grip marks

At crime scenes, crime weapons and crime tools are touched or also objects of daily use such as cups, cutlery or the like. Heat signatures on corresponding objects can be a strong indication of their relevance to the crime if they are found with heat traces at a crime scene shortly after a crime. One might think of a knife after an assault. Thus, if there were a number of knives at a crime scene, it might be possible to identify one with a particularly high heat radiation at the handle. The heat measurement would thus considerably simplify the selection of several potentially eligible objects. However, one could also think of finding a screwdriver near a burglary scene if heat can still be measured on the handle of the tool. Ballpoint pens, a drinking glass or other objects of daily use can also be identified as relevant to the crime if they show traces of heat shortly after the crime.

Other traces caused by body heat

Objects that are carried close to the body, for example in a trouser, shirt or jacket pocket, also absorb energy through the transferred body heat. Therefore, it can be proven over a certain period of time that a wallet, for example, must have been in a trouser pocket and cannot have been there for long when it is found. Small objects such as drug packets found on the ground at the scene of a police check give an indication by their warmth that they were obviously thrown away by the checked person immediately before the police action. In the same way, shoes or items of clothing found at the scene of a crime indicate that they must have been worn by someone shortly before.

Thermal traces caused by technical actions

Heat-generating appliances for daily use

Just as body heat transfer leads to heat signatures on objects, the use of technical equipment in a home, office, workshop or other place also provides temporary and detectable heating of objects. As with body heat, the questions to be asked when looking for technically heated objects are always: Has there been any action in this place recently - and thus thermal traces created? Approximately how long ago were these actions carried out? How many people are likely to have been at the scene?

Technical equipment that should be detected with a thermal imaging camera for thermal traces of recent activities are, for example, lamps, especially those that are found switched off. Also of interest, however, are cookers and the pots on them, coffee machines and kettles, irons, heaters, washbasins and bathtubs with hot water supply, whether filled with water or not, and all other objects that are regularly used only for a short time and for acute reasons. Such heat-generating devices radiate heat for considerably longer than objects that have been heated by body heat. In washbasins and bathtubs that have been filled with warm/hot water or through which heated water has passed, not only the fittings show traces of heat, but also the basins and tubs themselves that have come into contact with the water.

Motor vehicles

The use of motor vehicles causes certain components to heat up quite quickly and strongly. For example, the engine heats up quickly when driving. It radiates its heat just as quickly to the surrounding components, especially the bonnet and the wings. The wheels, and in particular the brake discs, also show strong signs of heating after a journey, and it takes many hours for them to cool down again and reach the ambient temperature. This can be helpful for police operations, especially when it is necessary to determine inconspicuously which vehicle may have been parked in a controlled area only recently. In this case, a thermal imaging camera can be used to determine which vehicles may be relevant and which may not during an inconspicuous and speedy drive past parked rows of vehicles. If necessary, this can also be used to detect specific vehicles that might be suitable for observation. After hit-and-run accidents, it is also possible to quickly determine whether or not a vehicle suspected of being involved in a hit-and-run is at all relevant for a recent accident.

Other heated objects

In a thermal image detection, objects at a crime scene can also be of interest that have only been heated indirectly by the operation of technical equipment. For example, cups for hot drinks, cooking pots with and without contents, hot-water bottles, thermos flasks, etc. are of interest here. With a corresponding heat signature, they can also provide information that use has taken place within a traceable period of time. However, a plurality of drinking vessels can also provide information about the number of people who were at a crime scene at a certain time. When detecting heat, however, one should not only think of objects that are particularly warm, but also of those that have a temperature that is clearly below average - in relation to the ambient temperature. This can be the case, for example, with drinking vessels containing strongly cooled beverages. A lower temperature in relation to the ambient heat can also be detected with a thermal imaging camera.

Use of firearms

After the use of firearms in violent crimes, two problems often arise. On the one hand, fired bullets and cartridge cases have to be found as evidence, and on the other hand, it may be necessary to find a discarded firearm. The problem with ammunition parts is that they are particularly small and can easily be lost to the human eye, especially outdoors, because they do not stand out visually among stones, vegetation and rubbish. Rapid detection with a thermal imaging camera at an early stage of the incident can lead to a quick location of such objects, which are of greatest interest for further crime investigation. Even a firearm that has been thrown away in unclear terrain and has been strongly heated up by a shot fired shortly beforehand can still be found thermographically for a limited time. However, the following applies to all thermo-traces: The traces are fleeting and the time window for successful detection is narrow. It is therefore important to start the search quickly.

Determining the time of death of corpses

The reliable determination of when a person has died plays a major role, especially in cases of intentional homicide. When the police arrive at the scene of the discovery of a corpse, the investigators will usually take a tactile sample by hand to determine whether the corpse is still warm or already cold to the touch. In the more favourable case, a corpse thermometer is carried along to measure the temperature. However, this procedure is always associated with the fact that the corpse has to be manipulated and possibly deceptive traces are laid by the raining of skin flakes, hair, saliva and textile fibres from the investigator's body. The determination of the corpse temperature by means of a thermal imaging camera makes it possible to avoid such traces of deception, since the temperature can be measured from a greater distance. However, it should be noted that the time of death is not determined by the surface temperature of the corpse, but by its core body temperature. Here, a conversion model still needs to be developed with which the body surface temperature can be inferred from the body core temperature.

3. Heat traces as other aids to police work

In police operations, the search for people who are deliberately hiding or who have unintentionally got into a rough environment plays a role time and again. In these cases, thermal imaging cameras can also be of great help. When searching for persons hiding from the police in closed, unclear or poorly lit or unlit rooms (e.g. factory hall, warehouse), the officers involved run a high risk of being overpowered and injured by the hidden persons. At least under certain conditions, such persons can be located with a thermal imaging camera. If someone is hiding behind a curtain, he will heat up this curtain by radiating body heat. In this case, the silhouette of the person behind the curtain may be detected. However, if the person is hiding behind a more insulating material such as a door, the thermal imaging camera will reach its limits and will probably not show the person, as the door is a strong thermal insulator and wood is a poor conductor of heat. However, if the person is hiding in such a way that a small section of their body is not protected by insulating material, they can be located. For example, a person can be detected behind a door that has ventilation slits in the lower area. The thermographic camera will detect the body heat through the slits. However, not only people who want to hide from a police approach, but also those who are in distress in impassable surroundings can be found and rescued by their body heat radiation. A police helicopter with a thermal imaging camera is not always available and in certain environments it might not even be able to detect the person from the height.

Thermal imaging cameras are very successful outdoors when people are hiding in bushes. Even where the person is no longer visible to the naked eye, the thermal imaging camera can make them visible through gaps in the foliage and trace the contours so well that there is no doubt in the mind of the camera user that a person is hiding in the bushes. A thermal imaging camera can also prove its worth in the search for dangerous animals. Time and again, the escape of poisonous snakes, large spiders or other animals leads to extensive search operations, during which entire apartment buildings may have to be evacuated for a longer period of time in order to find the animals and eliminate the danger to the building occupants. Since animals also radiate body heat, the use of thermal imaging cameras may also be indicated here.

A determination of heat radiation always takes place at crime scenes by feeling with the investigator's bare hand. On the bonnet of a car, it is checked whether it is still warm and thus the previous use of a car can be determined. On the body of a corpse, the temperature is felt to determine whether the death may have occurred some time ago or not so long ago. However, this purely haptic experience of heat is too imprecise and, unlike with a thermometer or the heat-visualising thermographic camera, does not allow an objective and exact determination of a heat value. Also, the question of whether an object or a mass is perceived as warm or cold by touch depends on the stimuli to which the nerves with which heat is felt were previously exposed. If we hold our hand in a bucket of ice water for a while, a drinking glass that we then take out of the cupboard will feel warm. If we have previously held a hot water bottle with the same hand instead, we will feel the same glass to be cold. [3]

[3] Stuart et al. (2010), p. 87.

4. Current working areas of thermal imaging cameras

Before the results of a study on thermal traces are presented below, a brief look should be taken at where the instruments needed to detect and secure thermal traces are already being used.

Thermal imaging cameras found use for military purposes at an early stage of their use. This use still exists today. Everyone is familiar with television images showing the detection of heat radiating objects such as buildings or tanks from an aircraft and their subsequent bombing. An important field of application for such cameras is also building thermography, which is used today to detect heat loss in residential and commercial buildings and with the help of which thermal weak points are to be found. Thermal imaging cameras are also used in medicine, where, for example, inflammation foci in the body can be localised and mapped for therapeutic purposes. [4]Other areas of application include troubleshooting technical equipment - here, for example, overheated components threatened by short-circuits or scorching can be detected [5]- or modern automotive technology, with which obstacles such as people or animals on the road can be registered at an early stage and automatic braking can be initiated. But such cameras are also used today in aerospace technology, in the chemical industry or in geology.

Police forces at home and abroad have been using thermal imaging cameras in helicopters and aircraft for many years. They are regularly used in the search for missing or escaped persons. Since people in the open usually emit a temperature that is different from their surroundings, they can be easily recognised in the displays of thermal imaging cameras, so that police forces operating on the ground can be directed by the crews of the aircraft to the persons they are looking for. Thermal imaging cameras have also been used in the forensic field for a few years now. This usually involves making latent blood visible on certain objects such as textiles, which cannot be seen with the naked eye because, for example, the surface of the traces is dark or has an uneven pattern that does not allow blood traces to be found without aids. To detect such traces, water vapour is introduced into the trace carrier in order to detect the infrared radiation of the traces, which is now different from that of the trace carrier. According to the author of this article, heat radiation has not yet been used as crime scene evidence to reconstruct the course of events. [6]However, this possibility is seen as a new chance to make the course of criminal offences comprehensible, to solve them and thus to convict the perpetrators.

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[4] Roman, Jean-Philippe (2010), p. 40.

[5] FLIR Systems Inc. (ed., 2011), p. 81 f.

[6] Research in this area has been limited worldwide. For example, a Dutch study dealt with the detection of blood, saliva, semen and urine traces with thermal imaging cameras (Edelman et al. (2013)). A study by Xu et al. (2020) focused on thermal radiation from footprints. In a paper in the journal "Kriminalistik", Matzdorf and Reußner (2021) present a study in which they investigated the question of what types of heat traces people leave behind at crime scenes and how long these traces are detectable (Matzdorf et al. (2021)).

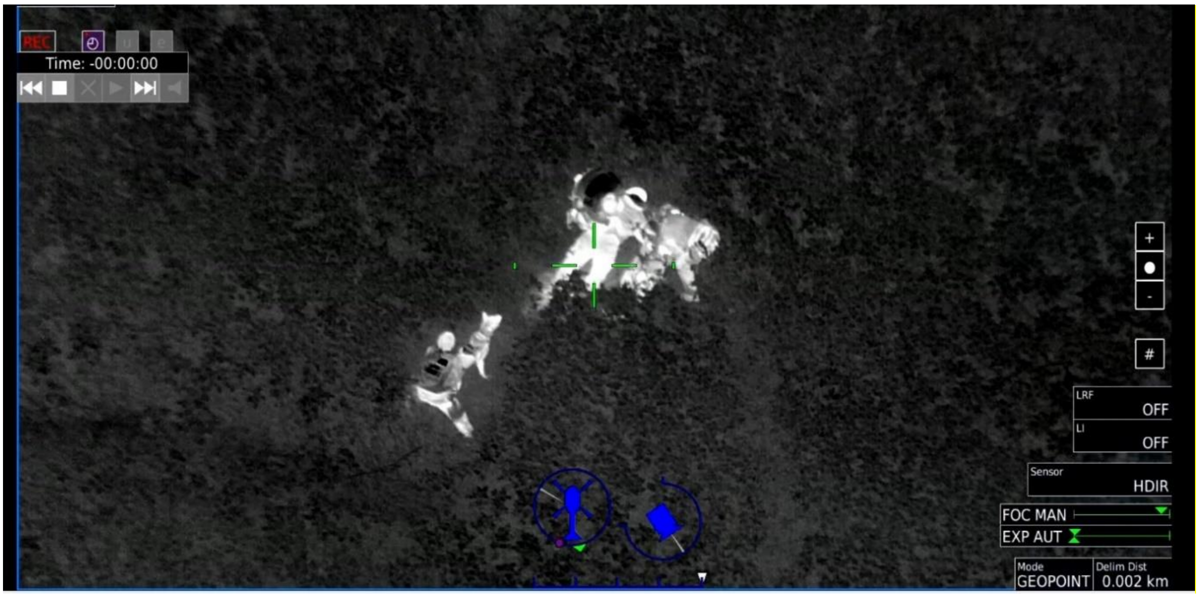

Fig. 1: A fugitive motorcyclist lying in a bush was captured by a thermal imaging camera from a police helicopter. The fugitive can be seen in the centre of the picture. The visor of his helmet obviously has a strong insulating effect, as hardly any heat is emitted in this area. To the left below the man is a police dog handler with his animal, to the right of the man a second police officer is leaning down towards him (Source: LZPD NRW).

5. Experimental exploration of heat traces - the results of an investigation

The author of this article has experimentally investigated the question under which circumstances thermal traces are generated and how long the heat dissipation takes. A leading manufacturer of thermal imaging cameras, FLIR Systems, provided the author with two cameras for two months for his experiments. These were an E6 type device and a small pocket-sized C5 camera. The majority of the experiments were carried out with the E6 camera type. Only for comparison purposes was the C5 model also used in some experiments. To anticipate the results here: Even with the smaller and less expensive camera (approx. 600 euros), good results were achieved that were useful for forensic purposes. The larger E6 camera is in the price range around 2,000 euros. According to Matzdorf and Reußner, good results are also achieved with even smaller devices, which are smartphone attachments and are operated with an app (costs approx. 200 euros).

During the experiments, situations were simulated that could also be encountered at crime scenes. Thus, hot water taps of hand basins were used, coffee was made in coffee machines and poured into earthenware cups, body heat was transferred to seating surfaces, walking surfaces and beds, and in the same way, motor vehicles were used or persons hiding were detected. The results of the investigations were summarised in a larger paper and can be read there. [7]Only a few experiments with a small selection of thermographic images will be presented here to give the reader a rough idea of what can be detected with a thermal imaging camera. In the following, the use of a hand basin, a cooking pot on a cooker, the filling of a coffee cup, the use of a bed as well as the measurement of footprints and the detection of a hidden person are documented. Basic findings of the measurements were that

- the intensity of the heat on the affected objects gradually decreases

[7] Kawelovski (2021)

- concentrated traces of heat gradually diffuse to their surroundings as they warm them up with them and that
- Body heat traces degrade much faster than heat traces generated by the use of technical devices. Body heat traces were lost in a time frame of a few minutes to an hour. Heat signatures on technical equipment were visible for between an hour and sometimes even up to half a day.

The experiments in detail, for which thermographic images are shown below:

Experiment 1: Use of hand wash basin

Water at a temperature of approx. 61 degrees Celsius is allowed to run into a hand-washing basin. The water is not collected in the basin, but runs directly down the drain. The water is allowed to run for about 15 sec. and then turned off. Photographs were taken during the water run and afterwards. For 75 min, there was noticeable heating of the faucet and sink. The visible heat radiation is likely to have persisted well beyond this time. However, the experiment had to be stopped after 75 min for organizational reasons.

Experiment 2: Using a cooking pot on a stove

A cooking pot with a capacity of 3 liters is filled with 2 liters of water. The water is brought to a boil and then immediately turned off. The water is left in the pot. Even after more than 12 hours, significant heat radiation can be seen on the hotplate and the underside of the pot. This test was also terminated prematurely after 12.5 hours. The heat radiation was probably still measurable well beyond this time.

Experiment 3: Filling coffee cups

Three cups are placed next to each other at a distance of 5-7 cm. The left cup is filled with boiling water to 2 cm below the rim and the water is left in the cup. Boiling water is poured into the middle cup, but poured out immediately. Cold tap water is filled into the right cup and left in the cup. After the start of the experiment, the left and middle cups show clear heat radiation, while the heat signature of the cup with the cold water indicates a below-average temperature, i.e. well below the ambient temperature. The heating of the left cup, in which the hot water was left, still shows increased heat radiation after four hours. In the case of the middle cup, which was emptied, this radiation disappears after about half an hour.

Experiment 4: Use of a bed

A test person spends 9 hours lying on a cold foam mattress. Immediately after getting up, the first pictures are taken. The contours of the person are clearly recognizable. The different intensity of the heat signatures on the mattress also indicates that the person was last in the supine position and previously in the right lateral position. The person's contours disappear after about half an hour, but the mattress still shows a clear, albeit now diffuse, warming even after an hour.

Experiment 5: Footprints

A test person stands for 1 min. with stockinged feet on a tiled floor. The traces could still be clearly detected after 10 min. and only very faintly after 15 min.

Experiment 6: Person hiding in bushes

A person hides in a bush with a total depth of about 6 meters. When positioned 1.5 meters from the front of the bush, the person's contours are clearly visible on the thermal imaging camera, despite the fact that the bush is covered with foliage. Although there is good daylight, the person is no longer recognizable when looking directly at the bush. With increasingly deeper positioning of the person in the shrubbery, the person is more difficult to recognize in its contours on the display of the thermal imaging camera, since it is covered in each case by more foliage and branches that obstruct the infrared radiation. At a position depth of 4.5 m, only a few bright spots can be seen on the thermal image, which no longer necessarily have to be interpreted as a person. The person is wearing dark pants and a light-colored hooded sweater.

Experiment 1 photos: Use of hand wash basin

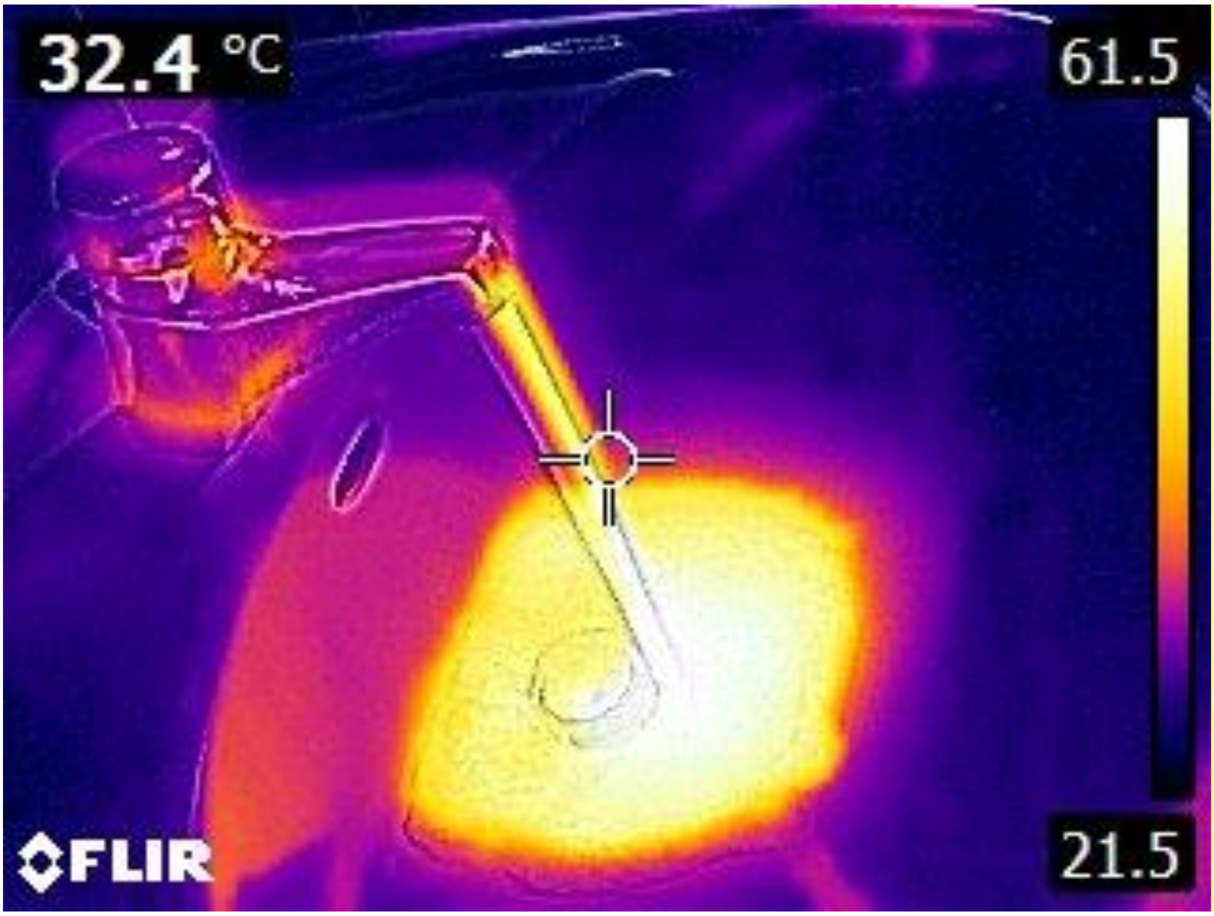

Fig. 2. situation of the water inlet.

Fig. 3. the washbasin 2 min. after turning off the water

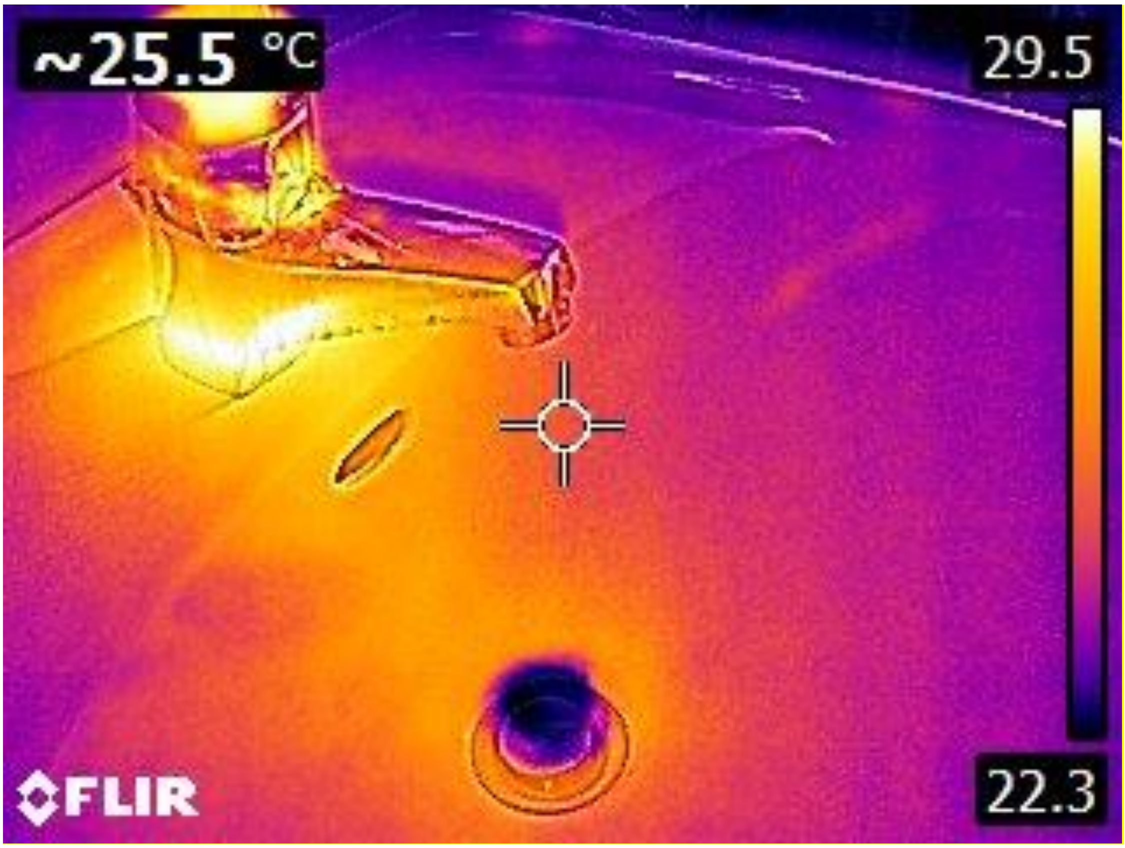

Fig. 4. the washbasin 75 min. after the water was turned off

Experiment 2 photos: Using a cooking pot on a stove

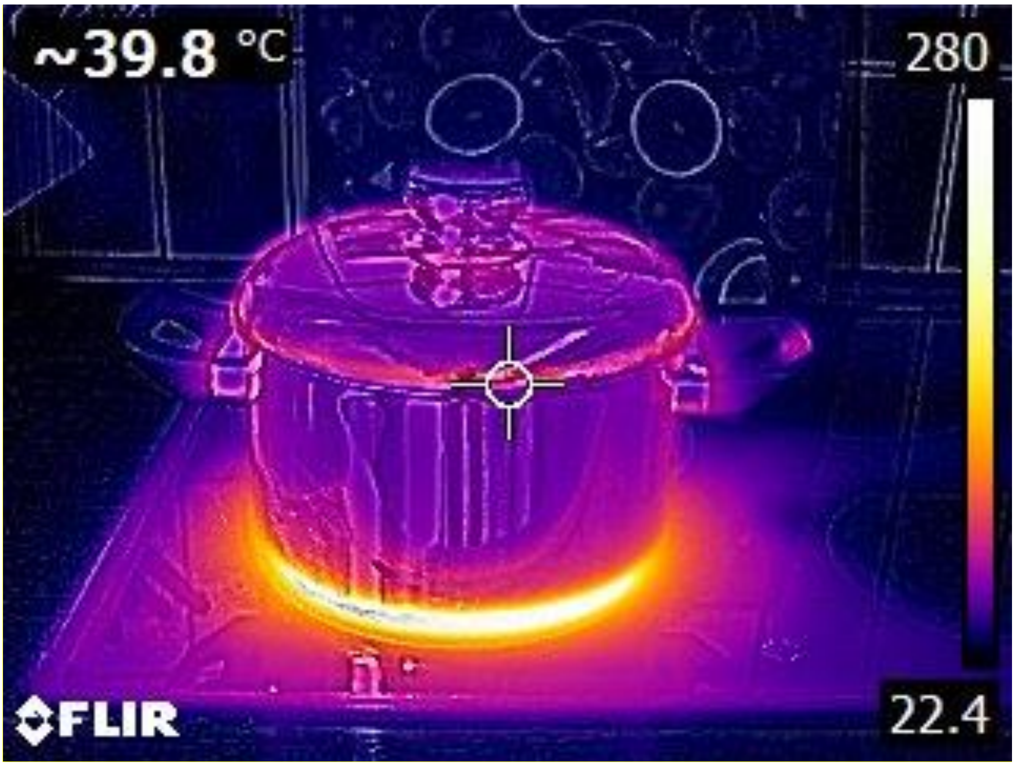

Fig. 5. cooker and saucepan 12 min. after turning off the hob

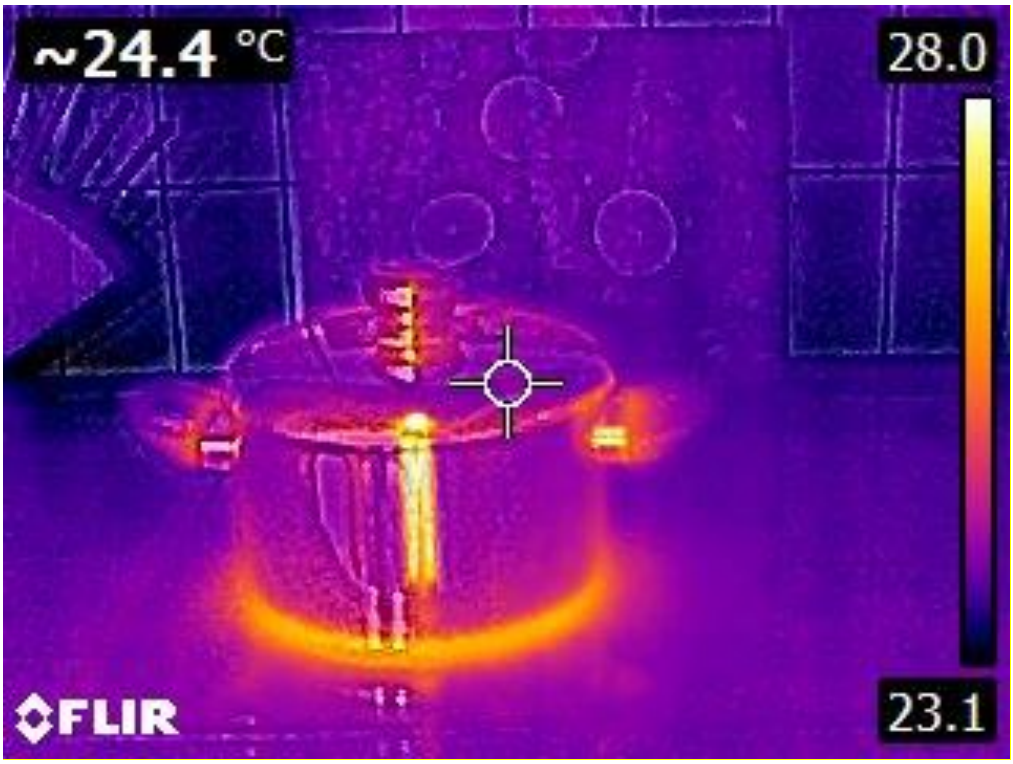

Fig. 6. cooker and saucepan more than 12 hours after turning off the hob.

Experiment 3 photos: Filling coffee cups

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Fig. 7: Cups immediately after filling the two outer cups and emptying the middle cup. Empty cup

Fig. 8. cups after 2 hours

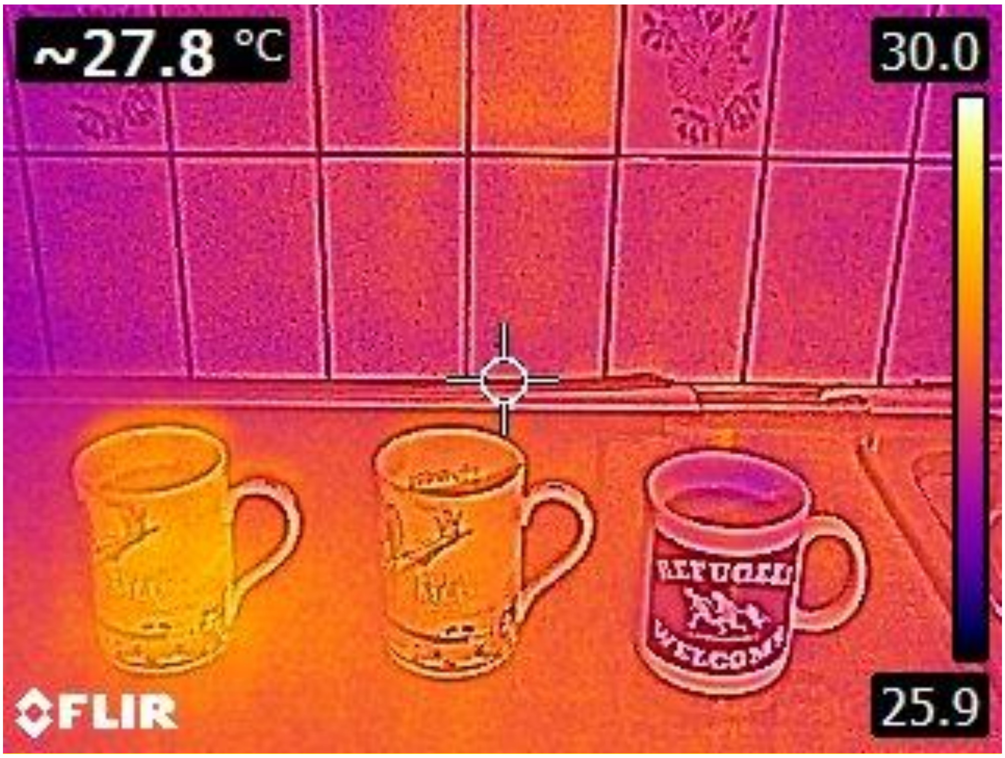

Fig. 9. the cups after 4 hours

Experiment 4 photos: Use of a bed

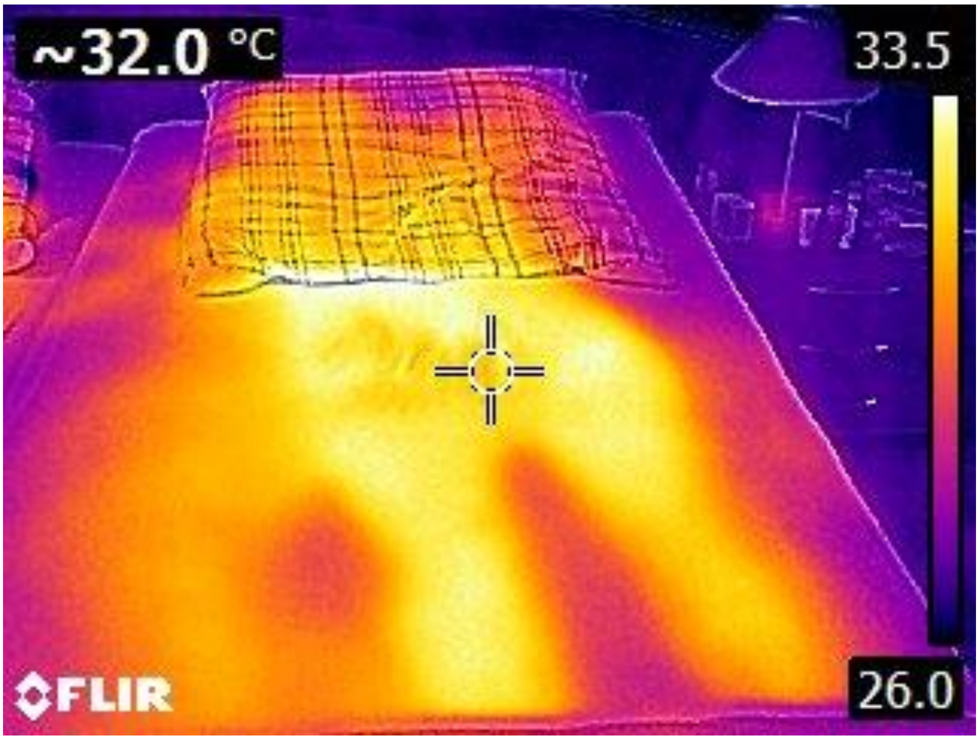

Fig. 11: Mattress immediately after the test person has left it after 9 hours of lying. Two different lying positions are visible, namely the supine position as the last position (strong heat radiation) and the previous side position (weaker heat radiation).

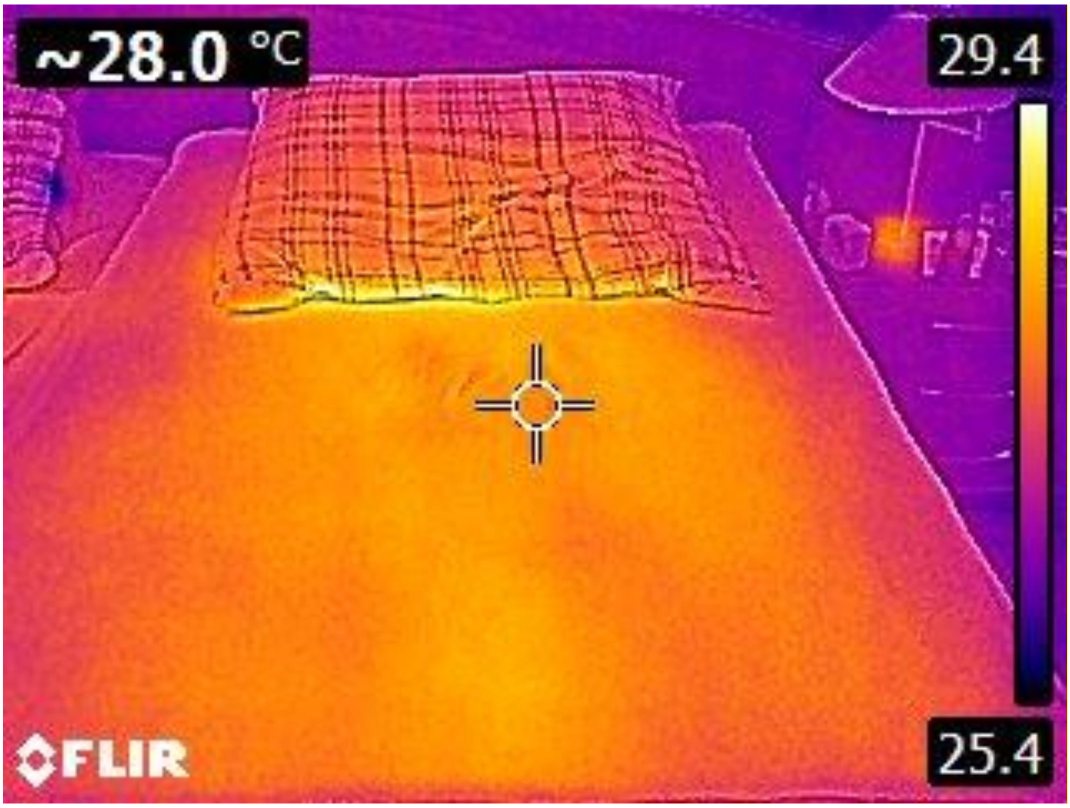

Fig. 10. The mattress 30 min. after leaving the lying surface. The contours of the person are still faintly visible.

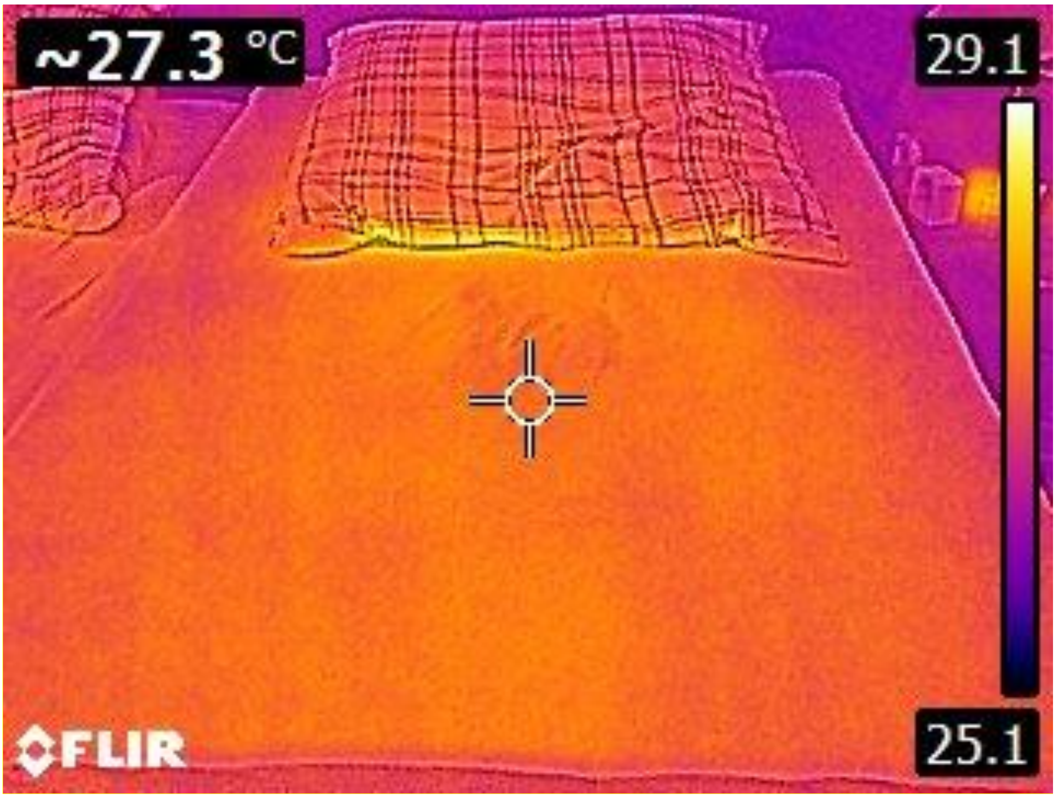

Fig. 12: The mattress after 60 min. A diffuse heating of the surface is now visible, but the contours of the test person can no longer be traced.

Experiment 5 photos: Footprints

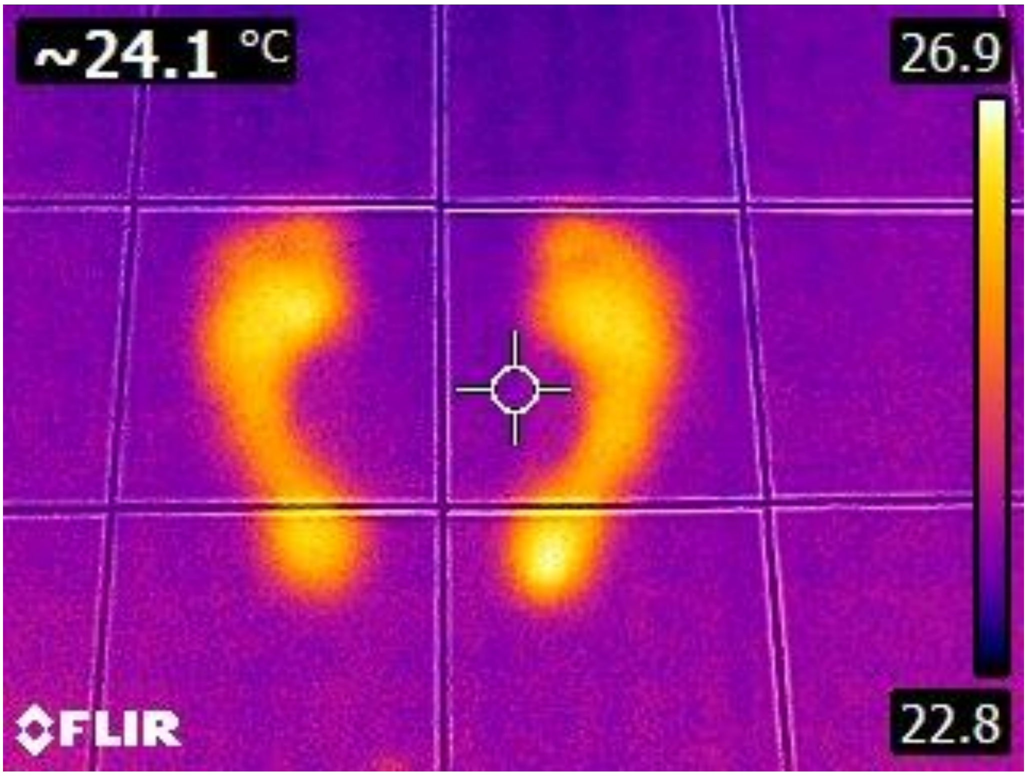

Fig. 13. standing area immediately after the test person has left it

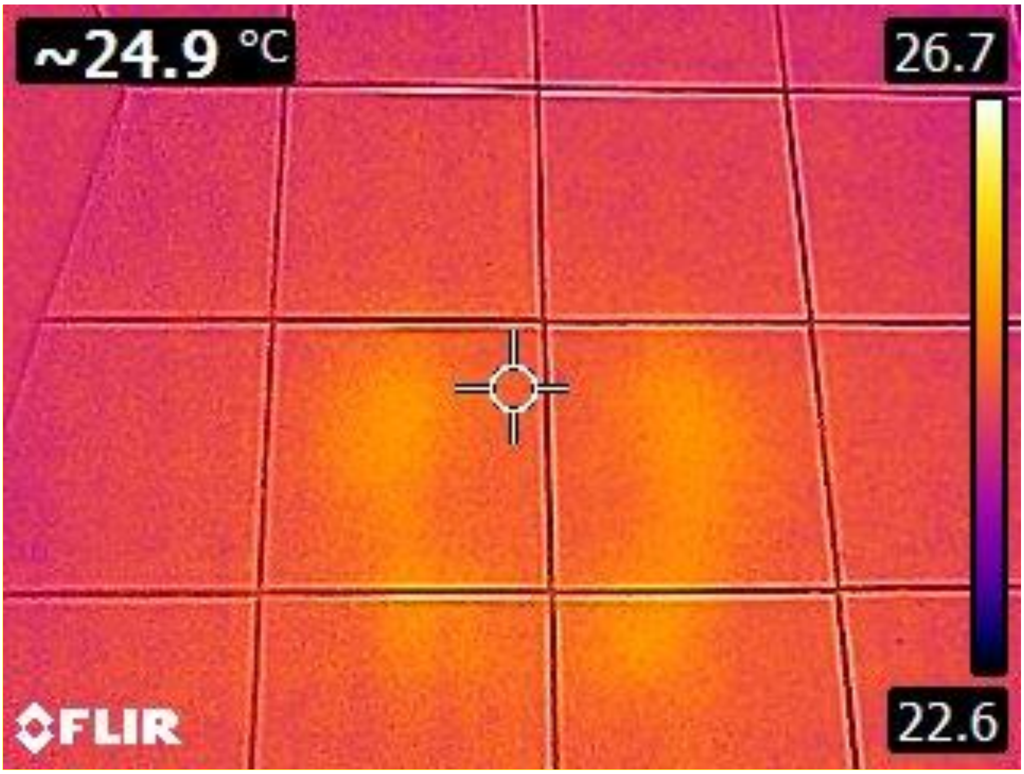

Fig. 14. footprint after 10 min.

Experiment 6 photos: Person hiding in bushes

Fig. 15. unconcealed person in front of bushes (normal shot)

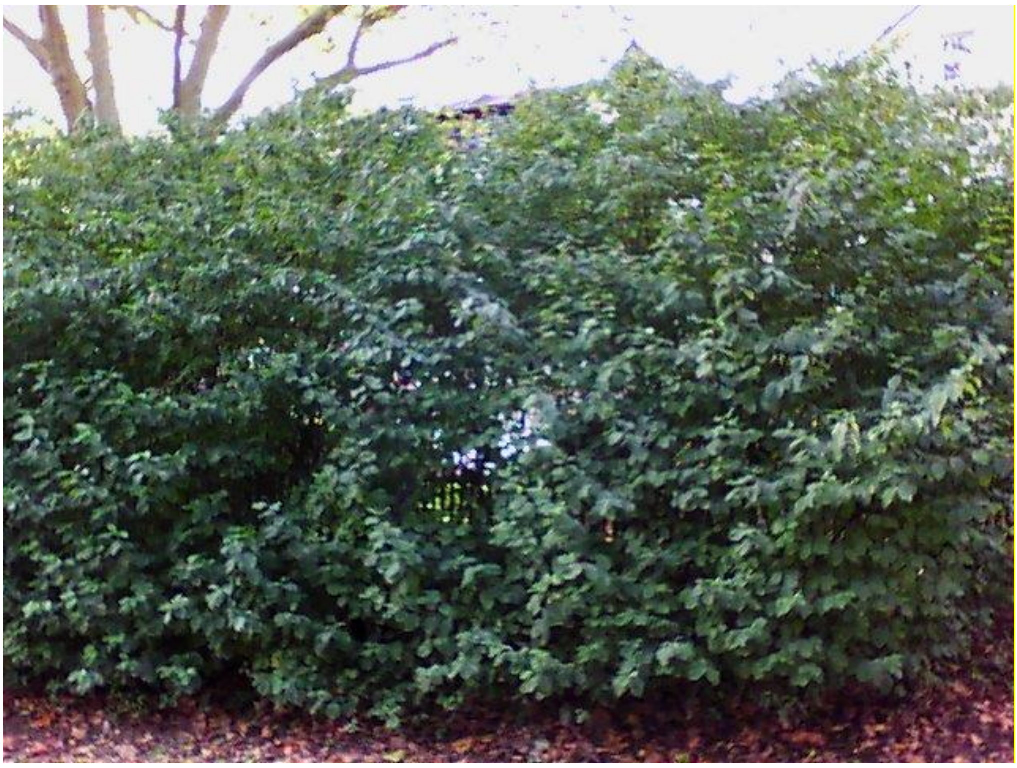

Fig. 16. person in the bushes. 1.5 metres from the front (normal shot).

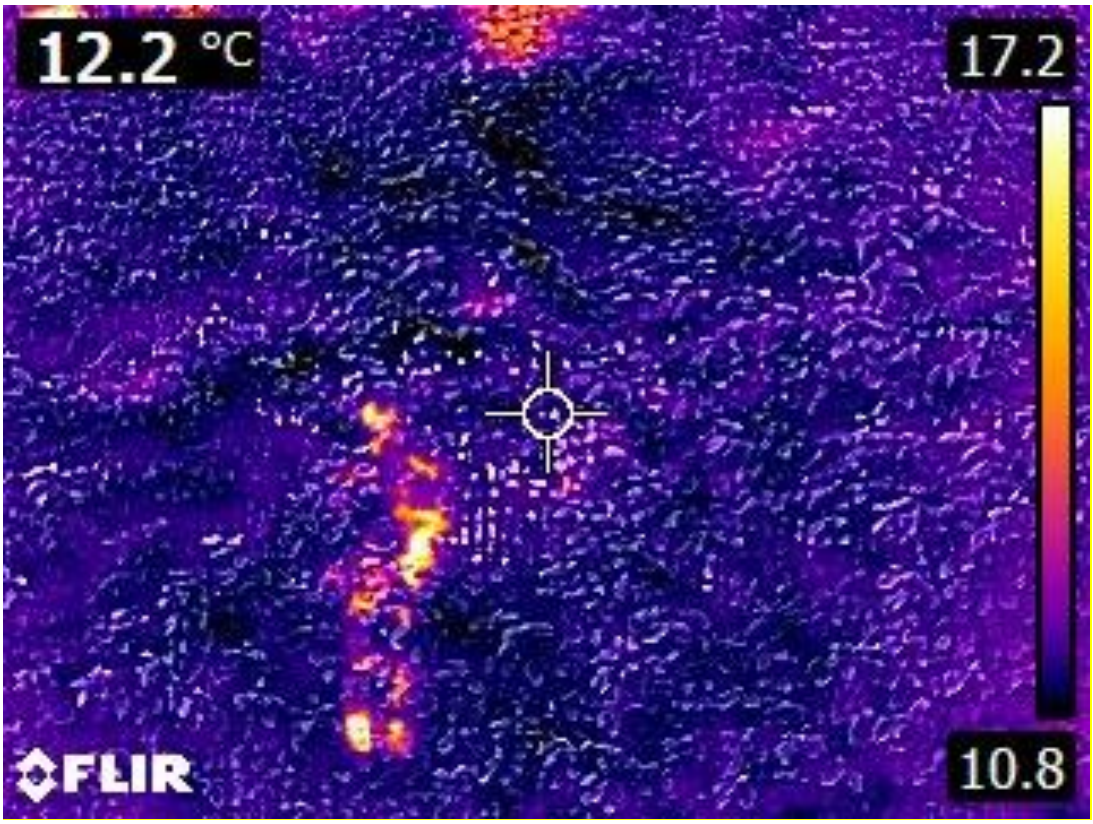

Fig. 17. person in the bushes. 1.5 metres from the front (thermal image).

Here is an overview of some measured values from the test series:

Object	**Duration of the Heat exposure**	**Start of heat measurement**	**Maximum heating on the object surface at the start of measurement**	**Maximum temporal visibility of the thermo track**
Seat Imitation leather couch	5 min.	after the subject has stood up	34,1° C.	13 min.
Standing lane Tiled floor stocking	2 min.	after leaving the area	26,9° C.	15 min.
Standing track carpet shod	1 min.	after leaving the area	24,5° C.	< 2 min.
Outdoor standing lane shod	1 min.	after leaving the area	15,3° C.	3 min.
Outdoor standing lane shod	2 min.	after leaving the area	14,5° C.	4 min.
Lying track	9 hrs.	after leaving the bed	33,5° C.	approx. 60 min.

Cold foam mattress				
Grab track Kitchen knife	1 min.	after releasing the knife	31,4° C.	> 20 min.
Water tap and hand basin	90 sec.	after the water inflow has been turned off	61,5° C.	> 75 min.
Wearing shoes	30 min.	After taking off the shoes	29,9° C.	> 80 min.
Purse carried in trouser pocket	60 min.	After removing the wallet from the trouser pocket	32,6° C.	> 33 min
Car use (engine and tyre heat)	30 min.	after the journey has ended	42,3° C. Bonnet / approx. 30° C. Tyres	> 6.5 hrs. bonnet / > 50 min. tyres
Heating heat after shutdown	Heating up to maximum temperature	After switching off the heating	64,7° C.	> 3.5 hrs.
Filled bathtub	Approx. 10 min. (half filling of the tub)	After turning off the water supply	48,0° C.	> 7 hrs.
Cups with hot water	1st cup filling left / 2nd cup poured out immediately	After filling the cups	83.6° C. at 1st cup / approx. 50° C. at 2nd cup	> 6 hrs. for 1st cup / > 1 hr. for 2nd cup
Cooking pot with boiling water on hotplate	Water brought to the boil	After switching off the hotplate	280° C.	> 12 hrs.
Used Iron	Heating up to maximum temperature	After switching off the iron	215° C.	> 9 hrs.
Used Coffee maker	Water boiled and left in coffee maker	After the hot water has passed through	69,7° C.	> 7 hrs.
Metal lamp with bulb	5 min.	After switching off the lamp	69° C.	approx. 30 min.

6. Conclusion and outlook

People leave traces of heat wherever they are. They create these traces partly by transferring body heat and partly by using technical equipment. Heat traces have the disadvantage that they are volatile and, depending on how they are created, can only be measured for a few minutes up to about 12 hours. With thermal imaging cameras, such traces can not only be measured at crime scenes, but also visualised in such a way that they can be recognised even by untrained persons. The advantage of thermal traces is that they can provide information about the time of their formation, are easy to find with thermal imaging cameras and neither the search for such traces nor their securing requires any physical impact on the trace carrier. Trace carriers are therefore neither contaminated nor altered in the course of evidence recovery. Moreover, thermal traces are easy to find and secure even under unfavourable visibility conditions or even in complete darkness. Apart from the detection of thermal traces, working with thermal imaging cameras in the police can also contribute to an increase in self-protection in the search for persons and significantly increase the chances of success in the search for fugitives or missing persons.

Thermo traces have not played a role in crime scene work so far. Their potential seems to have been neither recognised nor explored. One problem in working with such traces is that police forces need to be sufficiently equipped with thermal imaging cameras. However, this is currently not the case. There are also still many open research questions on this topic that would need to be answered by further studies beyond those of the author. In particular, it would be helpful to develop calculation models for heat dissipation on different materials in order to be able to make reliable back-calculations on the time of origin of heat traces. However, it might be worthwhile to further investigate the phenomenon of thermal traces and to implement them into the portfolio of evidence in the future. Here, cooperation between criminologists and physicists would certainly be indicated. It is to be hoped that the present research approach will be taken up by interested bodies.

The entire study is presented in a book published in May 2021:

Kawelovski, Frank, Thermospuren. Wärmeabstrahlungen als Tatortspuren und Hilfsmittel der Polizeiarbeit, Mülheim 2021, 124 pp. , 127 photos, ISBN 978-3-9822560-1-6

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