Distances of transmission risk of Covid-19 inside dwellings and evaluation of the effectiveness of reciprocal proximity warning sounds

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ABSTRACT

One of the main modes of transmission and propagation of Covid-19 (SARS-CoV-2) is the direct contact with respiratory droplets transmitted among individuals at a certain distance. There are indoor spaces, such as dwellings, in which the transmission risk is high. This research aims to record and analyse risk close contacts in this scope, experimentally assessing the effectiveness of using electronic proximity warning sound devices or systems. For this purpose, the methodology is based on monitoring the location of the occupants of a dwelling. Then, the days in which a proximity warning sound system is installed and activated are compared to the days in which the system is not activated. The results stressed the significant reduction of time and number of close contacts among individuals when the warning was activated. Regarding the relation between the number and the duration of close contacts, together with the reductions mentioned, the possibility of making certain predictions based on the distributions obtained is proved. All this contributes to the progress in the prevention of Covid- 19 transmission because of close contacts in dwellings.

KEYWORDS:

Covid-19; dwellings; close contacts; proximity warning.

PRACTICAL IMPLICATIONS

-Currently, Covid-19 is a global epidemic that causes hundreds of thousands of deaths and high economic repercussions around the world. Despite advances in diagnosis and treatment, the global incidence remains high and additional strategies of prevention are urgently required.

-This study provides the first empirical data showing that the application of an electronic proximity warning sound system is effective in improving the control of a Covid-19 outbreak in indoor environment of a dwelling, also being a breakthrough in recording systems and analysing the risk of close contacts in dwellings and in the possibility of predict of the number of such contacts.

1. INTRODUCTION

Certain behaviours and characteristics of individuals are directly related to the level of infection risk [1–3], and close contacts are the main causes of the expansion of many viral respiratory diseases [4–9]. These close contacts usually entails a certain interpersonal distance which facilitates the inhalation of viral droplets [10,11]. Breathing, talking, coughing, and sneezing are activities that produce such droplets in various amount and size [12–16]. The distance that these droplets can reach, and therefore the security distance among individuals, has been repeatedly studied for several types of situations [17–19].

Since 31 December 2019, when the Wuhan Municipal Health Commission (Wuhan is in the province of Hubei, China) communicated to the World Health Organisation (WHO) the existence of patients affected by Covid-19, the world scientific community knows much better this virus, particularly its infectious behaviour. Similarly to other coronavirus, the main mode of transmission, although not the only one [20–22], is the contact with respiratory droplets, that is, the mucus of the mouth, nose or eyes [23], as the virus is found in nasopharyngeal secretions and saliva [24]. Thus, the modes of transmission and propagation among individuals, if individuals do not use other means of protections, are directly related to the distance among them and the exposure time. A closer interpersonal distance implies a greater inhalation of the virus, thus increasing the risk of infection through the close contact route [25]. After analysing the existing research studies trying to establish the most adequate security distance, it is clearly deduced that there is no unanimity when establishing an accurate unique distance [26] because many factors could vary the distance from a metre to eight or nine metres for specific situations, such as sneezes [27,28]. However, various bodies and countries have recommended to keep minimum distances among individuals between one [29] and two metres [30] because this is generally a reasonable measure to reduce the risk of infection as long as there are not other factors contributing to propagation, such as strong sneezes, air currents, infectious aerosols in closed spaces [31] or contacts with contaminated surfaces [32].

Recent research studies [33] and experts like Bromage [34] indicated that most transmissions are the result of the spread of the infection at home. If a family member is infected outside the dwelling, then the other members usually become infected when the infected individual returns. This fact is confirmed by Qian et al. [33], who identified 318 outbreaks with 3 or more cases, involving 1,245 cases confirmed in 120 cities.

The scientific literature related to transmissions in buildings [35], the spread of infection in family environments and households [36] and the behaviour of close contacts including the body positioning in detail [37] is almost unanimous in considering that in a closed architectural environment, such as dwellings and similar spaces, the risk of transmission due to proximity is high, particularly if an occupant is infected outside and lives with the other occupants of the dwelling. The main reasons are the characteristics of these closed spaces and the occupants' behaviour because there is usually a greater interaction among them [38], particularly in modest dwellings and in situations in which the cohabitation is intensified [36]. In these cases, the transmission risk is closely related to the distance and position among individuals, the numbers of individuals, the actions related to the expulsion of contaminated droplets (sneezing, coughing, speaking or just breathing), and the exposure time, among other specific characteristics of these spaces. Nevertheless, the level of presence of the virus due to the exposure time is the tracking basis of the risk close contact. Although sneezing or coughing implies sufficient viral droplets to directly infect, some minutes talking face-to-face to an infected people [10,39] and even 20 minutes exposed to their breathing are necessary to be infected, all this based on the number of droplets expelled and received per minute [34].

Various companies and entrepreneurs from the technological sector are today offering warning sound devices and systems which, with greater or lower success, intend to detect the reciprocal proximity among individuals. These devices or systems are applying several technologies and procedures and are presented in various formats, such as independent units, applications for smartphones, etc. This research is therefore focused on analysing the effectiveness of these devices by applying them in a dwelling whose dimensions, characteristics, and family unit are relatively common. For this purpose, this research is based on the studies on the human behaviour when there are non-verbal warning sounds [40,41]. In addition, an experimental campaign is conducted in a real environment by using spatial position locators, and a system that generates a warning sound if reciprocal proximity is detected among individuals is established. It should be emphasized that if there is no infected individual in the dwelling, then family members can be close. For this reason, this research focuses both on the hypothesis that the risk exists when a family member meets other individuals, becomes infected and returns home and on the analysis of to what extent these devices or systems are effective to control and prevent infections related to social distance, such as the case of Covid-19.

2. SIMILAR WORKS

Several research studies have recorded the real-time location of individuals and have analysed the duration and distance of contacts in a certain period and in various indoor spaces [2,37,42–46]; however, no research analyses and compares the results from activating or not a warning sound device or system to avoid close contact and therefore transmission in a dwelling like that chosen.

3. MATERIALS AND METHODS

As a test bed, a dwelling located in the south of Spain was used. Its characteristics and the family unit living in it are usual in this country [47].

3.1. Characteristics of the dwelling and family unit

The dwelling has a hall, a living-dining room, a kitchen, three bedrooms, two bathrooms, a balcony, and a corridor, all made independent by walls and doors. The occupants of the family unit are four individuals (a man, a woman, a boy, and a girl). The adults are between 40 and 50 years old, and the subjects under 18 are 10 and 12 years old. All occupants have been living in the dwelling for more than ten years, so they are familiarized with the experimental environment, thus compensating any bias originated by that environment. The actual spatial characteristics, dimensions, uses, surfaces, and furniture of the dwelling are reliably represented with the lowest possible error by using a three-dimensional modelling Autodesk Revit 2019® [48]. The model and representation of the floors corresponding to the dwelling (Fig. 1) are used in the graph of the location data obtained.

3.2. Detection devices

For the experimental phase, detection devices were used for the real-time location of each subject. Given that these devices should provide readings as accurate as possible regarding the recording of the location from which the interpersonal distance could be deduced, the technologies not meeting these requirements were not considered, following the specificities of the scientific literature [42,49,50]. As a result, the real-time locating system (RTLS) based on ultra-wide band (UWB) was the most adequate technology for the purpose of this research [49,51–55]. Based on both the comparisons conducted by other authors [56] and our analysis and available resources, a Decawave® [57] equipment was chosen as there were experimental precedents in several spaces and situations [58–65]. This equipment is an ultra-wideband network constituted by fixed nodes (anchors) and moving nodes (tags). Regarding the accuracy, although manufacturers' technical requirements indicate ±10 centimetres and second intervals, other indications were also considered [66,67]. However, these technical characteristics were adapted to the basic requirements for this type of experimentation in relation to the real-time collection of the position coordinates. Regarding the number of "nodes", four nodes were configured in tag mode which each experimental subject permanently had, and the remaining anchors were placed in the walls of the dwelling near to the ceiling. The system generated real-time data which were collected by a mobile device and a computer though the procedure, the software and the APIs indicated by the manufacturer. On the other hand, an Excel® spreadsheet was used for the data compilation and processing, and Microsoft Visual Studio®[68] for the programming of some algorithms, as well as Html, Php, and Mysql, among others. When an individual was getting closer to another or others from a certain distance, a not very high sound signal, but audible, was generated, whose tone and intensity were previously chosen by the experimental subjects to be as most pleasant as possible. To sum up, the system was designed by placing anchors in several points of the dwelling and tags of the experimental subjects (Fig. 2), so the location data of these subjects were generated. After data processing, the distances among subjects were determined, and all was coordinated by portable Bluetooth Speakers for the proximity warning sound system among individuals. The placing of the anchors therefore constituted a coordinate system to an origin corresponding to one of these anchors, so the distance from each tag to each anchor was calculated, thus allowing the tags to be always placed as the initial coordinates of the anchors were known because they were previously determined.

Lastly, before starting the experimentation, the correct calibration of devices was checked by verifying if the offered data corresponded to actual data.

3.3. Distance and risk position considered

This study only considered the distances among experimental subjects and not their corporal position due to the reasons mentioned below.

To make the goal of the research feasible regarding the comparative study, the concept of risk contact or "close contact" was initially established in a unique, clear and accurate way. Considering the authors aforementioned and the indications given by the most known international health organisations, such as WHO [29] or the European Centre for Disease Prevention and Control (ECDC) [30], the approaches at a distance less than 2 metres or approximately 6 feet for more than 10 minutes were established as risk contact or "close contact", applicable to all members of a household as long as the contact took place without protection (face mask, eye protection, etc.). Regarding time, although the duration of 15 minutes is used in certain scopes [30], the security margin was increased by using 10 minutes. The same occurred when 2 metres were chosen, instead of 1 metre, as recommended in some cases.

As for the exposure time, there is no absolute certainty of how many particles should be inhaled and therefore how much exposure time is necessary in each circumstance to produce a transmission. For this reason, this study uses a time mark that may seem high but assures that the results reflect high-risk contacts.

After counting close contacts, although they were first defined as episodes of 10 continuous minutes at less than 2 metres in some moments, some cases were not strictly suitable to these conditions. However, these cases were also considered because one of these conditions was fulfilled and the other was almost fulfilled.

The goal of the research was not to establish whether transmissions would take place at other distances or exposure times different to those previously chosen. The main goal was to assess the effectiveness of proximity warning sound devices or systems with respect to the individuals' behaviour when avoiding distances which could imply this transmission, regardless of whether the transmission was produced, so the reasonable and founded references chosen were enough.

3.4. Data collection and processing

Regarding the data collection, all occupants were monitored from the hour in which the first occupant got up in the morning to the hour in which the last occupant went to bed at night, so the programmed time was from 8:00 a.m. to 24:00 p.m. (16 hours). When a subject got up, the location device was immediately placed and activated. However, the connection to the warning sound device was not activated until at least 2 subjects got up, around 9:00 a.m. On the other hand, the subjects on bed after 8:00 a.m. were assigned a fixed coordinate of their locations which coincided with the lying position in their respective bed until they also got up and the location devise was placed and activated. The experimental days coincided with the confinement days decreed by the Spanish Government in March 2020, so all family members stayed in the dwelling all the experimental hours. The internal temperature was between 21 and 23 ºC. According to the Spanish Building Technical Code, the ventilation rate of dwellings was 0.94 air changes per hour. In these experimental days, the distances of the tags of each subject to the anchors were obtained at each moment. With these data and by triangulation, the coordinates (x, y) of each individual were automatically obtained in real time, and the coordinate (z) was not required, as previously justified, considering the goal. Not all the coordinates were the result of the data record provided by the location devices because these were updated based on the activity of the movement sensor. In addition, certain disparities were sometimes produced in the emission of data by implementing a simple algorithm that completed the coordinates by a simple approach to not losing the sequence in time and the trajectory. On the other hand, the locations with a fixed separation element among subjects that constituted a barrier and in turn made null the risk were not recorded as approach. For instance, these cases took place when subjects 3 and 4 were at the same time in their respective bedrooms (bedroom 2 and 3) divided by a partition wall or when a subject was on the sofa of the balcony near to bedroom 2 but divided by a wall. Doors were possible influential elements, so they were always opened to not being considered. All the work was complemented by the subsequent manual verifications to verify the results, to detect incidences, and to analyse and correct them, without none of them being singular enough to distort the measurement results. On the other hand, members' habits were briefly studied. Data were obtained by interviewing the subjects and asking them to record these habits manually for a few days. To make a better comparison among the experimental days, each occupant was committed to consider a basic chronogram of the places where they intended to stay at each moment. This list of places and hours was printed and given to the subjects, as well as kept in their PCs and smartphones, so it was helpful to know always where they should be.

With the coordinates obtained at each moment from the location devices, the distances in metres among subjects were calculated through Eq. (1). On the other hand, the data of these coordinates turned into another origin or scale easier to be used when used in the graphs in which the layout of the dwelling was superimposed at a scale that coincided with that of the new coordinate system (Fig. 3), thus creating location maps which represented, with points of different colour, the place where each subject stayed at each moment. So, when a day without the warning sound connected was monitored, the concentration of points and the distances among subjects were shorter than the day with the warning sound connected was monitored.

$$\text{Distance between } (S_{1,}S_2) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2)} \quad (1)$$

After finishing the experimentation, each subject was asked for giving their impression about the experience. Subsequently, the results were analysed.

4. RESULTS.

4.1. General behaviour aspects of the experimental individuals

Both in the day when the warning sound device was and was not connected, the time and moment to stay in the various areas of the dwelling was similar. However, with the warning sound activated, some subjects modified some of these places, presumably to reduce risk distances.

On the other hand, the experimental subjects manifested that the warning sound was sometimes uncomfortable because, apart from adding an environmental sound, it forced them to go to other places which were not exactly coincident with their usual likes or activities, which could introduce certain uncertainty about whether it was possible to keep these situations in a medium or long-term, or otherwise whether subjects would get used to.

4.2. Indoor behaviour and close contact

Regardless of the number of contacts and the duration, the sum of contact times of two or more experimental subjects at less than 2 metres achieved a total of 12.2 hours out of the 16 hours monitored with the warning sound disconnected, that is, 76.25% of the total time. When the warning sound device was connected, this time was 3.37 hours, that is, 21.06% (Fig. 4 (a)), thus reducing the time of risk contact by 8.83 hours. Nevertheless, the number of hours could be more reduced as, apart from taking place many short-term contacts every time the warning started to sound at around 21:00 p.m., the experimental subjects were located on the sofa in the living room, in front of the TV, despite being aware of the distances less than 2 metres. There was a similar behaviour of voluntary risk contact between adult subjects and subjects under 18 when the latter went to bed and said goodnight to the adults.

Both with or without warning sound, the close contacts between two subjects were predominant in comparison to the close contacts among three or four subjects at the same time. With the alarm activated, the sum of the time when two subjects were at a distance less than 2 metres was reduced by 4.30 hours, 1.95 hours among three subjects, and 2.58 hours among four subjects in comparison to the time without the warning (Fig. 4 (b)).

All subjects responded to the warning positively, with significant reductions of the total contact time when the warning was activated. Subjects under 18 recorded a lower contact than adults, both with the warning activated and particularly deactivated. Risk proximities between adult subjects were recorded in a similar number, with the respective reduction being also similar when the warning was activated (Fig. 5 (a)). A total of 43 episodes of close contact (>10 continuous minutes;<2 metres) were recorded the day in which the warning was disconnected, and 4 with the warning connected (Fig. 5 (b)).

Regarding the risk proximities related to the duration of each close contact and the hour (Fig. 6) without the warning sound, they were continuously distributed throughout the day. However, with the warning sound connected, close contacts were concentrated at the end of the day and some of them superimposed among them, thus indicating that they had a similar duration.

There were also time intervals which, although not being strictly continuous, were maintained throughout the time with interruptions of less than 1 minute. Nevertheless, there were contacts of seconds at distances close to 2 metres, so they were not considered as close risk contact according to the definition adopted.

Based on these results, the subjects with less close contact episodes among them the day when the warning was disconnected were subject 1 and subject 4, who did not have a close contact with the warning connected, like between subject 1 and 3. The subjects with more close contacts the day when the warning was disconnected were the two adults (subject 1 and 2), and precisely the number of close contact related to both adults the day when the warning was activated was significantly reduced, from 13 contacts to 1, although the latter was a long-term contact.

Regarding the episodes of close contact per hour, the comparative graphs of these data (Fig. 7) show the almost total reduction in the contacts with the warning activated. However, after the first 13 hours with the warning on and at almost the same time, several contacts occurred due to affective relationships at the end of the day. The subjects answered that these are deeply rooted customs and therefore are difficult to be avoided.

Regarding the distances among subjects, the mean, median and mode (Fig. 8) with the warning activated were always greater than 2 metres. However, if the warning was not activated, although the means were also greater than 2 metres with respect to the distances between subjects 1 and 2, the resulting median and mode were the only ones less than 2 metres.

As for the frequency and probability of close contacts (Fig. 9) with the warning disconnected, the contacts between subjects 1 and 2 presented a greater frequency and probability of contact (greater than 30%), followed by those produced between subjects 1 and 3 (greater than 20%), with the contacts between subjects 1 and 4 or subjects 3 and 4 presenting the least frequency and probability (around 9%). However, with the warning sound activated, both the frequency and probability were very low (lower than 3%) and even null in some cases.

Regarding the relation between the duration of contacts in minutes and the number of contacts between experimental subjects, both with and without warning sound (Fig. 10), there were more close contacts with a low duration, with the contacts with a duration lower than 10 minutes being the predominant.

The greatest number of approaches at a distance less than 2 metres and of greater duration when the warning was disconnected was obtained by subjects 1 and 2. The relation between the duration data and the sum of contacts when the warning sound was disconnected was adjusted to a logarithmic distribution (Fig. 11 (a)). In this case, the determination coefficient (R^2) was 93.8%, that is, the number of contacts was related to their duration. With this margin, the number of close contacts which would be produced from the duration could be therefore predicted, particularly after 10 minutes which is the minimal time defined to consider the close contact if subjects are at a distance less than 2 metres.

In the day in which the warning sound was installed and connected, the relation between the duration data and the sum of close contacts was adjusted to a linear regression (Fig. 11 (b)) for contacts greater than 5 minutes, with a R^2 of 87.71%. On the other hand, if any duration was considered, the distribution would be adjusted to both the exponential equation (Fig. 11 (c)) and a R^2 of 87.93% like that of the linear regression. These equations are very interesting because theoretically one of the unknown x or y (duration or number of contacts) could be deduced in each case by simply entering in the equation one value of the other unknown. These kinds of equations are theoretically useful to make predictions with a probability of success greater than 80% in all cases and even in some of them greater than 90%.

The location of close contacts in the various rooms when the warning was not activated was mainly focused on the living room, and particularly on the sofa, at the table in the balcony to eat, and in the kitchen. When the warning was connected, the warning of close contacts was focused on the sofa in the living room. The heatmaps clearly show these concentrations of close contacts and the significant intensity difference when the warning was disconnected with respect to when it was connected (Fig. 12).

Finally, the experimental subjects manifested certain annoyance with both the warning sound and the obligation of modifying sometimes their activities or relations to which they were used as family unit. Nevertheless, considering the goal of this research, particularly from a qualitative perspective, the ultimate results were adequate with respect to the conclusions drawn. Regarding the fatigue associated with the warning, although during the first days the subjects sometimes ignored it, after some days they put some distance between them due to a greater perception of the warning.

5. DISCUSSION

The results of this research showed interesting aspects about the spatial location of the occupants of a dwelling in their daily tasks, but the most outstanding aspect was that a new comparison was reflected in case of using or not a proximity warning sound device, as well as the confirmation of the effectiveness and feasibility of using these devices daily regarding the actual reduction of risk of infection by avoiding close contact.

On the other hand, the human behaviour inside dwellings was a determinant factor with respect to the transmission risk. Moreover, if a family member was infected outside due to the contact with another individual not belonging to the family unit, the level of transmission risk to the other members was higher than in other closed spaces, such as transports, catering facilities, shops, gymnasiums, hairdresser's, or leisure centres, among others, as Hua et al. [33] indicated.

The close contact in dwellings was therefore frequent, so these are spaces very favourable to the transmission of infectious diseases whose transmission mechanism is related to the proximity between individuals.

According to references, the duration of close contacts is a crucial aspect with respect to the probability of transmission. Several research studies [2,37,42–46] have recorded the location and distance between individuals, as well as the duration of contacts in a certain period, which in turn entails the distributions and their respective graphs. This research showed that short close contacts were the most usual, thus decreasing the frequency as the duration increased by following a logarithmic distribution.

The transmission risk increased by reducing the interpersonal distance, and vice versa [18,69–71]. Although the location of individuals could not be accurately quantified at each moment, human behaviour usually varied according to certain factors already mentioned [2,3]. Based on the results, all subjects responded to the warning in a similar way most of the time. Given the family unit and the dwelling analysed, it would be interesting and even in certain cases necessary to experiment with several dwelling typologies and family units to diversify the test bed and to obtain more data to verify the results, and even to add conclusions.

Regarding the results of the means of the distances in the day when the warning sound was not activated, the mean personal distances in case of more affective subjects were the most frequent and sometimes even inevitable, although the warning sound was connected. These risk contacts were usual according to what some authors indicated [25,37].

As for the activities and the way of circulation of subjects throughout the day, although habits strongly influenced the probability of close contacts, the results also showed that these habits could be modified by the warning sound, thus greatly reducing these contacts, at least in the short term. In this regard, the subjects, who at the same time were carrying out different activities, usually recorded a low probability of contact among them, thus indicating that the design of dwellings should influence this aspect contributing that each subject has their own space according to the activity. In this manner, subjects could carry out their activities in far zones, particularly if they were aware of a possible close contact, such as the case when the warning sound was activated.

On the other hand, the zones with comfortable seats were usually hotspots to contribute to close contacts, and if these seats were big, such as the sofa, and playful activities could be carried out, they turned into a space where contacts were frequent even with the warning sound connected, as subjects usually sat together.

Another aspect was a high probability of short close contacts when the subjects went from a point to another of the house as the subjects who coincided in the passing places of the dwelling did not generally have enough space as these zones were not wide enough to keep the distance required. Nevertheless, contacts were short and sporadic in these cases. The performance of the sensors was generally adequate; however, to rely on the motion sensors, these were checked at intervals similar to the times established to consider close contacts. Data were not generally corrected, but when the tags were away from the anchors or when there were more obstacles between them data were corrected.

Finally, these results could be useful to analyse the risk of infection at a greater scale. For instance, if the number of dwellings, their typology, and family units in the households of a certain zone are known, the number of close contacts which could be reduced by applying warning sound devices or systems could be calculated.

6. CONCLUSIONS

The probability of risky close contact at a distance less than 2 metres is very high in closed spaces, such as dwellings, and the human behaviour inside them is a determinant factor for the transmission risk.

Close contacts could be decreased with these warning sound devices or systems, making the contacts almost null.

Both when the warning device was disconnected and connected, the living-room of the dwelling, and particularly the sofa, the zones in which people usually eat, and the kitchen were the zones where close contacts were more frequent and therefore there was a greater probability of proximities at a distance less than 2 metres for more time. In this regard, the subjects carrying out different activities at the same time usually recorded a low probability of contact among them, thus indicating that the design of dwellings should facilitate that each subject has their own space for the respective activities. However, there was an important decrease of close contacts in these places when the warning sound was connected.

On the other hand, if the warning was disconnected, the results indicated that the relation between duration data and the sum of contacts followed logarithmic distributions. If the warning was connected, the distribution was linear after around 5 minutes, or exponential including these 5 minutes, so predictions could be made with a determination coefficient greater than 80%. Based on the data of some of these two variables, the other variable could be deduced with a probability of success of 80%, although this limit should be increased by studying a more extensive casuistry.

Regarding a more long-term feasibility of using warning sounds in a dwelling, and according to what experimental subjects manifested, it could be less feasible if it is intended to be used for a long time. On the other hand, there are still situations in which security distances are not respected consciously, whether the warning is connected or not, either because it is materially difficult to fulfil according to the characteristics of the dwelling or because the options or alternatives for the distance are contrary to certain habits which subjects do not want to renounce regarding their relationships as family unit. Finally, as the day passed, the warning was less effective.

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Figure 1. Characteristics of the dwelling chosen as a test bed.

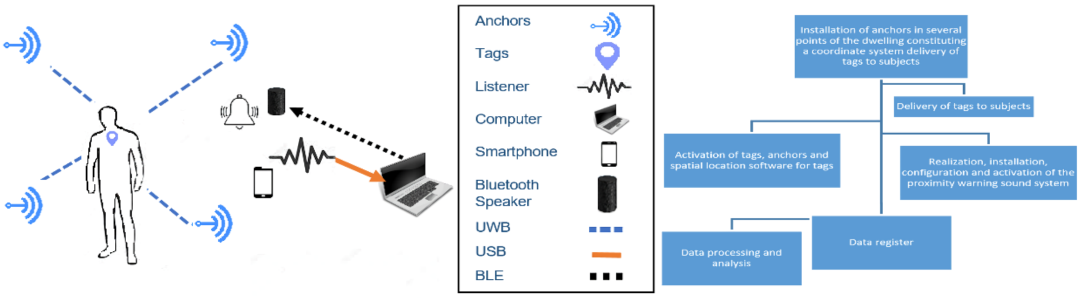

Figure 2. Scheme of the system and devices.

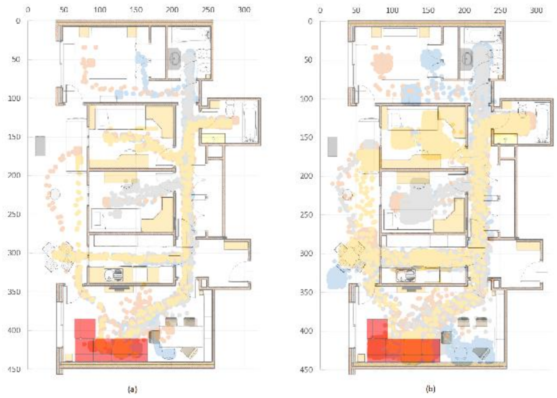

Figure 3. Visual record maps of the position of subjects during the experimentation periods; **(a)** map with the non-activated warning sound; **(b)** map with the activated warning sound.

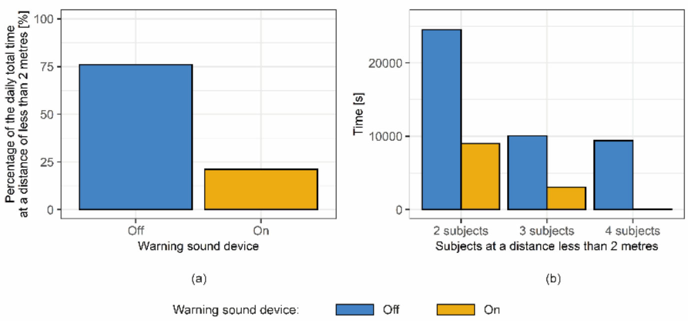

Figure 4. (a) Percentage of the daily total time at a distance less than 2 metres with respect to the hours monitored. Results with the warning connected and disconnected. **(b)** Total time in seconds of the approach of subjects at a distance less than 2 metres. Results with the warning connected and disconnected.

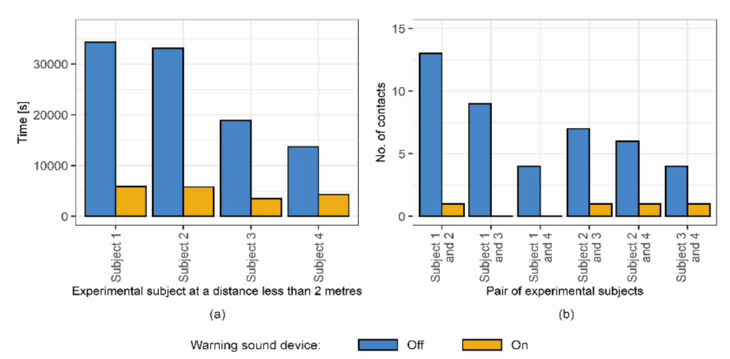

Figure 5. (a) Total time in seconds in 16 hours and per experimental subject at a distance less than 2 metres. **(b)** Number of close contacts per pair of experimental subjects.

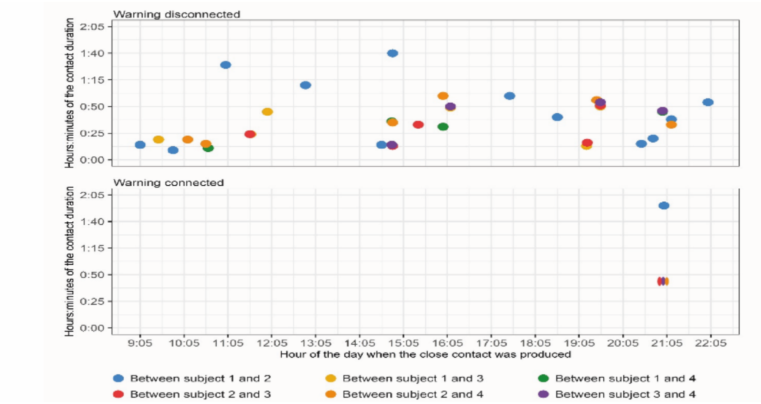

Figure 6. Hour of the day and duration (in hours: minutes) of close contacts (<2m;> 10min) per pair of subjects when the warning was disconnected or connected.

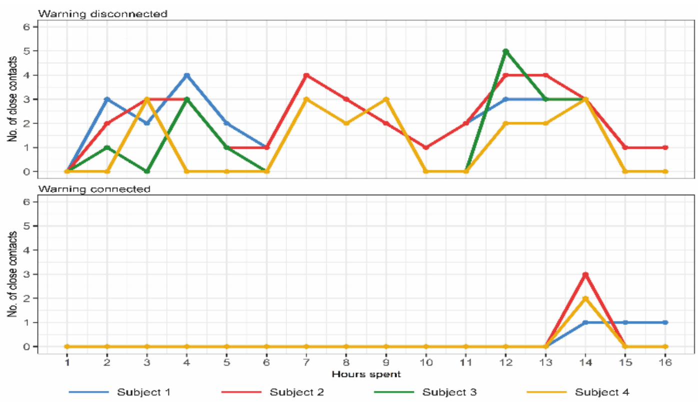

Figure 7. Number of episodes of close contacts experimented by each subject per hour with the warning disconnected and connected. In the plot of the warning connected, until thirteen hours have passed, there are no contact among subjects. For this reason, the lines of the graph are all overlapped until thirteen hours.

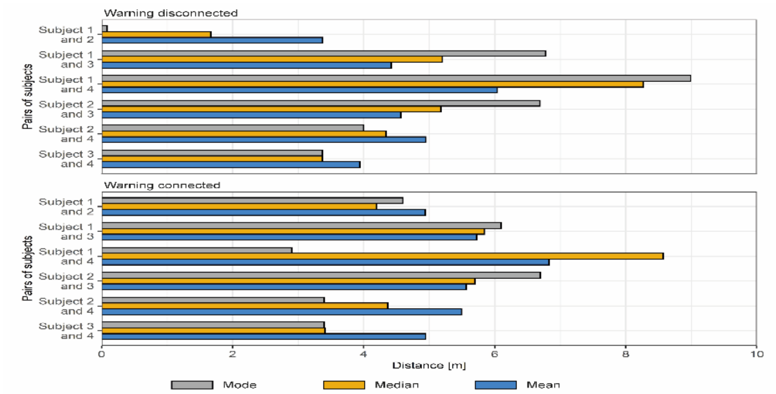

Figure 8. Mean, median, and mode with respect to the distances between the pairs of subjects with the warning disconnected or connected.

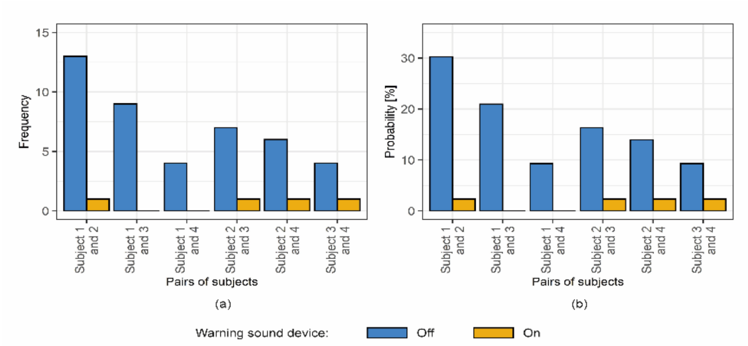

Figure 9. Frequency (a) and probability (b) of close contacts with the warning disconnected **or** connected.

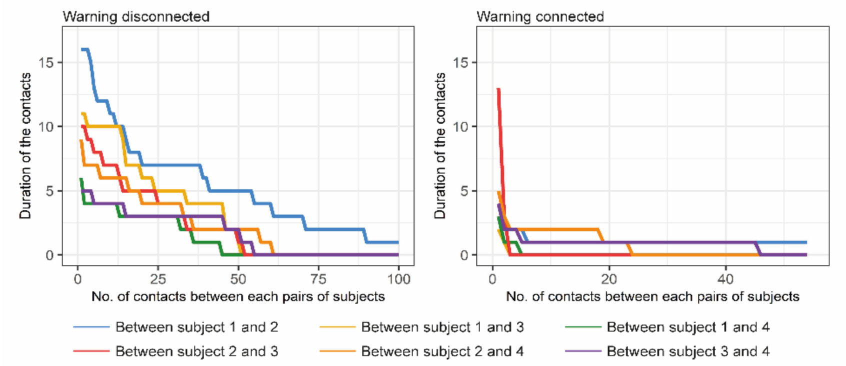

Figure 10. Relation between the duration of the contact and the number of contacts between each pair of experimental subjects with the warning disconnected or connected.

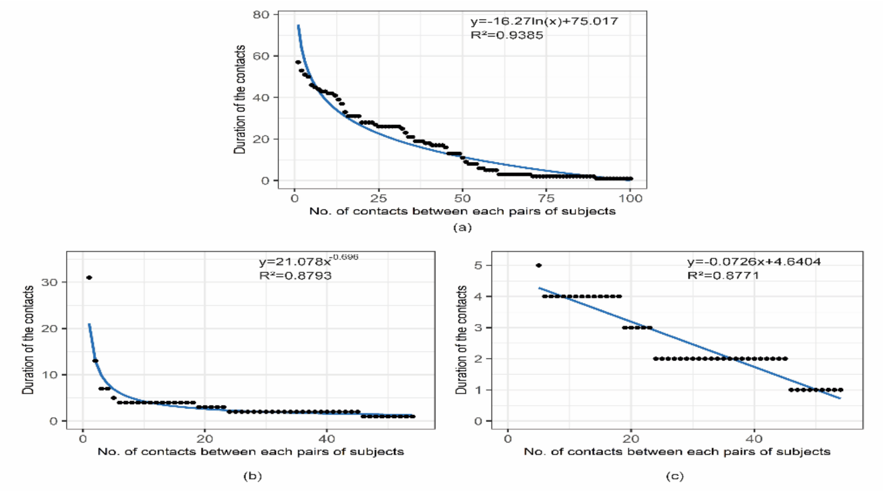

Figure 11. (a) Relation between the duration of the contact and the number of contacts between each pair of experimental subjects with the warning disconnected, and the logarithmic correlation; **(b)** Relation between the duration of the contact and the number of contacts between each pair of experimental subjects with the warning connected, and the exponential correlation; **(c)** Relation between the duration of the contact and the number of contacts between each pair of experimental subjects with the warning connected, and linear correlation after 5 minutes of duration.

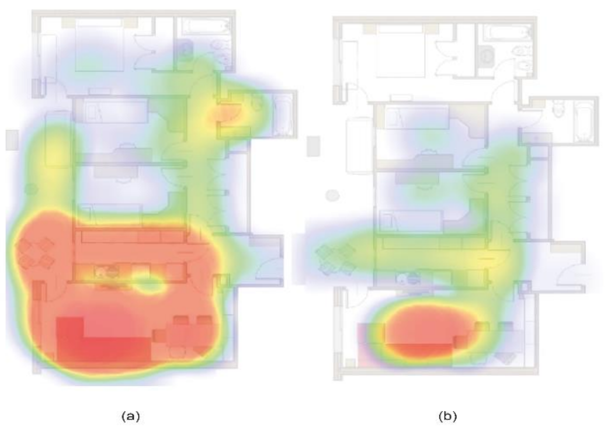

Figure 12. Concentration heatmap of close contacts with the warning **(a)** disconnected; **(b)** connected.