Accuracy assessment of spatial organization and activity of indoor cats using a system based on ultra-wide band technology

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Short communication

Accuracy assessment of spatial organization and activity of indoor cats using a system based on ultrawide band technology

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ABSTRACT

The study of mammalian societies and other similar social groups requires identification of group members and documentation of their spatial organization. Ultrawide band technology is a pioneering research technique that allows real-time automatic recording of the location of each group member. Cats living in a group were equipped with active transponders on their collars over a 2-week period. Cats traveled on average 965 ± 360 m per day, spending 30% ± 7% of their time moving. Their activity was characterized by 4 peaks of activity: 2 in the morning, another in the midafternoon, and the last at sunset. They spent most of their time in resting places, only 1 hour in the feeding area and a few minutes in the drinking and elimination areas. They interacted on average 53 ± 9 times with each other during the 24 hours they spent together per day and 32 ± 7 times with humans. This approach provides a new system to monitor groups of animals more accurately than Global Positioning System technology in indoor environments and in a much more convenient way than passive radiofrequency identification.

Introduction

Spatial distribution and social interactions of mammals or insects are typically investigated by human observers scoring behaviors in real time or from video data. The latter process, even with modern techniques based on digital image analysis, is time consuming and demanding in terms of data storage. Video recording is also fastidious and difficult to implement with animals similar in appearance or in conditions of low light or darkness. Another alternative is to follow the animals using Global Positioning System (GPS) trackers that can be very useful for long distances. This concept is based on the receiver-satellite distance estimated from the time taken by the signal to travel from the satellite to the GPS receiver. By monitoring feral cats with GPS collars in open landscapes, Recio et al. (2010) were able to determine their home ranges. Nevertheless, these technologies are unsuited to indoor environments. Furthermore, commercial GPS tracking collars also have data storage constraints, hindering collecting data with high temporal frequency (e.g., every 15 minutes or less) if animals are followed during long periods (up to 1 year or more).

Radiofrequency identification (RFID) technology represents an interesting alternative as it allows the storage of a hypothetically infinite quantity of data with excellent spatial resolution (<1 cm). In previous studies, passive RFID tags were chosen because of their miniaturized size and unique ability to yield accurate information about spatial distribution (Kritzler et al., 2006; Want, 2006; Serra et al., 2012). However, the tag must be close enough to the reader/antenna to be detected, and only 2 dimensions are documented. Furthermore, many RFID readers must be used to cover the spatial domains of interest. To overcome this limitation, some studies have developed a mobile reader able to cover the desired area of interest (Moreau et al., 2011), whereas others have used a large quantity of readers to cover larger areas (Kritzler et al., 2007).

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Ultrawide band (UWB) may be a more suitable technology to track animals in an indoor environment as the reader can be spatially dissociated from the tag: the tag emits a signal that can be detected by triangulation by a remote reader. Thus, the UWB technology represents an innovative solution to mitigate the accuracy of GPS systems and the spatial constraints imposed by passive RFID.

The objective of this research was to use UWB technology to simultaneously localize, with maximum accuracy, a group of cats 24 hours a day, during a 2-week period and to automatically infer behavioral parameters.

Materials and methods

Animals

A group of 6 European breed cats, aged 3, was studied: 4 spayed females (Farfale, Farfouille, Ficelle, and Fleurette) and 2 castrated males (Falstaff and Farwest). They lived indoor at the Royal Canin's cattery (Aimargues, France) and were observed continuously during 14 days. They all wore UWB tags on their collars during the entire period and were housed under natural light conditions with ad libitum access to food and water, a temperature of 20-21°C in the room and a relative humidity of 20%. The group was fed an extruded dry diet (Fit 32; Royal Canin, Aimargues, France). Staff entered the cat housing facility every day around 06:00 hours to clean the facility, between 08:00 and 09:00 hours and between 14:00 and 15:00 hours to interact with the cats. Cats showed no clinical symptoms of disease over the duration of the study. Each movement was recorded during the entire study and analyzed by software specially developed for this purpose.

Experimental device

Experimental setup

The room was divided into 2 parts, an indoor heated main area of 22.5 m^2 and an outdoor courtyard of 7 m^2. Different areas were defined as static areas in the software's parameters to quantify the time spent in each of them (Figure 1): the feeding area, the drinking area, the seat, 2 litter trays, the wall shelf containing several hiding places and cushions, the enriched area, and the cat trees also containing cushions.

UWB antennas (Ubisense, Paris, France)

With a detection range of 60 m, 7 antennas were placed in corners of the rooms ensuring a perfect coverage. UWB technology uses the principles of active RFID system. Active UWB tags emit a signal detected by UWB readers. By contrast with passive RFID, active RFID does not require closeness between the reader and the tag. It also allows automatic recording, in real time, during a theoretical infinite period, and in 3 dimensions (x, y, and z), each tag's location. The accuracy at the location was analyzed by the manufacturer and was on average 12 cm with a median of 10 cm.

Tags

The 7000 series compact tags were UWB devices certified European Conformity and Federal Communications Commission Part 15.519 (Ubisense, Paris, France). Their dimensions were: width = 38 mm, length = 39 mm, height = 16.5 mm, and weighed 25 g, approximately 0.6% of the cat's weight. The frequency of RFID UWB was 6-8 GHz. The Ubisense tags and readers used extremely low-power radio transmitters and met all applicable European Union requirements, including those for human exposure to electromagnetic radiation.

Figure 1. Experimental setup in 2 rooms. The main one (around 22.46 m^2: 6.4 m [length] × 3.51 m [weight] × 2.60 m [height]) contains an enriched area (with toys), a feeding area, a resting area (big elevated shelf), a drinking area, and a litter; the other, an inner courtyard (around 7 m^2: 2.9 m [length] × 2.4 m [weight] × 2.60 m [height]) contains another litter, 2 cat trees, and a big seat.

Tags were fixed to each cat's collar, and humans wore a specific tag attached to a thin cord around their neck every time they entered the cat housing facility.

Data processing

Detection algorithm and extraction of each cat's position

The litter boxes, shelf, seat, cat trees, drinking and feeding areas, and the enriched area were not moved during the protocol and defined as static areas. Cats and humans were considered as virtual dynamic areas surrounding the tag in a 15 cm radius (Figure 2).

Data were recorded every 0.9 seconds, during a 2-week period (April 22-May 5, 2013), whenever the subject wearing the tag moved. Data were stored in a SQL server database, and all the computations were done with C++ language with Microsoft.Net development platform.

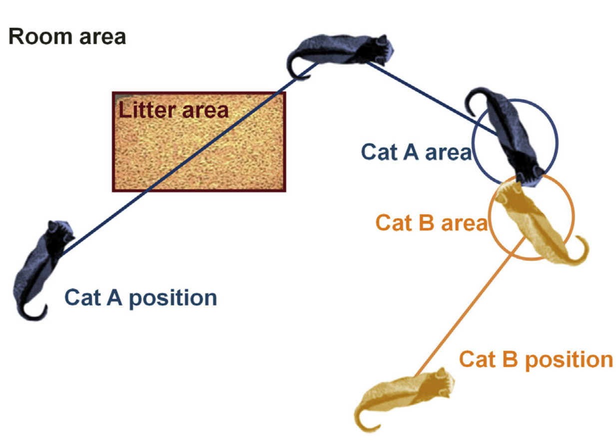

Figure 2. Schematic representation of a static area (litter area) and of dynamic areas (cats) around tags.

Extracted variables

Mean traveled distance per day and per hour. The mean traveled distance per day designates the distance traveled by an individual during the collection period, divided by the number of collection days. To infer daily activity patterns, we also calculated the mean traveled distance per cat and per hour on a 24-hour period.

Mean locomotor activity rate. Locomotor activity rate was calculated on a daily basis from the time spent traveling (i.e., the transponder is moving) compared with the time spent motionless. The algorithm did not take into account the moving artifacts because of activities such as autogrooming, eating, or other static behaviors.

Time spent in the different areas. The time spent in different areas designates the time a cat spent in each defined area per day (enriched, feeding, drinking, litter tray, shelf, cat trees, and seat).

Mean number and duration of intraspecific contacts. A contact was defined as a social proximity between 2 cats, as close as 30 cm, every time a cat's tag entered in another virtual dynamic cat area. From those data, we extracted the number of intraspecific contacts and their duration, defined as the amount of time a cat spent in another cat area.

Mean number and duration of interspecific contacts. The number of interspecific contacts was the number of times a cat area entered in a human area (as described before) and the duration as the amount of time a cat spent close to a human.

Results

Mean traveled distance per day

Overall, the 6 cats traveled on average 965.34 ± 359.51 m (standard deviation) per day (Figure 3). Huge differences in travel distances were observed between cats.

Mean traveled distance by hour

The traveled distance per hour was characterized by 4 peaks. The first at 06:00 hours (around 48 ± 39 m), and the second, between 08:00 and 09:00 hours, representing the highest level of locomotor activity (around 91 ± 33 m and 96 ± 31 m), both coinciding with the technicians' entrance to the room. The third happened in the early afternoon between 14:00 and 15:00 hours (around 42 ± 18 m), the fourth at sunset (around 21:00 hours, 50 ± 28 m) (Figure 4).

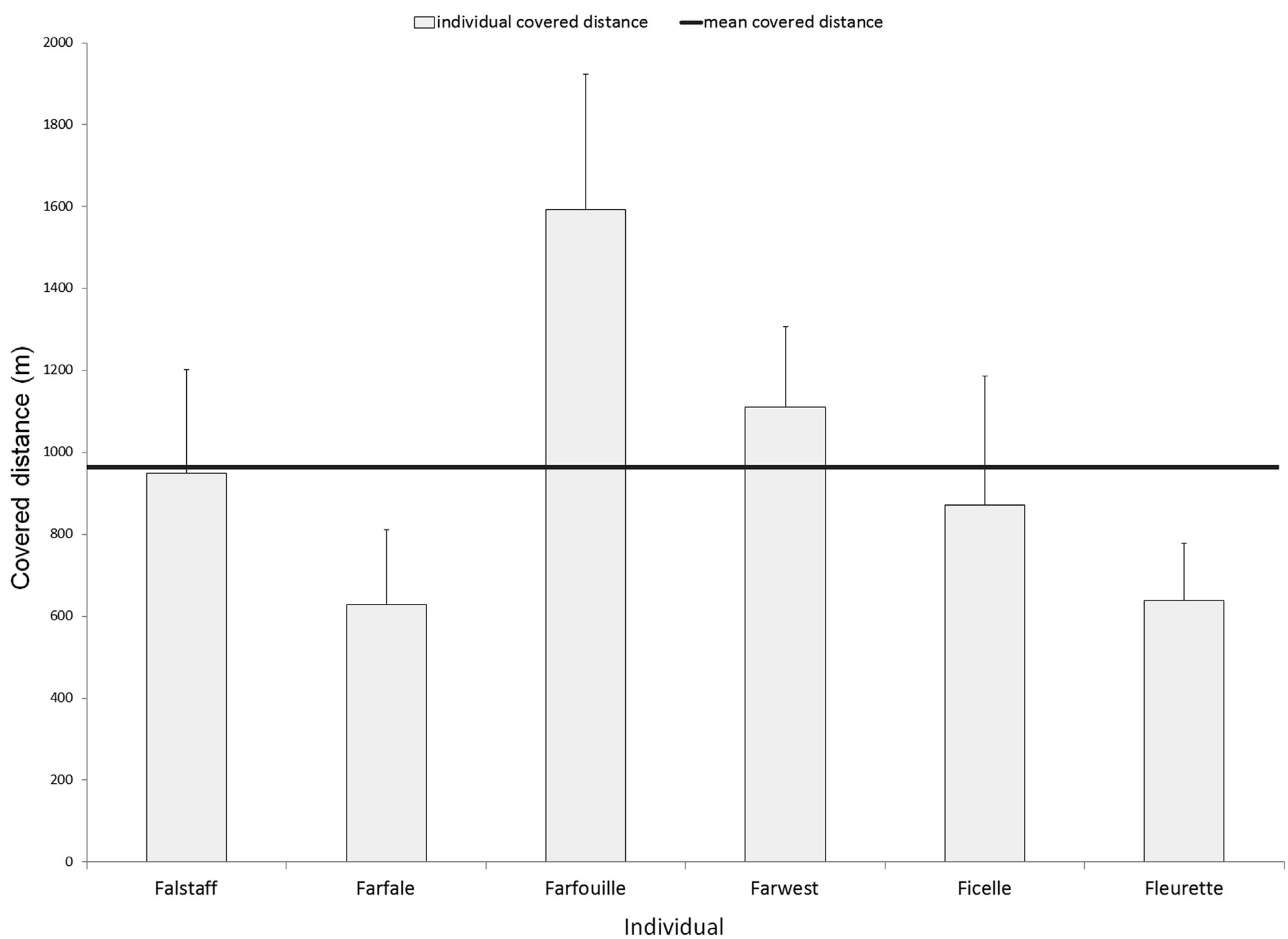

Figure 3. Mean traveled distance (m) per day. Data are presented as mean ± standard deviation.

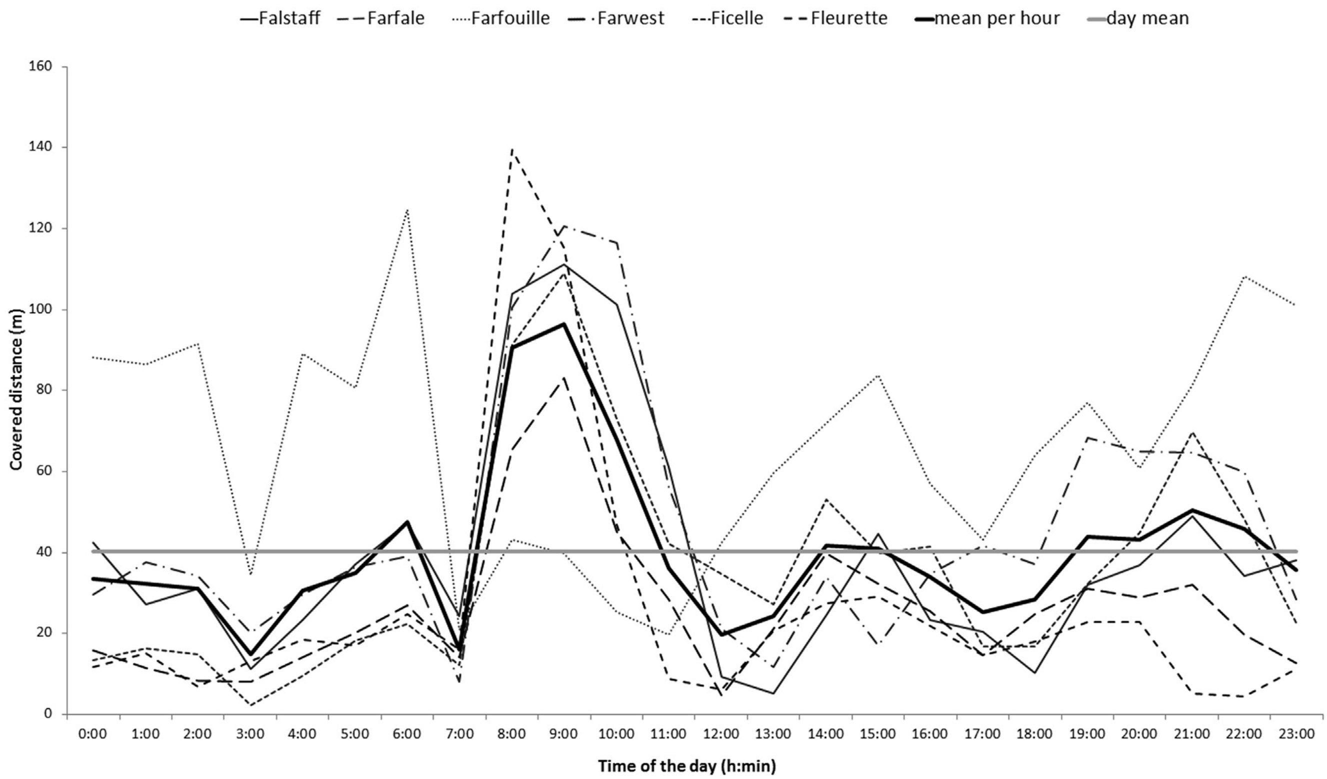

Figure 4. Mean traveled distance (m) by hour on an average day. The bold line illustrates the mean per hour, and each other line represents a cat.

Mean locomotor activity rate

Cats spent on average 30.37% ± 6.81% of their time moving. The differences of locomotor activity between cats were not as marked as those observed for the mean traveled distance, ranging from 21% to 41% of time spent moving.

Use of space

Cats spent around 15 hours 40 minutes per day on the wall shelf and on cat trees (on average, 11 hours 22 minutes ± 3 hours 54 minutes and 4 hours 10 minutes ± 2 hours 14 minutes, respectively; Figure 5). The seat was mostly avoided (7 ± 8 minutes). The cats spent on average 1 hour 25 minutes in the other areas (enriched area: 1 hour 04 minutes ± 19 minutes; feeding area: 1 hour 03 minutes ± 34 minutes; drinking area 10 ± 4 minutes; and litter trays: 8 ± 2 minutes).

Mean number and duration of contacts per day

Intraspecific

One cat interacted on average 53 ± 9 times with a conspecific per day (Figure 6A) (which means more than twice an hour). Fleurette was the most selective cat with a marked preference for Farwest.

Each member of the group got in contact during 17 minutes 57 ± 2 minutes 03 with another member per day on average. The variability was low among cats (Figure 6B).

Interspecific

On average, cats made contact 32 ± 7 times/day with humans (Figure 6A). Falstaff and Ficelle approached humans the most. The others did so less frequently, especially Fleurette who had the lowest score.

On average, cats made contact 4 ± 1 minute/day with humans (Figure 6B).

Discussion

The real-time monitoring provided by UWB technology enabled us to examine animal distribution and locomotor activity with an unmatched accuracy (15 cm) compared with all other current positioning systems. Other research has been carried out with video tracking, and our UWB accuracy was about the same as that using video tracking (Royal Canin, internal study data not presented). This technology makes 24-hour observations with a high acquisition rate and nearly unlimited data collection. Furthermore, the long-life batteries of the tags allow the recording of 3-dimensional locations during long periods without disturbing the animals.

This technology has been long awaited by ethologists as it enables them to conduct long-term behavioral studies. In this 2-week study, cats spent on average 30% of their time moving and traveling. In a study by Podberscek et al. (1991) using written observations, cats living in a space of 6.3 m^2 spent 24.5% of their time in locomotor behavior. This could suggest that the more space cats have the more active they are. The cats of this study are most active in the early morning (first peak of activity around 06:00 hours, second between 08:00 and 09:00 hours), early afternoon (third peak between 14:00 and 15:00 hours), and at sunset (final peak around 21:00 hours).

The first and third peaks coincide with the presence of cleaning or animal technicians. The second and highest peak of activity coincides with both the presence of animal technicians and food delivery. These observations suggest that the animals' rhythm of locomotor activity is affected by human activity. The evening peak occurs around sunset. This crepuscular activity underlines that, despite a mainly diurnal locomotor activity matching with food delivery and interactions with humans, the cats of this study still

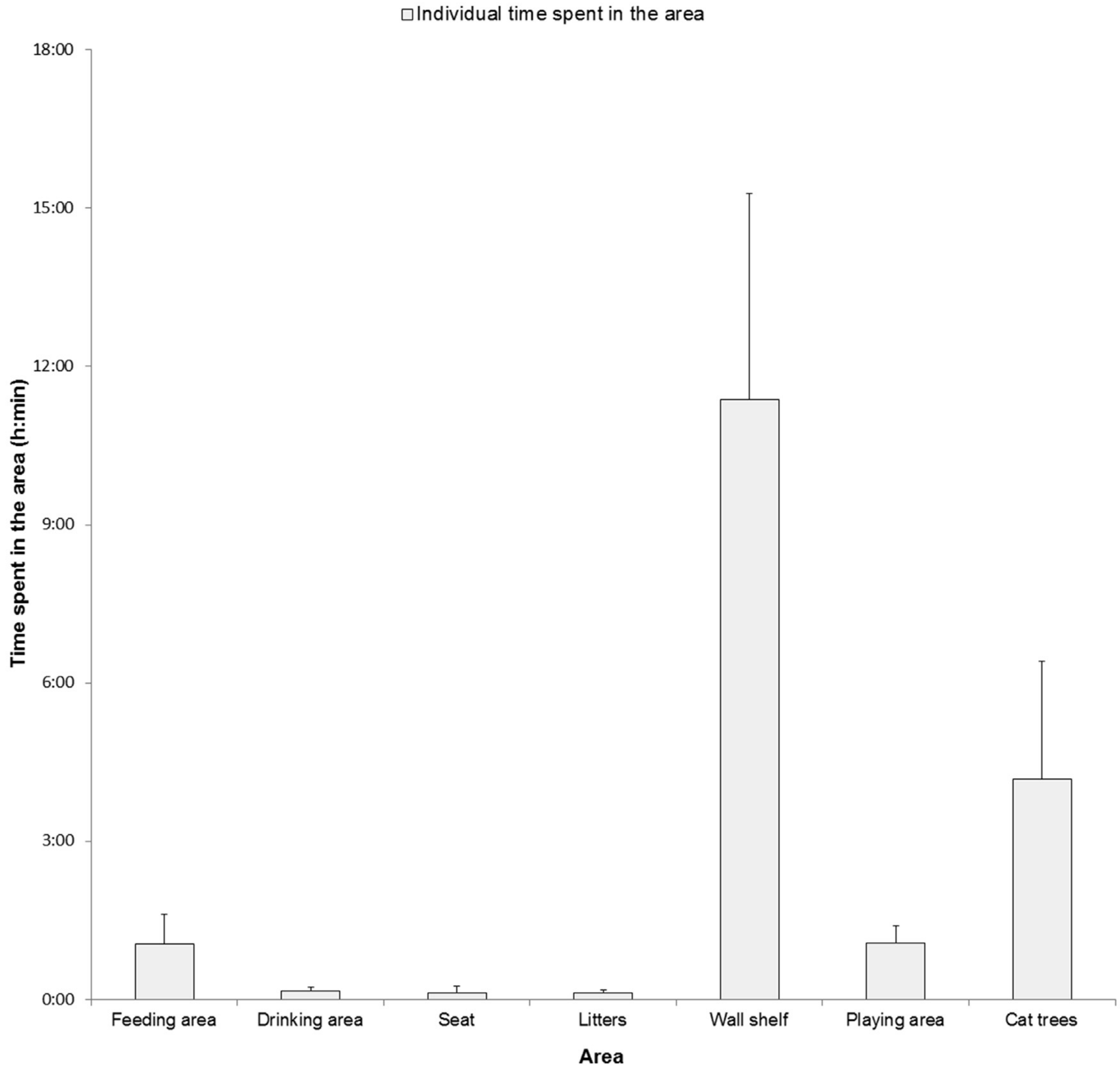

Figure 5. Mean time spent in the different areas per day. Data are presented as mean ± standard deviation.

maintain a spontaneous night locomotor activity. This observation corroborates those found in feral cats: without human disturbance, the felines showed moderate day activity and were mainly active at night (Alterio and Moller, 1997).

The number of intraspecific contacts estimated by our software showed that cats of this group interact in a selective way with their conspecifics. Interestingly, the most selective cat, Fleurette, who interacted very poorly with other cats, except Farwest, is the only cat not genetically related to the rest of the group. This result corroborates those of Bradshaw and Hall (1999) and Curtis et al. (2003) who found that cats spent less time in physical contact and showed less affiliative behaviors of proximity with unrelated individuals than with their littermates.

The cats spent around 15 hours 40 minutes (65%) per day in the resting areas, which corroborate the works of Sterman et al. (1965) and Jouvet (1967) reporting that laboratory cats spend approximately 55%-70% of their time sleeping. The cats in our study spent most of their time on the wall shelf and in the cat trees. They showed very little interest in the seat, an open space without hiding opportunities or comfort (no cushion). Studies have demonstrated a diminution of stress in cats when hiding places were provided (Rochlitz, 2000; Vinke et al., 2014). Our observation could also be due to difference in height (Podberscek et al., 1991), the seat being lower than the other resting places. Welfare is a major concern for domesticated cats, and our system may help to assess the relative usefulness of different furniture to enrich our pets' environment.

The use of the UWB technology has enabled us to define with great accuracy and objectivity different behavioral parameters of cats living in an indoor group. UWB technology allowed us to collect information regarding activity rate (46%), daily distance covered (965 m), favorite places (hidden and elevated), asymmetric interactions, and daily rhythmicity. In future studies, this new approach of tracking should help in comparing cats' behaviors in different conditions and enhance knowledge of the behavior of cats living in a community.

Acknowledgments

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Ethical considerations

The protocol was reviewed and approved by the Royal Canin ethical committee.

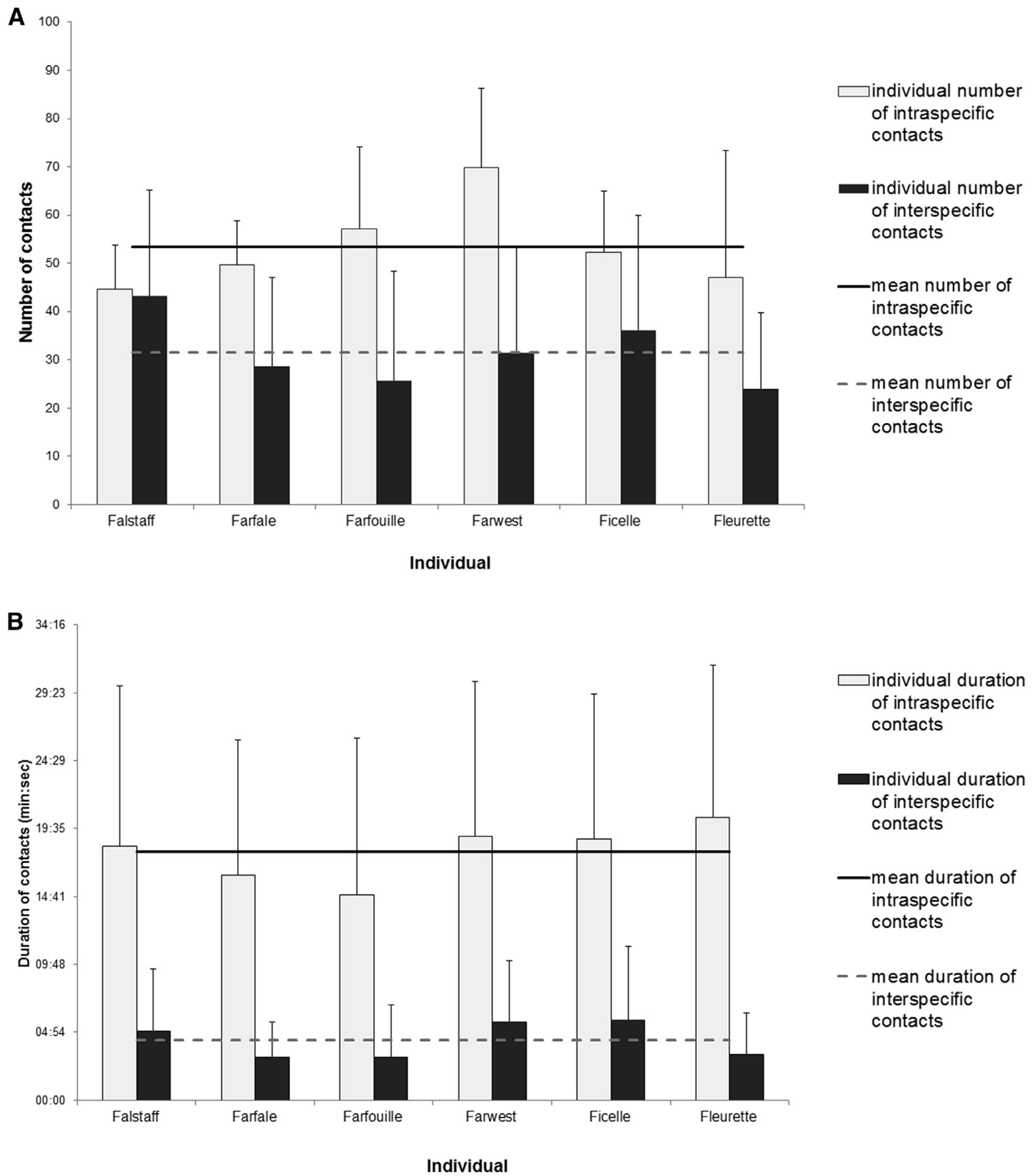

Figure 6. (A) Mean number and (B) duration (minutes:seconds) of contacts per day. Data are presented as mean ± standard deviation.

Conflict of interest

We confirm that there are no known conflicts of interest associated with this publication.

Authorship

The idea for the article was conceived by Jessica Serra. The experiments were designed by Jessica Serra, Benjamin Allouche, Jean-Alain Brossier, Mickaël Weber, Delphine Moniot, and Vincent Biourge. The experiments were performed mostly by Marine Parker (80%) and Jessica Serra (20%). The data were analyzed mostly by Marine Parker (80%), Sarah Lamoureux (10%), and Alexandre Feugier (10%). The article was written by Marine Parker and Jessica Serra (equal contribution). This study has been funded by Royal Canin.

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