Abstract

With commercialization and an increase in the area allowed for an urban apartment house, the ways in which a family makes use of the rooms have become a bigger priority in planning the layout of Chinese urban apartment houses.

Thus, this research focuses on room use of the elderly couples living alone and one-child families living in Chinese urban apartment houses. The purpose of this research is to propose methods that use sensing technology to acquire and analyze precise survey data in residents' daily behavior in room use, in aspects of their stay and talk in certain rooms and movements between rooms. Despite the subjects studied were based on specific and individual cases, by using the methods above, the author showed the characteristics of daily room use of subject families, as the basis for the improvement of dwelling layout for these families.

This dissertation comprises three parts. A general introduction (chapter one) is given first, then four studies are presented in the main body of the text. Finally, conclusions are drawn. The main body of this dissertation comprises two sections. The first (chapters two and three) focuses on the methods used for recording and analyzing data of room use through sensing technology. On the basis of the method established in this section, the room use of elderly couples living independently and one-child families is clarified in the latter section (chapters four and five).

Chapter 1 introduces the background, the purpose and the difference between this research and previous ones about the room use of elderly people and families with children. Unlike previous studies that attempted to use the sensing technology to detect abnormal behavior patterns, this study is characterized by using the technology to identify the daily usage pattern of rooms.

Chapter 2 establishes the recording and a number of analysis methods that the author used in this research. The sensing technology had been used to record continuously on a resident stay in certain rooms and movements between rooms. In the experiments, the first challenge was to identify and to approve an optimized wearing position of the Active RFID tag on research subject's body, in which way the Active RFID readers may achieve good signal receptions, as well as it is convenient for the subject to wear the tag continuously. Then the author identified the relationship between the sensitivity parameter and detection range and accuracy of the readers. This chapter also introduced a method to fill in the missing values in the Active RFID data according to the acceleration data. Furthermore, the survey described in this chapter shows that, by

using the methods introduced above, the characteristics of the room use by one single elderly woman could be clarified. Findings showed that the subject stayed for the longest duration (68% of the total time of stay) in the living room. This survey also found that the subject stayed in the living room 1.6 times more in duration during the night than during the day. The subject stayed most frequently (36% of the total frequency of stay in certain rooms) in the kitchen. The survey also recorded the subject moved between the living room and the kitchen 2.4 times per hour in average, which is at least 3.6 times more frequently than movements between other rooms.

Chapter 3 clarifies the relationship among time period, duration of stay and movement between rooms for one single elderly woman by using a probabilistic model. The findings show that the duration of stay in certain rooms does not relate to the room which the subject occupied previously or directly afterwards; therefore, the duration of stay in certain rooms does not relate to the order of movement. Thus, the characteristics of duration of stay in certain rooms and of movement between rooms should be analyzed independently.

Chapter 4 clarifies the room in which the six elderly Chinese couples stayed for the longest duration (base) and the route between the two rooms that they passed through most frequently (main link) during each time period (morning, afternoon and evening). There might be multiple bases or main links for certain person in certain period in some cases where the second longest duration or second highest frequency was very close to the longest or highest ones.

Findings showed the bases indicated by objective observation using the device (objective bases) and the bases identified by interviews with the subjects themselves (subjective bases) in a day. The objective and subjective bases in accord was over twice as many for the husband as for the wife. For both the husband and wife, the ratio of objective and subjective bases in accord during the day was over one-and-a-half times more than during the evening.

The rooms that the couples stayed in together or separately vary with the time period. Most subject couples (five out of the six couples) tended to use the same room- the living room- as the base during the evening and different rooms- dining room, master bedroom, studio and kitchen-as bases during the day. There was also one subject couple, who tended to use the bedroom as their base during any given period.

Moreover, the author overlapped the patterns of main links of the two persons in a couple during all time periods and clarified the room that had a main link with most other rooms (hub) for each couple. Four out of the six couples used living room, dining

room or bed room, the bases of both the husband and wife during certain time periods, as the hub and the other two couples used the kitchen, the wife's base in the morning, as the hub.

In this chapter, the author described an example that used six elderly couples as the study subjects, in an attempt of the exploration of room layout planning based on the specific room use of elderly couples, using the sensing technology. The findings suggested that it is important to satisfy the elderly couple's individual use of different rooms during the day in the room layout planning for them.

Chapter 5 identified which rooms the father and child tended to stay in together and talk, and which rooms they stayed in separately in seven one-child families. The findings show that the instances in which child and father stayed in different rooms fell into two groups: i) five of the seven subject fathers tended to stay in the living room, whereas the children stayed in the child's room, or in the parents' room in order to use PC; ii) there were also two subject fathers who stayed in the studio or dining room in order to work, while their children stayed in the living room or the child's room. For both groups, the duration of these periods of stay covered 30.0–81.4% of the time when both the father and child stayed at home.

The father stayed together with the child for 0.5-25% of the time when both the father and child stayed at home. The use of the living room as the place in which the child stay with the father and talk was found to be highest (five out of seven families), followed by the dining room and the child's room. In addition, in over half of the cases when the child stayed with the father in the living room or dining room and either of them had talked, the child spoke over 1.6 times more than the father. However, in individual rooms, in all cases and particularly in the child's room, the child always spoke less than the father, and the duration of the child's speech was less than 70% of that of the father.

In this chapter, the author studied seven single child families. This study set up an example that explores the room layout planning that might increase the father-child communications based on their room use, which can be captured and identified through sensing technology. The findings suggested that it is important to increase the spatial attraction of the living rooms, which encourage the father and child to spend more time in these living rooms.

Chapter 6 reviews the findings as follows: firstly, the author proposed methods that use sensing technology to precisely survey and analyze residents' daily behavior in room use, in aspects of their stay and talk in certain rooms and movements between

rooms; secondly, despite the subjects studied were based on specific and individual cases, by using the methods above, the author showed the characteristics of daily room use of subject families, as the basis for the improvement of dwelling layout for these families.

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Chapter 1 General Introduction

1.1 Background

1.1.1 The elderly couple living independently and the one-child family in urban areas of China

Although China has the largest increasing population in the world, the declining birth rate and aging are already an issue. On the one hand, it is projected that the proportion of people older than 60 in China*[1] will rise from 10.8% (2005-2010) to 16.7% (2020-2025); on the other hand, the one-child policy has reduced the birth rate from 21.5‰ (1975-1980) to 14‰ (2000-2005) (Fig.1-1*[2]). With the declining birth rate and aging, family types have become diversified in the urban areas of China, where the population of elderly couples living independently and one-child families is increasing rapidly.

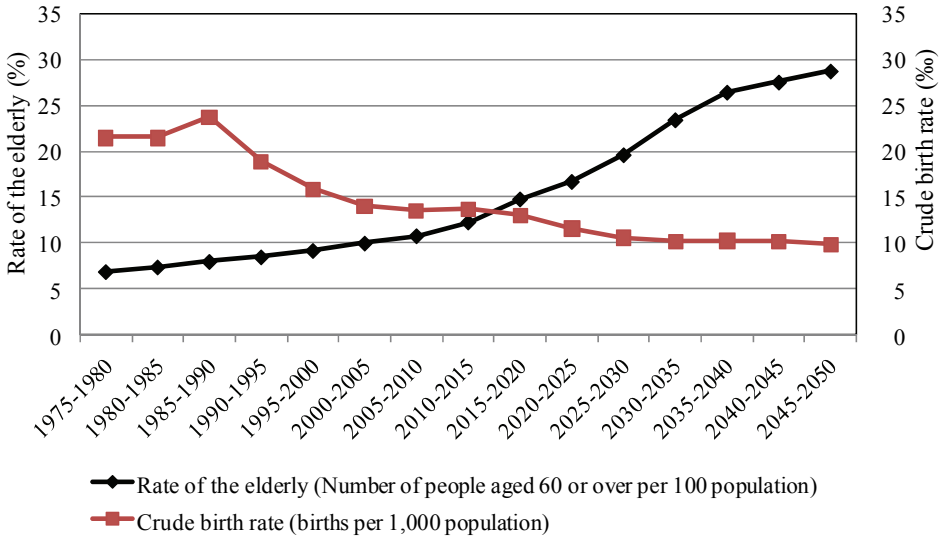

Figure 1-1 The rate of the elderly (Number of people aged 60 or over per 100 population) and Crude birth rate (births per 1,000 population) from 1975 to 2050 (Data for 1950-2010 are estimates and those thereafter are projections) *[2]

On one hand, the one-child policy has resulted in over 100 million only children, many of whom live in a family consisting of a couple and one child, which is now considered the basic family unit in urban China*[3].

On the other hand, unlike in Japan, the aging problem in China is concentrated in urban areas[1)]. At the same time, an increasing percentage of China's urban elderly population lives independently. In Beijing, such families will number over one million in 2010—40% of all the families comprising elderly people*[4]. Since a family unit

comprising a couple and one child has been considered the standard type since 1979, when the one child policy was enacted. The time frame of those children getting married and starting to live by themselves coincided with the couples' initiation into the elderly age group, which has resulted in a larger number of elderly couples living independently.

1.1.2 Development and design challenges for dwellings with common and individual rooms in the Chinese urban apartment house

Dwelling conditions and room layout planning for ordinary Chinese salaried persons have been improved with the sustained economic growth of the last 30 years. Before the reform and opening up of the late 1970s, one average urban resident had a usable living space of about 4 m^2. Based on the policy stating that "one family should live in one room", many families had to share one dwelling unit with other families. The common space in a dwelling unit at that time tended to be small, windowless, and was used as a circulation space or buffer space between the two families living in one dwelling[2)]. Six percent of the 40 million urban families shared a kitchen and 10% of them shared a toilet until 1986[3)]. The design code for residential buildings provided that the dwelling unit should be designed for only one family in 1987[4)].

When television began to be popular in the 1980s, residents were found to need a space in which to locate the television and sofa[5)]. Small common rooms for family members to have dinner, enjoy time together and to sleep sometimes appeared in the 1980s[6)].

Controlling the dwelling area under a limitation had been the most important principle for designing room layout in the time of welfare housing allocation, when the average usable living area per person was extremely low. With commercialization and the increasing area of the urban apartment house since the end of 1980s, the use made by residents has become a bigger priority in room layout planning[3)]. Also with the commercialization of the urban apartment house, the average usable living space of the urban resident has been increasing, and it had reached 22 m^2 per person by 2006. The common room became bigger and had better lighting in the 1990s, and an independent dining room appeared in many urban apartment houses[7)]. The design code for residential buildings in 1999 provided that the dwelling unit should have a living room with natural lighting. The basic constitution of a plan with common and individual rooms was established.

In order to improve the dwelling quality, the government proposed the concept of

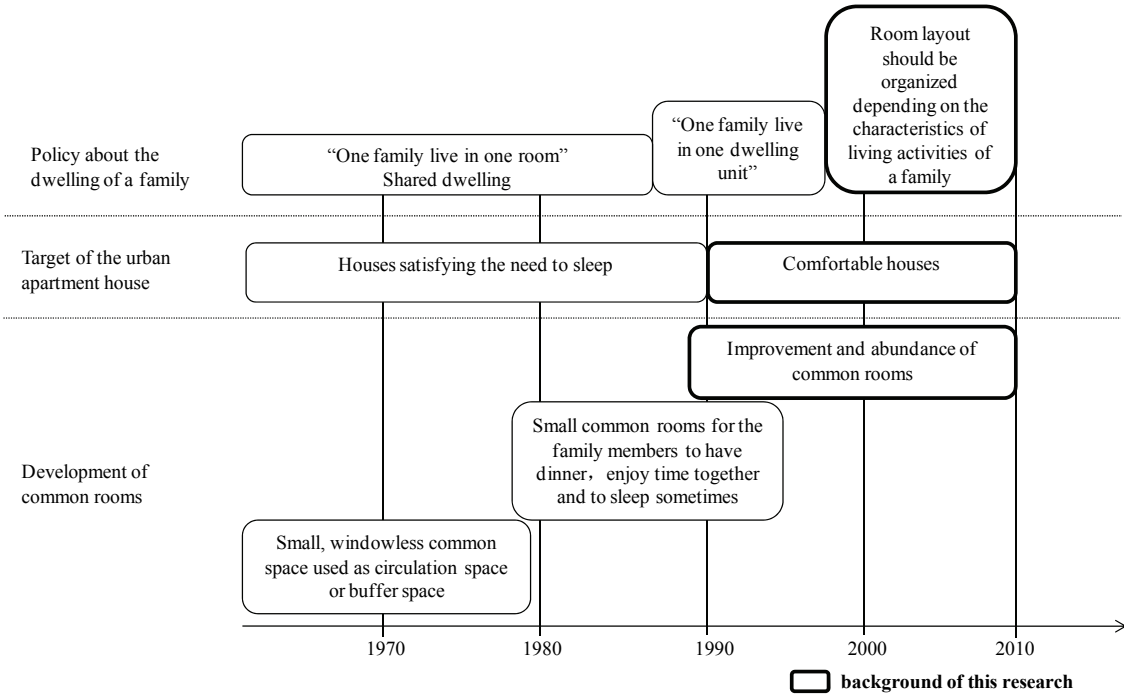

Figure 1-2 Development flow of Chinese urban apartment houses and the background of this research. (This figure is based on references 2), 4), 6), 7) and 8))

"comfortable urban apartment houses" in the 1990s. In the design guidelines for the demonstration residential quarter of comfortable urban apartment houses in the early 21st century, it is suggested that the room layout should be organized depending on the characteristics of the living activities of a family[8] (Fig. 1-2). Thus, the improved design of dwellings with common and individual rooms needs a deeper understanding of the behaviors of specific families in room use. Although studies have been conducted to clarify the needs and use of general residents of the facilities and individual rooms in urban apartment houses[9], the room use of specific family types, in terms of elderly couples living independently and one-child families, has not been clarified.

With the declining birth rate and aging population, the size of a family has been growing smaller in Japan. In 2005, over 40% of the families in Tokyo, and over 32% of those in Kyoto and Osaka had only one member*[5]. After focusing on diversified dwelling needs and also diversified families, latest Japanese dwelling studies have begun to focus on the lifestyle of single-member families and the use of shared houses or collective housing in which single residents or small families live together and share common rooms. Additionally, aiming at the individualization of living style, dwelling plans that emphasize the relationship between individuals and society have been proposed, which form the basis for rethinking the basic dwelling plan that comprises

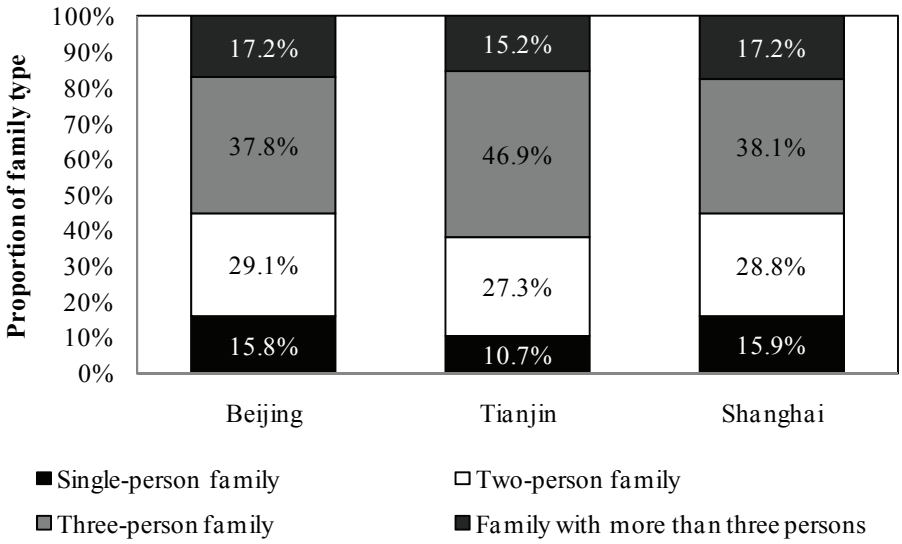

Figure 1-3 Composition of family types in big cities of China. (Source: reference 11))

common and individual rooms. For instance, Yamamoto proposed a room layout mode with individual rooms directly connecting outside spaces, other than the common room[10]. The themes mentioned above are a part of the themes in Japanese dwelling studies, but they are important themes that many latest studies focus on.

Although family size has also been becoming smaller in urban areas of China, two-person and three-person families are still the overwhelming majority (Fig. 1-3[11]). The family is also the basic unit that needs to be considered when designing a room layout[9]. Thus, a dwelling plan satisfying the room use of family members and interpersonal relationships in one family is regarded as important at present and will remain important in the near future. Based on this situation, this research attempts to clarify the behaviors in room use of specific family types with multiple members, in terms of elderly couples living alone and one-child families.

1.1.3 The study questions about apartment houses for the elderly living independently and one-child families

A specific family type may have specific concerns about the dwelling and thus present specific study questions. The study questions concerning the elderly couple living independently and the one-child family are as follows:

1) The stay in certain rooms and movement between rooms for elderly couples living independently

A recent survey suggests that 90% of the elderly in Beijing and Shanghai choose to live in regular houses rather than in nursing homes[12].

It has generally been observed that the elderly spend more time at home compared with the working young. Thus, the quality of the houses in which the elderly reside is closely related to their quality of life and, especially for elderly couples left to their own devices, safe, comfortable, and convenient houses have become all the more important.

In cognizance of this burgeoning societal section, some new Chinese dwelling units have been designed to cater for the needs of the elderly. Major attention has been paid to the construction of barrier-free and safe facilities in the house (such as in the toilet), or "pair-housing" for the elderly living in the neighborhood of the young, but there are few studies focusing on the layout of rooms based on measuring their actual room use. In the decades of their lives, most elderly people may have developed a specific way of being in a certain room and of moving between rooms, and this knowledge is the basis for designing room layout and planning rooms of appropriate size and orientation and with convenient circulation for them.

For an elderly couple, the room which the two persons use together or separately is a basic factor in the use of common and individual rooms. Studies have shown that they tend to use different rooms to carry out individual activities[13], stay together after supper[14], use the same room in the waking hours when they sleep in the same room, and use separate rooms when they sleep separately[15]. However, for any specific Chinese couple, the rooms which are used together or separately during different times of a day have not been clarified (Fig. 1-4).

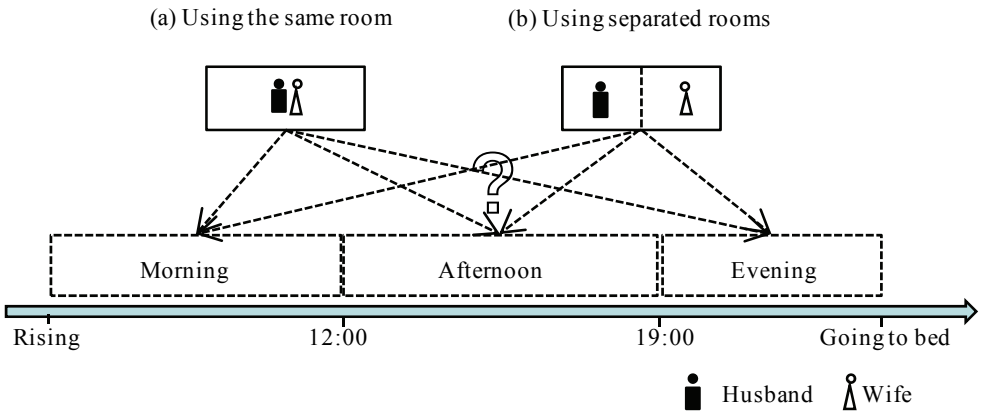

Figure 1-4 The question of which rooms the couples use together or separately during a day

On the other hand, several studies focus on the circulation in a house. Alexander Klein[16] once summarized the three types of circulation that connect main functions in the dwelling: i) Cooking-dining, ii) Sleeping-having a bath and iii) Acting-resting. Ikebe[17] summarized three circulations as the lines of i) guests, ii) personal life and iii) housework. He also clarified the circulation between appliances and facilities involved in housework. However, no measurement of the actual movement of residents between rooms was mentioned.

Varieties of circulation have different levels of importance. As pointed out by Nishiyama[18], the importance of a certain circulation should be considered on the basis of the number of family members and the movement frequency, and the assumed circulation for general residents usually has to be adjusted in real life. Furthermore, there was also a study that used time allocation to investigate and quantitatively record the movement between rooms in the houses of 10 families, and which clarified the relative location between rooms from the recorded movement[19].

However, the actual movement of an elderly couple living independently in a house has not been clarified, and thus their specific needs in terms of the relative location of rooms are not clear. Moreover, according to the general assumption, the room that residents stay in longest is characterized by a good orientation[7], whereas the room from which residents access other rooms frequently should be located at the center of all the rooms, from where they can conveniently access most of the rooms. Whether the two above rooms are used as the same room for a particular couple is regarded as a factor that reflects different needs in connection with the room layout. However, the movement between a room in which the elderly couple stays for a long duration and other rooms has not been clarified, and thus the relative location of this room in the whole circulation of a house is not clear (Fig. 1-5).

Taking the above factors into account, in order to approach a room layout that satisfies the specific use of elderly couples living independently, the following questions need to be clarified: i) which rooms do the couples use together or separately during each time period (morning, afternoon and evening); ii) how do they move between the room (s) that they stay in for the longest time and other rooms.

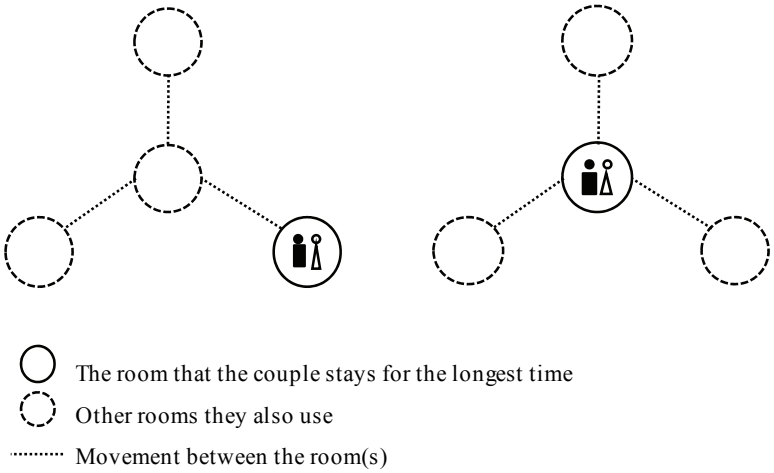

Figure 1-5 The question of whether the room they stay in for the longest time is also the center of movement of the house

2) Father-child communication in the one-child family

In the one-child family, parents invest a lot of energy in taking care of their child and place a lot of hope in him/her. The parent-child relationship is one of the most important relationships in the family. However, when the child becomes an adolescent*[6], a communication gap often develops between parent and child, especially between the father and child.

A questionnaire investigation of 1855 urban middle school students and their parents in 14 Chinese cities showed that the father-child relationship is more estranged than the mother-child relationship. The children felt that they met and talked with their mother more at home, and they considered their mother to be a person who understands them[20]. Another questionnaire investigation of 644 families with children over the age of 10 in Shanghai showed that the father spent less time communicating with his child than the mother, and less than 20% of the fathers communicated often with their children[21]. There has also been research suggesting that parent-child relationships can be improved by increasing face-to-face communication between fathers and their children[22].

Ideas for solving the communication problem might be learned from Japan, which is facing a similar problem in parent-child communication. In Japan, with an increase in respect for personal privacy, the child's room, an individual room where the child can study, play and sleep, has been a necessary component of the dwelling plan. However, the child's room has increasingly become an independent space that can be accessed directly from the entrance in many dwellings, and thus it is quite likely to cause the

separation of children and parents. It is regarded as necessary to reconsider the position of the living room and the whole dwelling plan to improve the parent-child conversation[23]. With this motivation, Tomoda clarified children's evaluation of the relationship between the child's room and the living room in a house comprising individual rooms that have access from the living room (L-hall type). Children under the age of 11 felt it is good to have a living room close to the child's room and those over the age of 16 felt it is bad to have a living room close to the child's room. Thus, it is considered that the L-hall type is more appropriate for a family with children under the age of 10[24]. Another study showed that communication durations tended to be longer in layouts where residents reached the stairs by passing through the living room[25].

However, the room in which the father and child communicate has not been clarified. The parents and child might see or talk to each other in any room of the house. They might also stay separately in different rooms and have no visual or verbal contact with each other. A comprehensive identification of the rooms in which they stay together and talk, and the rooms in which they stay separate, as well as an understanding of the reasons for this would form a basis for providing spatial conditions that increase opportunities for parent-child communication.

1.2 Purpose

The dwellings with common and individual rooms, in which ordinary Chinese salaried persons live, have improved with the sustained economic growth in the recent 30 years. Controlling the dwelling area within limits had been the most important principle for designing room layout in the time of welfare housing allocation, when the average usable living area per person was extremely small. With the commercialization and increasing area of the urban apartment house, the use made by a family has become a bigger priority in room layout planning. The increasing numbers of elderly Chinese couples living alone and one-child families have a specific room use, which presents specific needs for improvement of the room layout.

Against this background, this dissertation focuses on only regular-sized (usable living space less than 105 m^2)*[7] contemporary Chinese urban apartment houses, comprising common and individual rooms, in which ordinary families of salaried persons reside. The purpose of this research is to propose methods that use sensing technology to acquire and analyze precise survey data in residents' daily behavior in room use, in aspects of their stay and talk in certain rooms and movements between

rooms. By using the methods above, the author attempted to show the characteristics of daily room use of subject families, as the basis for the improvement of dwelling layout for these families.

For this purpose, the author has attempted to quantitatively clarify, using individual cases, the characteristics of room use for the elderly couple and one-child family. The detailed goals for the study of elderly couples living independently are as follows:

1) In which rooms do the couples stay together or separately;
2) The relationship between the room that the couples stay in for the longest time and other rooms in circulation.

In addition, the detailed goals for the study of one-child families are as follows:

1) In which rooms do the father and child stay together and talk;
2) In which rooms do they stay separately.

1.3 Significance

Since the subjects studied were specific and individual cases, the findings cannot be interpreted as the general room use of most elderly or one-child families. However, they do reflect specific characteristics of room use that exist in some cases, thus making them concrete realities that should not be ignored. In the author's opinion, the knowledge of "general" room use is not a simple average of the room use of large samples, but a comprehensive and detailed understanding of the diversities of room use of certain groups of people. This research has only surveyed specific and individual cases, and the actual room use studied in this research is influenced by all the interpersonal relationship, the living style and the physical conditions of space in the specific families. However, the findings may be regarded as a small but important part

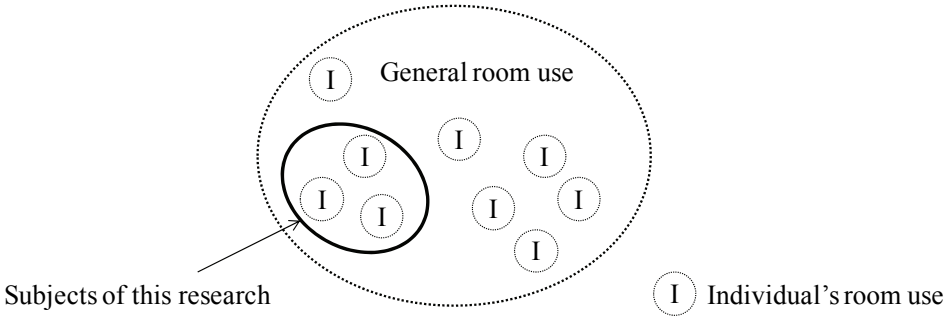

Figure 1-6 Relationship between the individual room use studied in this research and general room use

of the general knowledge. The accumulation of knowledge on the individual's room use through a precise survey, such as the one featured in this dissertation, is a significant step towards identifying the general room use of Chinese elderly couples and one-child families (Fig. 1-6).

1.4 Method

The method of this dissertation is to quantitatively clarify the characteristics of behaviors in room use by statistical analysis based on data obtained using a sensing device.

This dissertation focuses on three basic behaviors in room use (hereafter referred to as "room use") as follows:

1) Stay in a certain room (elderly living independently and one-child family)
2) Move between the rooms (elderly living independently)
3) Talk in a certain room (one-child family)

In this research, "stay" in a certain room does not mean the resident was absolutely static in the room, but that the resident was regarded as being inside the room in a particular minute. "Move" denotes a change of room.

The characteristics of room use were clarified through the factors shown in Table 1-1. The specific activities carried out in certain rooms are personal experiences varying by individuals, but the duration of staying or talking in that room is considered a common unit of measurement for each individual. In the same way, although the residents might move between the rooms for different purposes, the movement frequency is considered a common unit of measurement for the connection between the rooms in actual use. The room use of different individuals can be more easily compared and understood by the duration of staying or talking in certain rooms and the movement frequency between rooms.

Table 1-1 Studied factors of room use in this research

Room use (subject)	Factor of room use
Stay in certain room (elderly couple, one-child family)	Duration
Movement between the rooms (elderly couple)	Frequency
Talk in certain room (one-child family)	Duration , frequency

The collective periods of staying in rooms as well as movement caused by daily living activities during the survey period were recorded, and this data was regarded as the room use. The purposes behind the periods of staying still or movement were not

taken into account in the recording; these were broadly ascertained through subsequent interviews with the subjects that were based on the findings of objective recording of duration of staying and talking in certain rooms and movement between rooms.

1.4.1 Obtaining the primary data by continuous recording

The data above were obtained by precisely and continuously recording in which room they stayed (talked) and the time using the following devices:

1) Active RFID devices*[8]: sensing devices that can record which room each subject is located in and when. The components of the Active RFID devices were as follows:
   - ① Active RFID Tag (tag)
   - ② Active RFID Reader (reader)
   - ③ PC (platform)
   - ④ Cable LAN /Wireless LAN

The tag sent a signal with a unique ID on a per-second basis. Each reader was assigned a Static IP and installed in each room of the dwelling unit. A wireless LAN or cable LAN connected the readers with a PC, which recorded the IP of the reader that had received signals from the tag, providing continuous data on when and in which room the subject was present.

According to the specific location of the subject, the reader in the adjacent room might receive signals sporadically, which were regarded as noise. In order to reduce noise, RFID data was filtered every minute. The number of signals received by each reader in a minute was counted, and the room in which the reader received the most signals in a minute was specified as the subject's "staying room" in that minute. The "duration of stay" in a certain room was measured by the total number of minutes from when the resident began to stay in the room until he/she began to stay in another room. "Move" or "movement" denotes a change of room. All the subjects took only a few seconds to move from one room to another, and so this duration was not counted.

The strength of this research lies in a precise and continuous recording on a per-minute basis. Within this precision range, the use of each room was quantified by the duration that subjects spent there. In the same way, the movements that connect different rooms are considered equally important in the room use sequence, regardless of how long the stay in the rooms was, before or after movement.

2) Acceleration sensor: sensor that can record the acceleration of the subject. This device helps to judge whether the subject has moved and fills in the

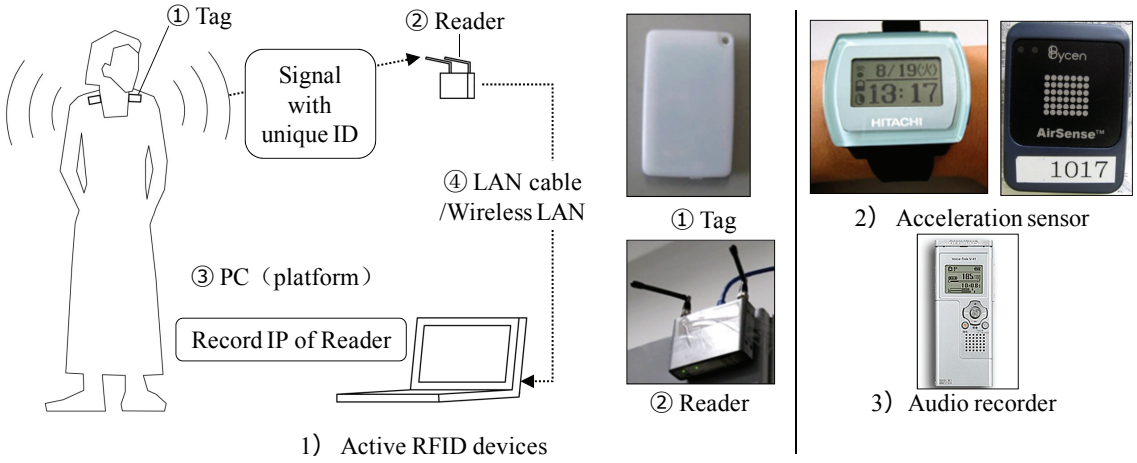

Figure 1-7 Devices

missing values in the Active RFID data.

3) Audio recorder: used to record the speech of subjects. Then, the recorded audio files were transformed into data that shows whether the subject talked, without knowing the content of their speech. The survey was conducted after all subjects understood the above details and agreed to cooperate. (Fig. 1-7)

1.4.2 Data analysis

In chapter 3, a Bayesian network is used to clarify the relationship among time, staying duration and movement order of the surveyed elderly.

In chapter 4, the characteristics of room use are identified by the room in which elderly Chinese couples stayed the longest (base) and the route between the pair of rooms that they passed through most frequently (main link). The center of movement throughout all the rooms was identified by the room(s) that had a main link with most rooms (hub).

In chapter 5, the room(s) in which the father and child tended to stay together or separately are classified according to their duration. The duration of talk is the number of seconds in a minute that the subject talked, judged by calculating the average sampling value that showed the loudness of the sound per second in the recorded audio file by using a software tool*[9].

1.5 General components of Chinese urban dwelling unit in an apartment house

Generally speaking, a contemporary Chinese urban dwelling unit in an apartment

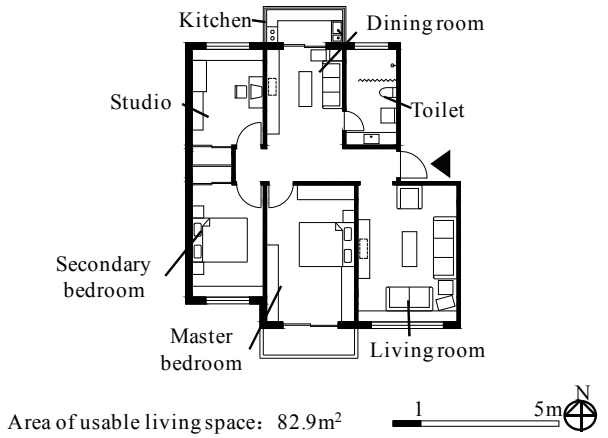

Figure 1-8 Example of the room layout plan of a Chinese urban apartment house

house may be composed of the following rooms, named on the basis of their main function (Fig. 1-8):

1) Living room: the room in which the subjects receive visitors and watch TV.
2) Dining room: where they have dinner daily, either by themselves or with guests. The dining room may be combined with a living room in a single space, but a separate dining room is often the case.
3) Toilet: the room comprising a lavatory, washbasin, and shower nozzle. Some apartment houses are also equipped with a washer inside the toilet, thus turning it into a room for carrying out housework
4) Kitchen: since it generates a large amount of smoke in cooking Chinese food, a fully enclosed kitchen is often the case in the Chinese urban apartment. With the variety of living styles, some families might have a combined dining room and kitchen, or have an enclosed kitchen and a combined dining room and kitchen.
5) Bedroom(s)
6) In some dwelling units, there might be a studio, which is a room with a bookshelf or PC, where the residents might read, nap, or carry out other activities.

The living room, dining room and kitchen are commonly combined in a Japanese apartment house, forming a DK (a combined dining room and kitchen) or LDK (a combined living room, dining room and kitchen). However, in a Chinese apartment house, there is usually a separate kitchen. The living room and dining room may be combined.

1.6 Previous studies and the difference between this study and previous studies

1.6.1 Literature regarding the dwelling unit of the elderly

1) Literature regarding dwelling facilities

There are several guidelines on dwelling facilities for the elderly. In Japan, since it is difficult for the elderly to tidy their bedding in Japanese style, they need a fixed bed. Handrails and barrier-free areas are also necessary in the dwelling areas of the elderly. They also need a western-style lavatory, renewal of water circulation system, a lower bathtub that is easy to get in, no difference in floor level, an antiskid floor and an adapted kitchen[26) 27) 28)]. An elevator is needed when the bedroom is on the second floor[29)].

2) Literature regarding room use

Studies focusing on the room use of the elderly have reported as follows (Table 1-2):

① Subject: single elderly people

Masunaga et al.[30)] found that single elderly people tended to use the larger room with the best natural light and seldom chose a north-facing room or a room next to the common corridor as their living room. Subjects living in a dwelling comprising only one bedroom were found to need another room for receiving guests. Koga and Takahashi[31)] interviewed single elderly people living alone and found that they usually stayed in a place facing the entrance or from which they could enjoy the outside view. Yang[32)] found that single elderly people tended to have dinner and stay during the day in the same room. They usually stayed in the DK during the day when the orientation of this room was good or it was located in the center of the dwelling. They might also stay in the Japanese style room.

② Subject: elderly couple living independently.

Yang[32)] found that the couple was satisfied with a dwelling comprising a DK and one room adjacent to the DK. It was a user-friendly layout where they could have dinner in the DK and make the room adjacent to the DK a living room. Kamo and Takada [33)] found that compared to the period living with a child, the elderly couple tended to use the living room for relaxing and indiviual activities and they did not need a guest room.

Yamazaki[34)35)] surveyed the time allocation of living activities of 493 residents over 25 years old and found that women (over 60 years old) in couples living independently tended to carry out activities associated with hobbies, work or socialising (such as writing letters, receiving guests, telephoning) in their personal space during weekdays and to carry out activities regarding hobbies in personal space or in common rooms (living room and dining room) alone at the weekend.

③ Subject: families with elderly people, the results not corresponding to a specific family type.

Yamazaki[34)35)] found that men (over 60 years old) might carry out activities regarding pastimes (such as watching TV, reading and so on) alone in a bedroom or studio, or do housework in the balcony or garden during the weekday. Arizuka[36)] interviewed 58 families comprising elderly members (most of the subject families were the elderly living with the young) and found that the elderly who had a closer relationship with the young tended to stay in the living room, and with their health status growing worse, they tended to stay in their own bedroom. Kataoka et al.[37)] used questionnaires and interviews to verify whether elderly family members recognized which rooms they used most, and it was found that the room use of the elderly living in rural areas was concentrated in the living room, while that of those living in urban areas was concentrated in the bedroom. Compared to the elderly living in rural areas, more instances of those living in urban areas were concentrated on the use of two rooms and individual rooms (bedroom, room for hobbies and so on). Cao et al.[38)] interviewed 24 families with elderly members in Tianjin and found that they usually stayed in their own bedrooms. Nakazono et al.[39)] found that in dwelling units with two rooms, the elderly tended to put tall furniture—such as wardrobes—in the smaller room, and used the larger room for main living activities—such as having dinner and relaxing. Murakami[40)] found that the single elderly or elderly couples often used a south-facing DK and tended to stay in the south-facing living room. They tended to open the door between the DK and the room adjacent to this DK. Sawada[14)] found that the elderly tended to have dinner and relax in a south-facing living room, and to sleep in separate rooms.

In families with elderly people, the elderly couple might use the same room or different rooms. Bamba and Takeda[13)] found that the elderly couple tended to carry out individual activities in different rooms in the house from the age of 65 to 79. As they got older, they might concentrate on using one room, thusit is considered it should befeasible to adjust the plan from three rooms to one. Sawada[14)] found that the elderly

couple tended to sleep separately and stay in the same room after supper. Lin et al.[15] found that Chinese elderly couples in Dalian and Harbin tended to use the same room in the awake time when they slept in the same room, and to use separate rooms when they slept separately. It was considered that there should be two bedrooms to fit these sleeping variations.

The studies above showed that elderly people tended to stay in a large[30) 39)], south-facing room[14) 40)] and that single elderly people tended to stay in a place facing the entrance or with a good view[31)]. Chinese elderly people tended to stay in bedrooms[38)] and Japanese elderly people who had a closer relationship with the young tended to stay in the living room[36)]. The room use of the elderly living in rural areas was concentrated in the living room, while that of those living in urban areas was concentrated in the bedroom[37)]. The elderly couple tended to carry out individual activities in different rooms[13)] and also to stay in the same room after supper[14)]. They tended to use the same room in the awake time when they slept in the same room, and to use separate rooms when they slept separately[15)].

However, the rooms in which they stay together or separately, and the time and duration of these stays has not been clarified. Furthermore, the actual movements of elderly couples have not been clarified. The movement between a room in which the elderly couple stays for longest and other rooms has not been clarified, and thus the relative location of this room within the whole circulation of a house is not clear.

Table 1-2 Review of previous studies on the room use of the elderly

No. of reference	Subject (number)	Methods	Findings
30) Masunaga et al.	Single elderly (40)	Interview	(1) Used the larger room with the best natural light (2) Seldom chose the north-facing room or room next to the public corridor as the living room. (3) Elderly living in the dwelling comprising one bedroom and a combined dining room and kitchen tended to need one more room for receiving guests.
31) Koga and Takahashi	Single elderly (25)	Questionnaire and interview	(1) Usually stayed at a place facing entrance or a place from where they can enjoy the out view. (2) They might have multiple places where they usually stay to carry out daily routine activities.
32) Yang et al.	Single elderly (147)	Questionnaire	(1) Used the same room to have dinner and stay during the day (2) Usually stayed in DK if the orientation of this room is good or this room is located in the center of dwelling, or stay in the Japanese style room.
	Elderly couples (34)		The couple was satisfied with dwelling comprising DK and one room adjacent to DK. It was a user-friendly layout that they could have dinner in DK and make the room adjacent to DK a living room.
33) Kamo and Takada	Elderly couple (1)	Interview	Used the living room for relaxing and indiviual activities and did not need guest room.
34)35) Yamazaki et al.	elderly couple (over 60 years old) woman (26) man (3)	Time allocation survey of living activities	Women tended to carry out activities regarding hobbies, work or sociality (such as writing letter, receiving guests, telephoning) in their personal space during weekdays and carry out activities regarding hobbies in personal space or in common rooms (living room and dining room) alone in the weekend.
	Families with elderly people (over 60 years old) (5)		Men might carry out activities regarding pastimes (such as watching TV, reading and so on) alone in bedroom or studio, or do housework in the balcony or garden during the weekday.
36) Arizuka	Families with elderly people: elderly couple (22) single elderly (5) living with the young and other (162)	Interview	The elderly who had closer relationship with the young tended to stay in the living room, and with the health status getting worse, they tended to stay in their own bedroom.
37) Kataoka et al.	Elderly people living with the young or elderly couple (105)	Questionnaire and interview	(1) The room use of the elderly living in rural areas was concentrated in the living room while that of those living in urban areas was concentrated in the bedroom. (2) Compared to the elderly living in the rural areas, more instances of those living in the urban areas concentrated to use two rooms and private rooms (bedroom, room for hobbies and so on)
38) Cao et al.	Elderly people living with the young (24)	Interview	Tianjin: usually stayed in their own bedrooms.
39) Nakazono et al.	Families with elderly people: couple (9) single (22)	Questionnaire and interview	In dwelling units with one kitchen and two rooms, the elderly used the larger room for dinner and relaxing.
40) Murakami	Families with elderly people: elderly couple (24) single elderly (34) other (2)	Interview	(1) The elderly often used a south-facing dining room and kitchen and tended to stay in the south-facing living room. (2) They tended to open the door between the dining room/kitchen and the room adjacent to this dining room/kitchen.
13) Bamba and Takeda	Families with elderly people: couple (70) single (38) living with the young (44)	Questionnaire and interview	Tended to carry out individual activities in different rooms in the house between the age of 65 and 79
14) Sawada	Families with elderly people (over 60 years): elderly couple (38) single elderly (4), elderly people living with the young (39)	Questionnaire and interview	(1) Had dinner and relaxed in a south-facing living room and slept separately in different rooms. (2) Stayed in the same room after supper
15) Lin et al.	Families with elderly people: elderly couple (Dalian: 48.8%, Harbin: 34.1%)	Questionnaire and interview	Tended to use the same room in the day when they slept in the same room, and to use separate rooms when they slept separately.

3) Literature regarding guidelines or proposals for the design of room layout for elderly people

① Families comprising elderly people

The Japanese government provides that the toilet and bedroom of elderly people should be located on the same floor, and recommends that the entrance, bathroom, washroom, dining room and bedroom of elderly people should all be located on the same floor[41].

There are also general proposals for the design of room layout for elderly people as follows[29]:

i) Access to the entrance or garden from the bedroom.
ii) A combined dining room and kitchen (DK), with a living room adjacent to this DK.
iii) Short circulation between bedroom and toilet/bathroom.

② Elderly people living with the young

In instances in which the elderly and the young live together in a dwelling unit, it is suggested that the elderly have a relatively independent living area separated from that of the young, or an independent bedroom that has convenient access to the dining room, where they could communicate naturally with other family members[42][43]. Since it is also suggested that a special living area for the elderly consists of the bedroom and living room, and even a kitchen, it needs a total dwelling area for the family that is enough for the elderly living with the young[44] [45] [46] [47].

③ Elderly couple

Murakami[40] proposed a room layout for the elderly couple which was composed of one Japanese style room and two function areas: (a) basic unit: bedroom, bathroom and toilet, and (b) living room, dining room and kitchen. The Japanese style room might be located: i) in between (a) and (b) and used as part of the common room or as a rest room for the nurse, or ii) next to the entrance for receiving guests.

However, as the guidelines or proposals in these studies were based on surveys using questionnaires and interviews, room layout planning based on the actual movement of the elderly couple was not considered.

1.6.2 Literature regarding room use and parent-child relationship

Based on the introductory book on dwelling design[48], the relative location of the bedrooms and the relationship between the bedrooms and common rooms relate closely

to the parent-child relationship. The family's needs from the layout were found to vary with the growth of the children. The parents slept in the same room with the infant. When the children entered elementary school, it was considered that they needed their own room, and it was suggested that this room should be located next to the parents' room. There was also a proposal that suggested providing two common rooms: one for the parents to relax in and receive guests, and another for the children to play in. When the children entered middle school, it was considered that they need an independent room separate from the living room and parents' room[48]. The layout of parents' room, children's room and common rooms was found to be diversified by families: i) some families might have two common rooms for the activities of the family and receiving guests respectively; ii) other families made sure that parents and children had their own individual rooms: each child might have his own room, and in some cases each family member might have his own room[49]. In Tomoda's study, residents' evaluation of the layouts of dwellings comprising separate common and individual rooms were compared with those comprising individual rooms that have access from the living room (L-hall type): the latter were found to be appropriate for families with children below the age of 10[24]. In addition, there were studies focusing on independent children's rooms and children's privacy. The findings showed that, compared to the United States, Japanese parents tended to enter and manage the children's room, while the children centered on studying in their room[50].

With increasing attention paid to the weak parent-child relationship resulting from the independence of children's rooms, several studies have focused on the relationship between a family's communication and the layout of room(s) in a house (Table 1-3). Honma and Kameda[51] classified the layout plans of houses published in housing magazines on the basis of the relationship among the child's room, parents' room and common room, and clarified their variations from the 1960s to 1990s. They found that, compared to the houses of the 1960s, both the child's room and the parents' room tend to be connected directly to the common room by around the 1990s. Although this change was considered to be related to parent-child communication, such communication was not measured.

Fujino and Kitaura[52] classified parent-child communication qualitatively using a questionnaire, and clarified its relationship to the use of the family room (the rooms in which family members are likely to stay together, in terms of L, LD or LDK). They found that the families of elementary school students who were on relatively intimate terms with their parents tended to use the family room frequently, whereas the families

of high school students used the family room less frequently. Ohta and Yanase[53] found that housewives felt that it was easy to "Danran" (a common method of communication where family members enjoy time together in Japan) and tended to talk with the family when doing housework in the kitchen, which faces the living room directly. Kitaoka and Machida[54] investigated 261 housewives and 300 senior school students and found that the subjects tended to feel that it was easy to "Danran" when the living room and dining room were adjacent. Yamazaki[35] used a time allocation survey to clarify that women with young children under three years old spent more time taking care of their children and talking to them. Activities regarding the parent-child relationship, in terms of taking care of them, pushing them to study, and talking to them, might occur in bedrooms, the studio, the child's room, corridor and other spaces. The father might carry out the above activities in the kitchen when doing housework.

Sawachi and Matsuo[55] asked the mother, father and children to record their living activities, in which room they carried out these activities, and when, investigating the time allocation on a basis of 30-minute periods, and clarified, for each group of people (mother, father and children), the probability of the room they stayed in and the living activities carried out every 30 minutes. The father tended to stay in the LDK after returning home in the evening. The children tended to study in their own room and then stay in the LDK to have supper, watch TV and communicate with their parents, and then return to their own room. Activities relating to communication were concentrated between 1900 and 2100 for both mother and child, and were concentrated between 2100 and 2300 for both mother and father, and thus it is considered that communication between the mother and children, and between the mother and father is concentrated in the above time periods. However, whether the children communicated with their parents in rooms other than LDK, in which room the father and child stayed together and talked, and whether there is any difference between the amount of talking in different rooms has not been clarified.

Although it is suggested by dwelling design guidebooks that a studio or housework corner could be a component of the living room if this room is as large as about 26m^2, they do not show the relationship between this layout setting and the parent-child communication[48].

Table 1-3 Review of previous studies on the family's communication in dwelling

No. of reference	Subject	Contents of communication	Methods	Findings
51) Honma and Kameda	Layout plans of houses published in housing magazines from 1956 to 1994			Compared to the houses in 1960s, both the child's room and the parents' room tend to be connected directly to the common room around 1990s
52) Fujino and Kitaura	Parents and children	The parent-child communication is evaluated by: whether the parents and children go to cinema, have dinner and go shopping together, whether the child can express their own opinions to the parents and so on	Questionnaire	The families of elementary school students who were on relatively intimate terms (have a higher level of communication) with their parents tended to use the family room frequently, whereas the families of high school students used the family room less frequently.
53) Ohta and Yanase	Housewives	Danran*, talk	Questionnaire and interview	Housewives felt that it was easy to "Danran" and tended to talk with the family when doing housework in the kitchen, which faces the living room directly
54) Kitaoka and Machida	Housewives and senior school students	Danran	Questionnaire and interview	They feel that it was easy to "Danran" when the living room and dining room were adjacent.
35) Yamazaki	Man and woman	Take care of their children, push them to study, and talk to them.	Time allocation survey of living activities	Women who had a young child not over 3 years old, spent more time in taking care of their children and talking to them. The activities regarding the parent-child relationship, in terms of taking care of them, pushing them to study, and talking to them, might occur in bedrooms, studio, child's room, corridor and other spaces. The man might carry out the above activities in the kitchen when doing housework.
55) Sawachi and Matsuo	Housewives, husbands and children	Danran Communication between certain pair of subject is clarified by: whether the activities relating to Danran of each subject group occurred simultanously	Time allocation survey of living activities	The communication between the mother and children was likely to occur during 19 to 21 o'clock, and that between the mother and father might occur during 21 to 23 o'clock.

*: Danran: a common method of communication where family members enjoy time together in Japan

1.6.3 Literature regarding methods for layout planning

Several studies focused on the methods for planning circulations or room layout in a building. Takagi et al.[56] proposed an analysis method for the circulation in architectural plans by using indices of graphs and networks, including the number of joints, distance between joints, number of routes and so on.

There were several studies that showed the process of generating room layout plan from component models. A study[57] proposed a method for designing dwelling room layout by searching aperture cards that recorded all the component models with regard to a dwelling, including family type, circulation pattern of daily routine activity, conditions of the site and so on. Ohta et al.[57] focused on two models: i) circulation model, which showed the connection between spaces, with no regard given to the size and shape of spaces; ii) unit model, which was composed of units with given size and shape, located adjacent to each other and inside a given site. He processed a design process for a room layout by combining design criterion and the two models. Terada[58] used an intelligent computer method to generate rectangular mosaic patterns, which were fundamental forms that could be modified into practical room layout, based on the relationship of adjacency between the given rooms in an example plan. Some books, such as the architecture of form[59], also described quantitative approches to architectural design. Unlike the studies that showed layout planning methods based on circulation models or relationship of adjacency, this study shows the characteristics of daily room use of subject families, as the basis for the improvement of planning of dwelling layout for these families.

Circulation of daily routine activities is one of the important models summarized from the use and components of a dwelling. Alexander Klein[16] once summarized the three types of circulation that connect main functions in the dwelling: i) Cooking-dining, ii) Sleeping-having a bath and iii) Acting-resting. Ikebe[17] summarized three circulations as the lines of i) guests, ii) personal life and iii) housework. He also clarified the circulation between appliances and facilities involved in housework. There was also a study[57] that clarified the network pattern consisting of daily routine activities (communicating with family members, dining, receiving guests, cooking and so on) and clarified the pattern into four types: i) the one centering on communicating with family members; ii) the one centering on communicating with family members and receiving guests; iii) the one centering on personal activities and iv) the one centering on housework. However, the residents' movement frequency between rooms during different time periods of a day has not been precisely measured.

1.6.4 Literature regarding human behavior assessed by using sensing technology

The development of sensing technology shows potential for precisely observing activities in the house. Some studies have focused on the walking track. Enta et al.[60] examined the accuracy of slipper-type RFID in recognizing the walking of subjects in their experiment.

Sensing technology was also used to study routine behavior in the house. In order to form a basis for detecting abnormal behavior patterns, Matsuoka[61] collected data on residents' daily routine activities - such as sleeping, dining, cleaning and so on - using sensors and a CCD camera in an experimental house and developed an algorithm to automatically clarify the time series pattern of daily routine activities. The findings were considered useful to develop a system that could detect the abnormal activities of a resident. Mori[62] built an experiment room, called a "Sensing Room", in which sensors were installed to measure the daily living data on testees. In the YUKARI project, Minoh[63] detected the subjects' daily routine activities by camera and sensors in an experimental house. Considering that users might behave unnaturally in the experimental environment, there were also experiments in a real house without a camera. Tapia et al.[64] designed a system that can recognize certain human activities in a house by gathering data from sensors affixed to every object the resident uses. Enta et al.[65] used ring-type RFID to record the frequency with which the subjects touched things by hand in the house, in terms of switches, furnitures and so on, and analyzed the network diagram that they formed on the basis of connecting the things that the residents touched .

However, the authors are unaware of research that has focused on the daily room use of residents in several home environments derived from the use of sensing technology.

1.6.5 The difference between the method of this study and previous studies

For the reasons mentioned in section 1.2, the duration of staying and talking in certain rooms, and the movement frequency between rooms need to be recorded continuously in a precise time series, because they need to be clarified in terms of actual time flow, and multiple residents' use or non-use of the same room is also judged by whether or not they stay in the same room at the same time.

The most commonly used methods to survey room use are questionnaires, interviews or time allocation surveys of living activities, in which participants record

their room-use schedules on a per-30 minute (or 5 minute) basis over one or two days. Such records comprise the factors of time, room, and activity. These methods, on the basis of the objective answers or recording of the subjects, are helpful to understand the purpose and thinking of the subject when using a certain room, but the self-reported data obtained by these methods is also influenced by the memory and cooperation of the subjects. Thus, previous studies tended to collect large amounts of primary data and use statistical analysis to clarify the general tendency or classification of the subjects. For instance, Sawachi and Matsuo[66] clarified the variation of living activities and the room of stay during a day in summer and winter by per-30 minute time allocation surveys for 319 individuals. Yamazaki [67] used the same method (per-5 minute) on 493 residents over 25 years old and used clustering analysis to clarify the relationships among living activities, rooms and the basic attributes of subjects. However, Sawachi and Matsuo [57], who used this method, pointed out that it suffers from one limitation: the difficulty of proving the conformity between the obtained data and the actual situation, and it is necessary to explore appropriate methods to record living activities in the house.

Therefore, the author chose to record the room use objectively and precisely by using sensing technology. The precise data provides the possibility of getting a deeper understanding of the specific room use. It is likely that we can see more details of an object when focusing on it closely. Unlike studies that aim to clarify the general room use of a certain group of people by surveying large samples, this study focuses on a deeper understanding of the specific room use of individual cases. Although the sample of surveyed subjects was small, the stay and movement of each elderly subject through all the rooms was recorded exactly and continuously on a per-minute basis for two to four days. In the one-child family survey, the speeches of each family member were also continuously recorded. Such an in-depth analysis is hardly possible through questionnaire-surveys and interviews of large study samples.

Compared to the investigation of time allocation, this method poses much less of a burden on the subject during a relatively long time survey, because the time and room in which the subject stayed can be recorded automatically using sensing technology (Table 1-4).

Moreover, unlike previous studies that aimed to use sensing technology to detect an abnormal behavior pattern of the subject (e.g., reference 60), caused by emergencies (injury or acute disease), this study is characterized by using the technology to identify the characteristics of daily usage pattern of rooms.

The subjects might behave differently after wearing the tags. However, since the

Table 1-4 Comparison of the survey method between this study and previous studies

	This study by sensing technology	Previous study by questionnaire	Previous study by interview	Previous study by investigation of time allocation
Sample size	Several cases	Hundreds of cases	Dozens of cases	Dozens or hundreds of cases
Survey period for each subject	Successive two to four days	Dozens of minutes	1 ~2 hours	One or two days
Qualitative or quantitative	Quantitative	Qualitative or quantitative	Qualitative or quantitative	Quantitative
Precision	On per-minute basis	-	-	On per-5 minute or per-30 minute basis
Findings	Specific characteristics and tendency of individual cases	General characteristics of a certain group of people	General characteristics of a certain group of people or specific characteristics of individual case	General characteristics of a certain group of people

sensors only recorded the presentence of subjects in certain rooms, it is regarded that they might behave more natrually and less feeling being disturbed during a survey using sensing technology rather than using a camera or video camera. The author did not observe obvious unnatrual behavior of the subjects during the survey.

1.7 Framework

This dissertation comprises three parts. A general introduction is given first, then four studies are presented in the main body, and a conclusion is presented finally. The main body of this dissertation comprises two sections. The first (chapters 2 and 3) focuses on the recording and analysis method applied for the room use. In this section, the author concentrates on a single elderly woman living independently. On the basis of the method established in this section, the tendency and diversity of room use in multiple individual cases are clarified in the latter section (chapters 4 and 5).

In Chapter 2, the author aimed to verify the best wearing position and parameter setting of the sensing device to improve the accuracy of location detection. Then the author attempted to use the sensing technology to exactly and continuously record in which rooms the subject stayed and when, on a per-minute basis for eight days without overly burdening the subject. The characteristics of the stay in certain rooms and movement were identified respectively by the duration that the subject stayed there and the movement frequency between the pair of rooms that she passed through.

Chapter 3 attempted to clarify whether there was any relationship between the duration of stay in certain rooms and the room in which the subject stayed before or after this stay by using a probabilistic model. This result was used to determine, in the following chapters, whether the author could respectively identify the characteristics of

stay in certain rooms and movement between rooms.

In Chapter 4, the author aimed to clarify, by studying individual cases, the personal room use in dwelling units of Chinese elderly couples in their daily life. The room use was identified on the basis of the room in which they stayed the longest (base) and the route between the pair of rooms that they passed through most frequently (main link) during each time period (morning, afternoon and evening). First, the author focused on their use of the base. A comparison was made between the husband and wife with regard to their use of the base and any difference between bases was identified by using a recording device (Objective base) and the base identified and reported by subjects in their interviews (Subjective base). Then, the overlapping pattern of bases and main links was used to show the characteristics of the individuals' room use and classify the studied couples.

Chapter 5 focused on the relationship between room use and father-child communication in Chinese urban one-child family dwelling units. It identified which rooms the father and child tended to stay in together to talk, and which rooms they stayed in separately. The author also identified the reasons they stayed there by conducting short interviews.

Chapter 6 concludes the findings with regard to the room use of the elderly and the one-child family (Fig. 1-9).

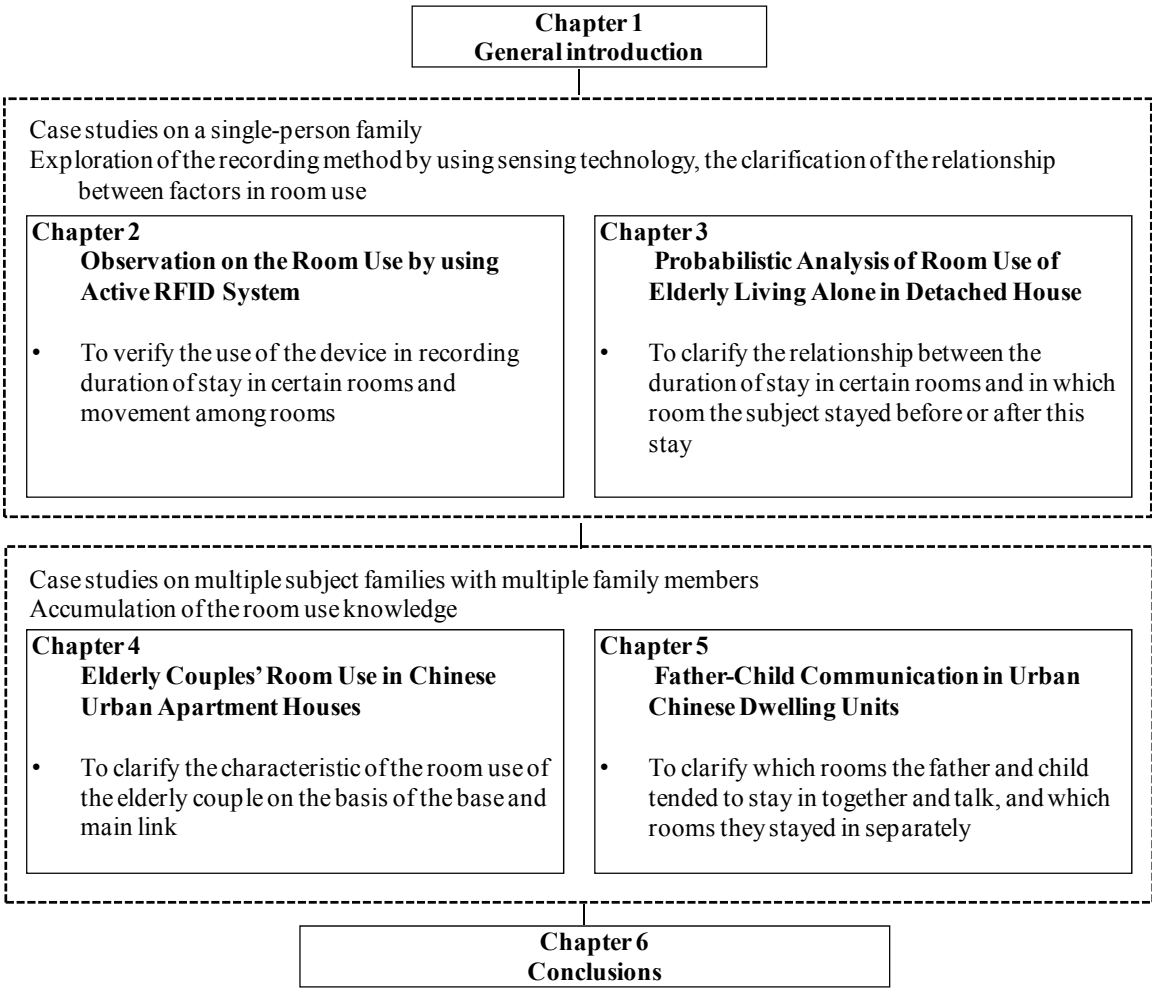

Figure 1-9 Framework of the Dissertation

Note

*1. The Government of China defines citizens over 60 as aged, according to the Law of the People's Republic of China on Protection of the Rights and Interests of the Elderly: Article 2: The aged referred to in this Law are citizens over 60.

*2. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision, http://esa.un.org/unpp

*3. Homepage of China Population Information and Research Center: http:// www.cpirc.org.cn

*4. Our country has a one-child number in excess of 100million, 2008.7, http://news.xinhuanet.com/

*5. 社会生活統計指標－都道府県の指標－2010, 社会生活統計指標, A. 人口・世帯,

政府統計の総合窓口，http://www.e-stat.go.jp

*6. According to the WHO's definition, adolescents are those aged 10-19 years.

7. Each provincial level city has its own definition of the area of a regular dwelling. The number used in this dissertation is calculated from the construction area (140m^2) provided by Beijing. *: Beijing Municipal Commission of Housing and Urban-Rural Development: Information announcing the criteria for regular dwellings that attract policy incentives. 2005.6.

Formula is as follows:

Su＝Sc× K**

Su: Area of usable living space

Sc: Construction area per unit

K: Parameter of usable living space of a typical floor. The regulation concerning K is as follows: K ≥ 78% (mid-rise apartment house) , K ≥ 72% (high-rise apartment house) ***

**: Ministry of Housing and Urban-Rural Development of the P.R. China: Design Code for Residential Buildings (GB 50096-1999)

***: Ministry of Housing and Urban-Rural Development of the P.R. China: Technical Standard for Performance Assessment of Residential Buildings (GB/T 50362-2005).

Since this research focuses on the room layout of the dwelling unit, irrespective of whether it is in a mid-rise or a high-rise apartment house, the author used an average K of 75% to show a reference for the minimum area of usable living space per unit.

From the above formula, Su＝140×0.75=105(m^2).

*8. RFID (Radio Frequency IDentification System) is an identification system that obtains location by radio wave. Active RFID is one type of RFID with tag that keeps sending signals automatically. It is better than the passive type in having a longer communication distance and needing fewer antennas to be installed. The Active RFID device and software used in this experiment were provided by FUJITSU Software Technologies Limited.

*9. The software to identify vocal duration was designed by Sun Miqin.

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Chapter 2 Observation Method on the Room Use by Using Active RFID System

2.1 Purpose

In this chapter, the author aimed to verify the wearing position and parameter setting of the sensing device that may improve the accuracy of location detection and show a method to continuously and precisely identify when and in which room a subject resident stays in a detached house through Active RFID devices. On the basis of the obtained time series data, the author attempted to identify the characteristics of the resident's stay in certain rooms and movement between the rooms.

2.2 Method of data collection

2.2.1 Sensing devices

1) Active RFID devices

The components of the Active RFID devices were shown as follows:

① Active RFID tag (tag)
② Active RFID Reader (reader)
③ PC (platform)
④ LAN cable

The tag sent a signal with a unique ID on a per-second basis. Each reader was assigned a Static IP and installed in each room of the dwelling unit. LAN cables connected the PC and readers. The PC recorded the IP of the reader that had received signals from the tag, providing continuous data on when and in which room the subject was present.

Since the detection range of the reader becomes larger and it can receive more signals per unit time when it is located higher, all of the readers were located at a height of about two meters up from the floor in the experiments and the formal survey.

2) Acceleration sensor

In order to fill in the missing values in the Active RFID data, the author also used an acceleration sensor that helped us judge whether the subject had moved. Fig. 2-1 and 2-2 show the components and specifications of the devices.

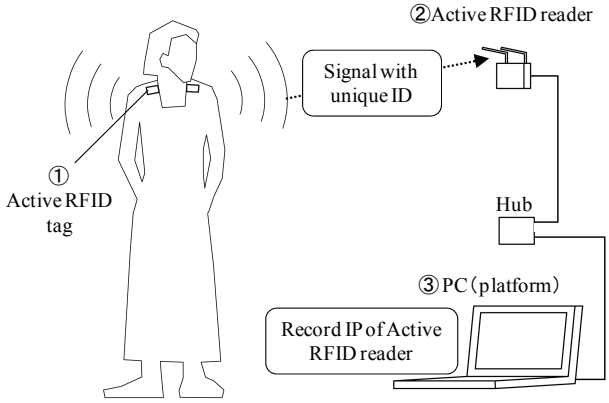


Figure 2-1 Components of device

			
	Active RFID Tag	Active RFID Reader	Acceleration sensor
Size (H×W×D)	34×55×9mm	110×30×80mm	40×43×16mm
Weight	15g	234g	40g
Power	Coin type lithiumion battery	AC adapter 6V 300mA	USB recharge battery
Frequency band	314.950MHz		2405MHz ~2480MHz
Operating Temperature Limits	－10℃~＋60℃		
Operating Humidity Limits	Below 95%RH		Waterproof (Level JIS)
Communication distance	Less than 15m		Less than 20m

Figure 2-2 Specifications of the sensors

2.2.2 Discussion on the wearing position of tag, the detection range and accuracy of the reader

1) Experiment 1: Discussion on the wearing position of the tag

The tag is small and light (34x55x9mm, 15g). Since the body of a human is comprised of water, which might influence the radio signal reception, experiment 1 was conducted to discuss the best wearing position of the tag on a body.

Five readers were installed in a room, and reference points were pasted on a per-meter interval on the floor (Fig. 2-3). The subject stood on each reference point for 30 seconds, wearing the tag respectively in the following positions: on the head, on the shoulder and hanging on the neck horizontally (Fig. 2-4). Then the number of signals that were received by the readers in each respective position was counted. Though the reader could receive the most number of signals when the tag was hanging horizontally on the neck, in practice it is difficult to keep the tag horizontal during the survey. Thus, the author chose to fix it on the position close to the shoulder (such as on the collar) of the subject, in such a way that the readers can also receive most of the signals and it is convenient for the subject to wear continuously. The subject was asked to wear two tags on each side of the collar because depending on the relative position of the subject and the reader, it might become difficult for the reader to receive signals in some cases, and two tags may increase the probability to receive signals (Table. 2-1).

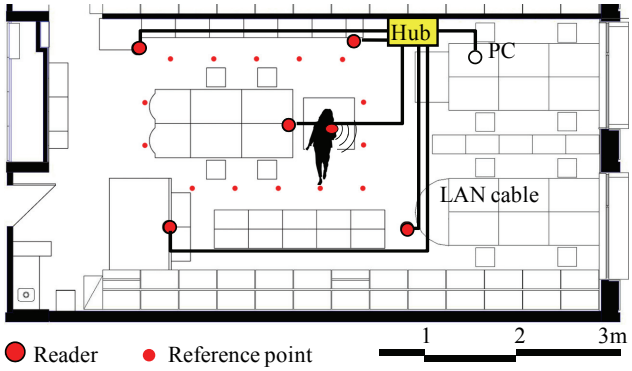


Figure 2-3 Composition of device in Experiment 1

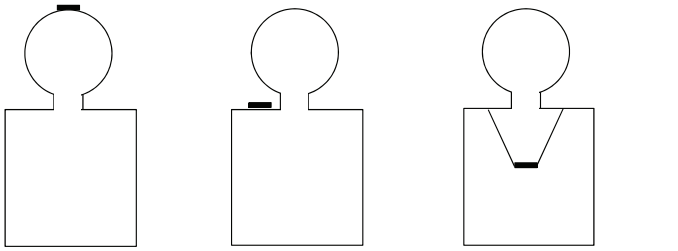


Figure 2-4 Wearing position of tags in Experiment 1

Table 2-1 The number of signals received in each position

Pk	Received signals (number/min)			
	On the head	On the left shoulder	Hanging on the neck Horizontally	On the right shoulder
160	51.6	59.1	59.1	59.1
170	30.4	48.7	60.0	57.3
185	1.1	38.0	59.1	44.0
Average	27.7	48.6	59.4	53.5

2) Experiment 2: Discussion on the detection range of the reader

The detection range of the reader could be adjusted by sensitivity parameter (Pk). When the Pk is set smaller, the sensitivity of the reader becomes high, and the detection range becomes larger. In experiment 2, the author attempted to clarify the detection range in different Pk, in the case that the tag and reader were in the same room.

A reader was installed in a room surrounded by concrete partitions, and reference points were pasted every 0.5 meter on the floor from the reader to the door (Fig. 2-5). Then wearing the tags, the investigator drew back from the reference point that was close to the reader, to that next to the door and recorded the distance when the reader failed to receive signals (Table 2-2).

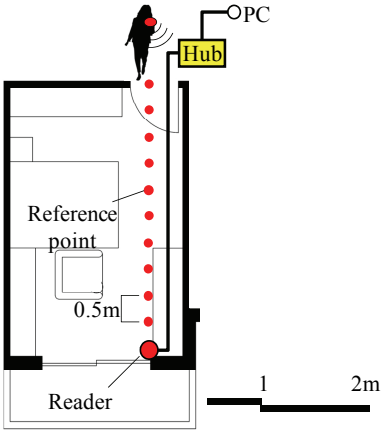


Figure 2-5 Composition of device in Experiment 2

Pk	Detection range
130	5m
150	4m
170	2.5m
190	1.5m

Table 2-2 Pk and detection range

3) Experiment 3: Discussion on the accuracy of reader

In experiment 2, the author clarified the relationship between the Pk and the detection range in a case that the tag and reader were in the same room. Then, experiment 3 was conducted to clarify the relationship between the Pk and the accuracy of location detection when there are multiple adjacent rooms installed with the readers.

In the adjacent two rooms, the readers were installed respectively at the same distance from the partition in between. In one of the rooms, reference points were pasted on a per-meter basis on the floor from the door to the reader (Fig. 2-6). Then under the setting of different Pk, the investigator wearing the tags stood at each reference point for 30 seconds and the number of received signals was recorded (Table 2-3). The proportion of received signals that correctly show the room in which the investigator stayed to all received signals in every minute (Accuracy) was calculated. Although there

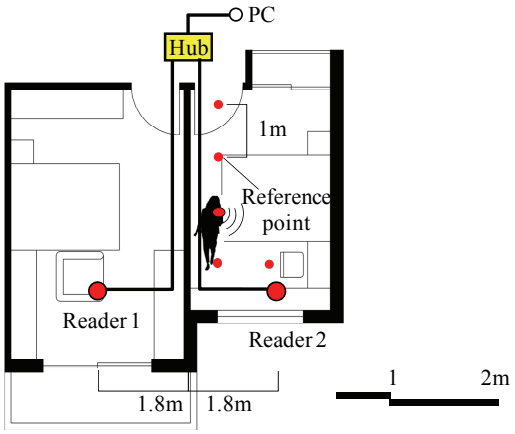


Figure 2-6 Composition of device in Experiment 3

Table 2-3 Pk and accuracy

Pk	Received signals (number/min)		Accuracy (%)
	Reader 1(a): cannot show the room of stay	Reader 2(b): can show the room of stay	
130	23.2	39.2	62.8
150	10.0	31.6	76.0
170	2.0	20.0	90.9
190	0.0	9.2	100.0

Accuracy=b/(a+b)x100%

was partition between the two readers, under a specific setting of Pk, the reader in the adjacent room in which the investigator did not stay might also receive signals from the tags, and thus there would be inaccurate location detection. However, the number of received signals per minute of the room where the tag was staying, was more than that of the adjacent room. In addition, the setting of a larger Pk for both of the readers could make their detection range become smaller and detect fewer signals, but the accuracy could be improved.

On the basis of the result of experiment 2 and 3, the devices were adjusted as follows:

① On the basis of the result of experiment 3, in order to improve the Accuracy of location detection in the subject house, the readers in adjacent rooms were located as far as possible from each other, so that the detection range of one reader would hardly extend to another room.

② On the basis of the result of experiment 2, a correct Pk of the reader was set according to the size of the room in order to limit the detection range inside the room in which the reader was installed.

③ Additionally, although the detection range was set carefully, the reader in the

adjacent room might receive signals sporadically, which were regarded as noise. According to the result of experiment 3, the author can sum up the number of signals from each room each minute and specify the room with the most signals as the room where the subject stayed.

2.2.3 Outline of the investigation

1) Investigation subject

An elderly woman, who lived alone and spent most of her time at home, was chosen as the subject. The basic information of the elderly subject and the house is shown by Table 2-4, figures 2-7 and 2-8.

Table 2-4 Basic information of the subject

Subject resident		House	
Gender	Female	Location	Kurashiki, Okayama, Japan
Age	63	Site area	327.1㎡
Years of living alone	3	Construction area	Total:125.9㎡. First floor:82.1㎡.
Health status	good	Completion	1993
Profession	Housewife	Structure	2 story house by wood

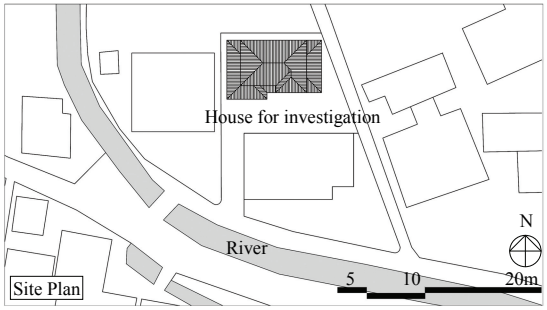


Figure 2-7 Site plan of surveyed house

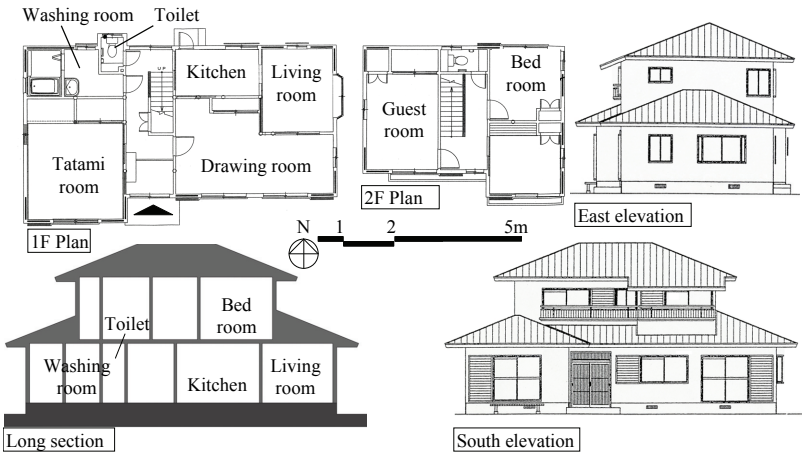


Figure 2-8 Plan, elevation and section of the house

2) Investigation Flow

According to a short interview with the elderly woman, the author had known she always uses the living room, kitchen, the washing room and the toilet on the first floor and the bedroom upstairs, and hardly uses other rooms. Thus, five readers were installed respectively in the above rooms (Fig. 2-9, Table 2-5). Then, the investigator wore the Active RFID tags, moved among the rooms and adjusted the Pk of each reader according to the size of the room. The author made sure that in most cases each reader could detect the tag in the room where it was installed, and meanwhile the other reader in the adjacent room could hardly detect this tag. Then, the investigation started after investigators left. The elderly woman wore two tags under her collars and the acceleration sensor between getting up and going to bed and lived as usual for eight days, from the 24th of June to the 1st of July, 2008.

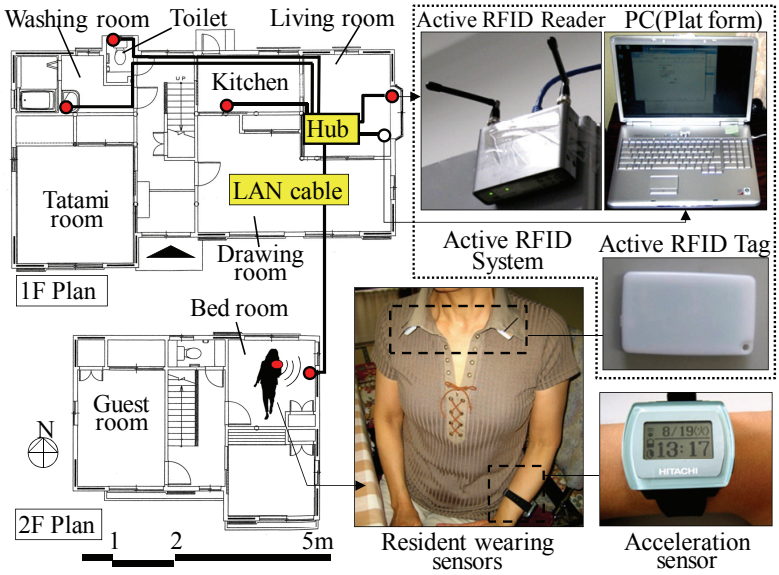


Figure 2-9 Configuration of device

Table 2-5 Basic information of the rooms and parameter settings of the reader

Floor	Room	IP address(Pk)	Fittings
1	Living room	192.168.1.102 (170)	TV set, Kotatsu with a hole in the floor
	Kitchen	192.168.1.103 (180)	Refridger,cupboard
	Toilet	192.168.1.104 (190)	Closestool
	washing room	192.168.1.105 (190)	Washer, washstand,closet
2	Bed room	192.168.1.106 (180)	Bookshelf,closet

2.3 Obtaining of time series data by Active RFID

2.3.1 The correction of data

According to the specific location of the subject, the reader in the adjacent room

might receive signals sporadically, which were regarded as noise. In order to reduce noise, RFID data was filtered every minute. The number of signals received by each reader in a minute was counted, and the room in which the reader received the most signals in a minute was specified as the subject's "staying room" in that minute (Fig. 2-10). In this paper, "staying" in a certain room does not mean the resident was absolutely stable in the room but that the resident was regarded to be inside the room in a particular minute. The "staying duration" in a certain room was the total number of minutes in the period from when the resident moved to the room until she moved to another room. Since the subject was healthy, it only took her several seconds to move from one room to another, so the duration of movement was not counted.

Moreover, there are some missing values in the data. Though the tag sent a signal every second, sometimes the reader failed to receive the signal when the subject with the tag kept still. Therefore, it needed to judge whether the resident was stable wearing the tags or had taken them off and forgotten to record why. The acceleration data helped to judge this and complete the missing information. If the acceleration data showed there was no walking, the missing values were filled by the same room prior to the missing values. If the acceleration data showed there was walking, the missing part was regarded as the period that the subject went outside of the detection range of the readers. (Fig. 2-11)

Before correction

Time	Counts of received signals in each room			Missing signals	Sum
	Living room	Kitchen	Dining room		
8:28:00	1	3	50	6	60
8:29:00		45	2	13	60

After correction

Time	Staying room
8:28:00	Dining room
8:29:00	Kitchen

Figure 2-10 Example of correction of data

Date and time	Staying room	Whether keep walking
2008/6/26 11:20	Living room	No
2008/6/26 11:21	Living room	No
2008/6/26 11:22	Living room	No
2008/6/26 11:23	Living room	No
2008/6/26 11:24	Living room	No
2008/6/26 11:25	Living room	No
2008/6/26 11:26	Living room	No
2008/6/26 11:27	Living room	No
2008/6/26 11:28	Living room	No
2008/6/26 11:29	Living room	No

Date and time	Staying room	Whether keep walking
2008/6/27 11:20	Living room	No
2008/6/27 11:21	Out	Yes
2008/6/27 11:22	Out	Yes
2008/6/27 11:23	Out	Yes
2008/6/27 11:24	Out	Yes
2008/6/27 11:25	Out	Yes
2008/6/27 11:26	Out	Yes
2008/6/27 11:27	Out	Yes
2008/6/27 11:28	Out	Yes
2008/6/27 11:29	Out	Yes

Figure 2-11 Complete the missing values

2.3.2 Time series data

After data correction, time series data could be expressed as illustrated in Fig.2-12. It showed the subject's movements and the time, duration, and room in which the subject stayed between rising in the morning and going to bed at night during the investigation period. The following analysis is based on the time series sequence.

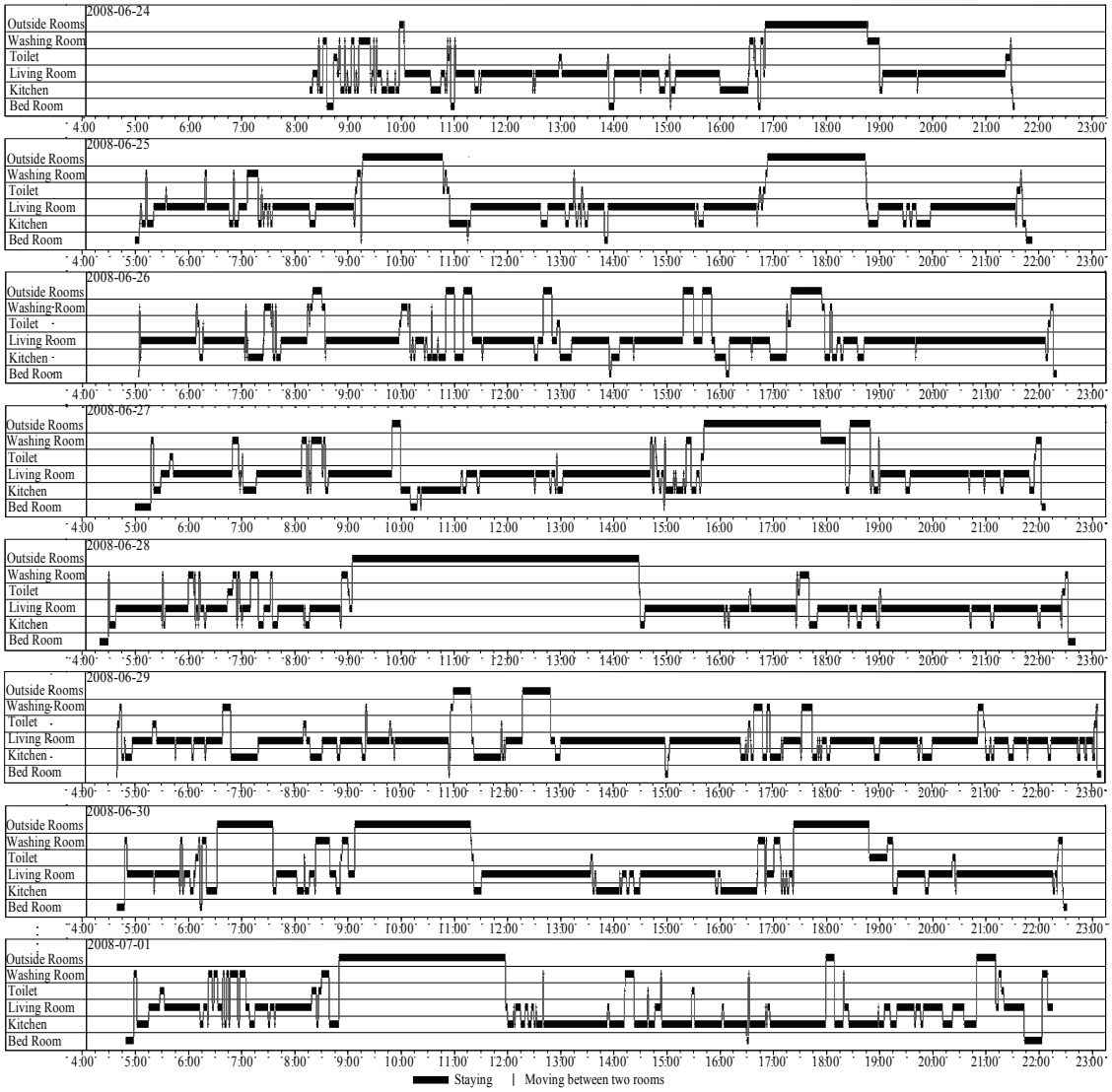


Figure 2-12 Time series data during waking hours from 24th Jun to 1st Jul

2.4 Discussion

2.4.1 Duration and frequency of stay in each room

Total duration and frequency of stay was calculated. The resident spent 82.2% of the time in the house and the remaining 17.8% outside the house. During the period in

the house, she spent most time in living room (67.6%) and stayed most frequently in the kitchen (36.4%). Although the total duration of stay in the washing room is only as many as 1/10 of the time spent in the living room, the frequency that she stayed in there is half as many as in the living room. The subject spent the shortest time in the bed room and toilet (Table 2-6, Fig. 2-13, 2-14).

Table 2-6 Total duration and frequency of stay

Min [times]

Date	In the house					Outside	Sum
	Bed room	Kitchen	Living room	Toilet	Washing room		
2008-06-24	25[6]	114[27]	465[28]	18[7]	53[17]	120[2]	795[87]
2008-06-25	19[5]	126[27]	616[27]	22[10]	29[11]	202[2]	1014[82]
2008-06-26	12[4]	153[29]	716[25]	18[9]	42[16]	97[7]	1038[90]
2008-06-27	34[5]	166[32]	575[27]	12[6]	77[13]	165[3]	1029[86]
2008-06-28	18[2]	72[25]	616[23]	20[8]	51[13]	324[1]	1101[72]
2008-06-29	10[4]	196[38]	785[38]	19[8]	49[10]	52[2]	1111[100]
2008-06-30	16[3]	158[29]	519[24]	36[9]	63[12]	279[3]	1071[80]
2008-07-01	32[3]	442[36]	267[30]	22[7]	64[15]	220[3]	1047[94]
Sum	166[32]	1427[243]	4559[222]	167[64]	428[107]	1459[23]	8206[691]
Average duration of stay in a day [Average frequency of stay in a day]	20.75 [4.00]	178.38 [30.38]	569.88 [27.75]	20.88 [8.00]	53.5 [13.38]	182.38 [2.88]	1025.75 [86.38]
Proportion of total duration of stay [Proportion of total frequency of stay]	82.2% [96.7%]					17.8% [3.3%]	100% [100%]
Proportion of total duration of stay in the house [Proportion of total frequency of stay in the house]	2.5% [4.8%]	21.2% [36.4%]	67.6% [33.2%]	2.5% [9.6%]	6.3% [16.0%]		

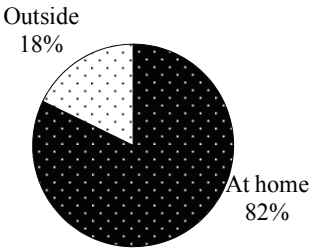


Figure 2-13 Proportion of Duration in the whole survey period

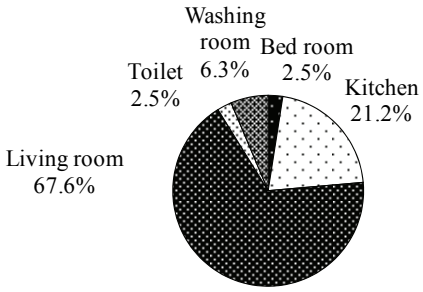


Figure 2-14 Proportion of Duration of stay in the house

Residents who have a routine for daily life might arrange their living activities by time, which might cause the variation of room use in each period of a day. In order to show this variation quantitatively, one day was divided into three time periods as follows:

1) Morning (getting up until 12:00)
2) Afternoon (from 12:00 till 19:00)
3) Evening (from 19:00 till going to bed)

The average duration of stay in each room per hour of the survey period was calculated. The subject stayed in the living room for the longest time during either period, and stayed there especially long in the evening (47.88min/hour), about 1.6 times as long as during the day. The living room and kitchen were the first and second rooms which the subject stayed in for long durations in either period. The summation of the average duration that the subject stayed in the two rooms occupied at least 40 minutes per hour in either time period. She stayed in the washing room longer than in the toilet and bedroom during the morning and afternoon, and stayed longer in the bedroom than in the toilet and washing room during the evening.

The average duration and frequency of stay per hour in each room was different by time period. Those were both largest during the evening and smallest during the afternoon in the bedroom. The subject stayed in the kitchen during the morning for over 1.2 times of the frequency per hour she stayed there in other periods, and she stayed there for the longest duration per time during the afternoon and for the shortest duration per time during the evening. In the living room, the average duration of stay per time was much longer during the evening than during the day. Conversely, the frequency of stay per hour was lower during the evening than during the day. In the toilet, the average duration per time was shortest during the morning, but the frequency of stay per hour was highest in the same time period. The subject tended to stay for a long time per hour in the washing room and stay in this room frequently during the morning, and stay in the room for a long time per time during the afternoon (Table 2-7, Fig. 2-15).

Standard deviation of the duration of stay per time in each room decreased in the following order: living room, kitchen, bed room, washing room and toilet. This might be because the subject did varied activities that took different amounts time in the living room, and repeated activities took similar time in functional rooms, such as in the toilet and washing room (Fig. 2-15).

Table 2-7 Total staying duration and frequency in each time period

	Period	Maximum duration of stay per time (Min)	Minimum duration of stay per time (Min)	Average duration of stay per time (Min)	Standard deviation	Total duration of stay (Min)	Average duration of stay per hour (Min)	Frequency of stay in the survey period (times)	Frequency of stay per hour (times per hour)
Bed room	Morning	18	1	5.33	5.05	80	1.48	15	0.28
	Afternoon	6	1	2.89	1.62	26	0.46	9	0.16
	Evening	20	3	7.50	5.32	60	2.25	8	0.30
	Whole day	20	1	5.19	4.64	166	1.21	32	0.23
Kitchen	Morning	45	1	4.84	6.54	523	9.66	108	2.00
	Afternoon	72	1	8.05	12.18	748	13.36	93	1.66
	Evening	16	1	3.69	3.50	156	5.85	42	1.58
	Whole day	72	1	5.87	8.97	1427	10.43	243	1.78
Living room	Morning	83	1	16.85	20.23	1612	29.79	91	1.68
	Afternoon	123	1	19.01	28.80	1671	29.84	91	1.63
	Evening	146	1	32.40	34.38	1276	47.88	40	1.50
	Whole day	146	1	20.54	27.30	4559	33.33	222	1.62
Toilet	Morning	6	1	2.40	1.48	72	1.33	30	0.55
	Afternoon	21	1	2.82	4.16	54	0.96	22	0.39
	Evening	5	1	2.75	1.36	41	1.54	12	0.45
	Whole day	21	1	2.61	2.67	167	1.22	64	0.47
Washing room	Morning	16	1	3.69	3.44	247	4.56	67	1.24
	Afternoon	28	1	4.83	5.97	137	2.45	29	0.52
	Evening	6	1	3.73	2.15	44	1.65	11	0.41
	Whole day	28	1	4.00	4.16	428	3.13	107	0.78

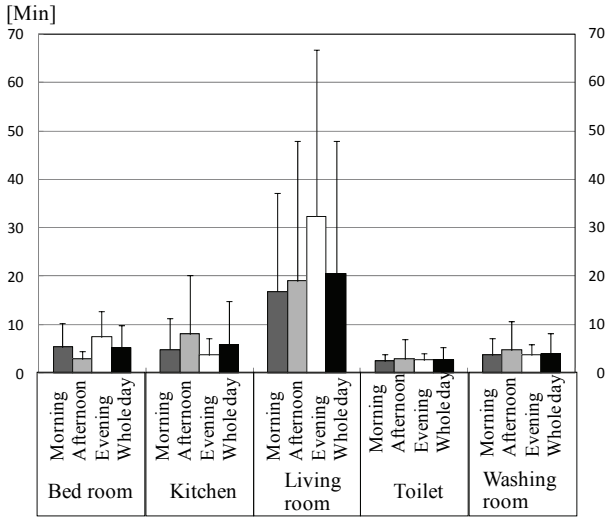


Figure 2-15 Average staying duration per time and staying frequency in each room in a day

2.4.2 Schedule of stay in the house and classification of the stay

In order to know the characteristics of the schedule of stay over the whole survey period, the probability of the subject's stay in each room was calculated during every half hour over one day. Since there were five rooms in the survey, if there was an equal

probability for the subject to stay in each room, the probability of stay in each room was 0.2. If the probability that the subject will stay in certain room is higher than 0.2 (1/5), it shows that the subject will more probably stay in this room than in at least one other room. In this way, the probability value is divided into five levels as below:

① (0, 0.2]: the probability that the subject stay in this room is low.

② (0.2, 0.25]: the probability that the subject will stay in this room more than in at least one other room

③ (0.25, 0.33]: the probability that the subject will stay in this room more than in at least two other rooms.

④ (0.33, 0.50]: the probability that the subject will stay in this room more than in at least three other rooms.

⑤ (0.50, 1]: the subject will stay most probably in this room.

Then, according to the combination of the probability of stay in the rooms during every given half hour, the stay in each room was classified as the followings:

① "Concentrated stay in one room": if there was only one room with a probability higher than 0.5 and there was no other room with a probability higher than 0.2 in a given half an hour, the stay during the period is classified as "Concentrated stay in one room". It showed the resident tended to stay in the room during the specific period.

② "Stayed in multiple rooms but tended to stay in one of them": if there was one room with a probability higher than 0.5 and there were other room (s) with a probability higher than 0.2 in a given half an hour, the stay during the period is classified as "Stayed in multiple rooms but tended to stay in one of them".

③ "Stayed in multiple rooms": if there was no room with a probability higher than 0.5, the tendency of this stay would be not as clear as the above types, and thus it is classified as "Stayed in multiple rooms".

The subject's stay was concentrated in one room or stayed in multiple rooms, but tended to stay in one of them during a certain period for 79% of the whole survey period, and stayed in multiple rooms in the remaining 21% of the time (Fig. 2-16). She tended to stay in the kitchen during the period of 10:30-11:00 and 17:00-17:30, and to stay in the washing room during 17:30-18:00. She tended to stay alternately in the living room and kitchen during the period of 7:00-7:30 and 16:30-17:00. The tendency of stay was not so clear during the period of 18:00-19:00 and the period before going to bed (table2-8).

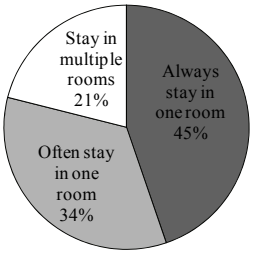
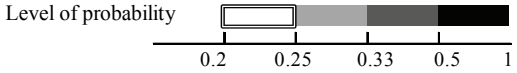


Figure 2-16 Proportion of room use types

Table 2-8 Probability of stay in certain room on a basis of per-30 minutes in a day

Period	Living room	Kitchen	Toilet	Washing room	Bed room	Tendency of stay
4:30-5:00	0.05	0.09	0.01	0.02	0.83	Always stay in one room
5:00-5:30	0.54	0.18	0.04	0.04	0.21	Often stay in one room
5:30-6:00	0.81	0.05	0.12	0.03	0.00	Always stay in one room
6:00-6:30	0.66	0.13	0.10	0.11	0.00	Always stay in one room
6:30-7:00	0.50	0.25	0.08	0.18	0.00	Stay in multiple rooms
7:00-7:30	0.36	0.44	0.04	0.16	0.00	Stay in multiple rooms
7:30-8:00	0.76	0.18	0.01	0.05	0.00	Always stay in one room
8:00-8:30	0.45	0.30	0.08	0.16	0.00	Stay in multiple rooms
8:30-9:00	0.59	0.17	0.10	0.13	0.01	Always stay in one room
9:00-9:30	0.58	0.17	0.08	0.16	0.01	Always stay in one room
9:30-10:00	0.56	0.35	0.06	0.03	0.00	Often stay in one room
10:00-10:30	0.81	0.11	0.02	0.04	0.01	Always stay in one room
10:30-11:00	0.35	0.56	0.05	0.04	0.00	Often stay in one room
11:00-11:30	0.58	0.40	0.00	0.01	0.02	Often stay in one room
11:30-12:00	0.72	0.26	0.02	0.00	0.00	Often stay in one room
12:00-12:30	0.79	0.21	0.00	0.00	0.00	Often stay in one room
12:30-13:00	0.62	0.35	0.03	0.00	0.00	Often stay in one room
13:00-13:30	0.66	0.29	0.04	0.01	0.00	Often stay in one room
13:30-14:00	0.79	0.09	0.03	0.01	0.08	Always stay in one room
14:00-14:30	0.85	0.09	0.01	0.02	0.04	Always stay in one room
14:30-15:00	0.80	0.17	0.01	0.02	0.00	Always stay in one room
15:00-15:30	0.68	0.27	0.01	0.04	0.00	Often stay in one room
15:30-16:00	0.82	0.16	0.02	0.00	0.00	Always stay in one room
16:00-16:30	0.62	0.37	0.00	0.00	0.00	Often stay in one room
16:30-17:00	0.42	0.33	0.08	0.15	0.02	Stay in multiple rooms
17:00-17:30	0.27	0.58	0.12	0.03	0.00	Often stay in one room
17:30-18:00	0.16	0.33	0.00	0.51	0.00	Often stay in one room
18:00-18:30	0.30	0.22	0.00	0.48	0.00	Stay in multiple rooms
18:30-19:00	0.27	0.30	0.22	0.21	0.00	Stay in multiple rooms
19:00-19:30	0.62	0.11	0.17	0.09	0.00	Always stay in one room
19:30-20:00	0.72	0.28	0.00	0.00	0.00	Often stay in one room
20:00-20:30	0.93	0.03	0.03	0.00	0.00	Always stay in one room
20:30-21:00	0.86	0.04	0.03	0.06	0.00	Always stay in one room
21:00-21:30	0.87	0.08	0.04	0.01	0.00	Always stay in one room
21:30-22:00	0.48	0.17	0.13	0.10	0.13	Stay in multiple rooms
22:00-22:30	0.13	0.15	0.18	0.19	0.36	Stay in multiple rooms
22:30-23:00	0.06	0.02	0.00	0.00	0.92	Always stay in one room
23:00-23:30	0.01	0.02	0.03	0.02	0.92	Always stay in one room



2.4.3 Movement frequency

Movement frequency (the number of movements between each pair of rooms per hour) was calculated. More than 40% of the movement frequency concentrated between the living room and kitchen in either period. The subject moved frequently between the kitchen and washing room during the morning (1.09 times / hour) and afternoon (0.52 times / hour). She moved frequently between the toilet and the washing room during the evening (0.38 times / hour) (Fig. 2-17).

The movement frequency increased between the living room and kitchen, and between the toilet and kitchen from the morning to the evening. Meanwhile, the movement frequency decreased between the living room and toilet, between the living room and washing room and between the washing room and kitchen.

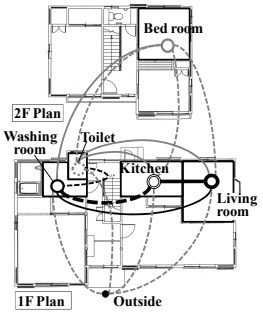
2.4.4 Characteristics of room use

Characteristics of room use comprised of stay and movement as shown in Fig 2-17. The subject tended to stay in the living room and kitchen, and to move between the two rooms in either period. The following room that had a high concentration of use was the washing room, which connected most frequently with the kitchen. Duration of stay in the washing room and movement frequency between this room and all the other rooms decreased from the morning to the evening.

Morning

Times/hour (percentage of movement frequency between the rooms)

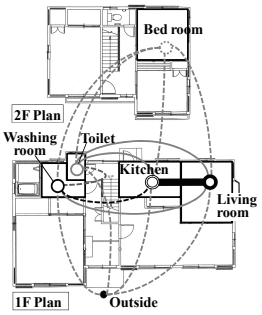
	Kitchen	Living room	Toilet	Washing room	Outside	Total movement frequency between the room and all the other rooms
Bed room	0.15(2.7)	0.02(0.3)	0.04(0.7)	0.22(4)	0	0.42
Kitchen	-	2.35(42.3)	0.26(4.7)	1.09(19.7)	0.15	3.84
Living room	-	-	0.39(7)	0.63(11.3)	0.09	3.38
Toilet	-	-	-	0.41(7.3)	0.04	1.09
Washing room	-	-	-	-	0.13	2.35



Afternoon

Times/hour (percentage of movement frequency between the rooms)

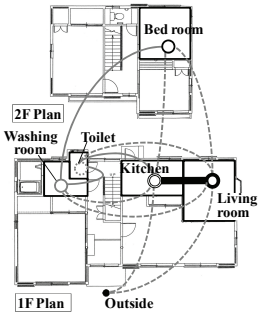
	Kitchen	Living room	Toilet	Washing room	Outside	Total movement frequency between the room and all the other rooms
Bed room	0.09(2.1)	0.14(3.4)	0.04(1)	0.05(1.3)	0	0.32
Kitchen	-	2.41(57.9)	0.27(6.4)	0.52(12.4)	0.07	3.29
Living room	-	-	0.25(6)	0.21(5.2)	0.18	3.02
Toilet	-	-	-	0.18(4.3)	0.05	0.73
Washing room	-	-	-	-	0.09	0.96



Evening

Times/hour (percentage of movement frequency between the rooms)

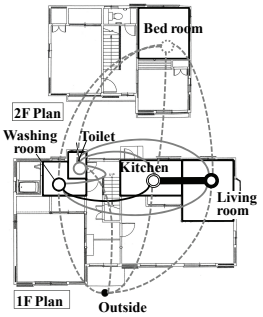
	Kitchen	Living room	Toilet	Washing room	Outside	Total movement frequency between the room and all the other rooms
Bed room	0.11(2.9)	0.04(1)	0(0)	0.19(4.8)	0	0.34
Kitchen	-	2.48(63.4)	0.3(7.7)	0.11(2.8)	0.04	3.00
Living room	-	-	0.19(4.9)	0.11(2.8)	0.04	2.82
Toilet	-	-	-	0.38(9.7)	0	0.87
Washing room	-	-	-	-	0	0.79



Whole day

Times/hour (percentage of movement frequency between the rooms)

	Kitchen	Living room	Toilet	Washing room	Outside	Total movement frequency between the room and all the other rooms
Bed room	0.12(2.6)	0.07(1.6)	0.03(0.6)	0.15(3.2)	0	0.37
Kitchen	-	2.4(51.3)	0.27(5.8)	0.67(14.3)	0.10	3.46
Living room	-	-	0.29(6.2)	0.36(7.7)	0.12	3.12
Toilet	-	-	-	0.31(6.7)	0.04	0.90
Washing room	-	-	-	-	0.09	1.49



Highest movement frequency
Second highest movement frequency
Third highest movement frequency

Movement frequency that increased from the morning to the evening
Movement frequency that decreased from the morning to the evening
Movement frequency that was similar in the morning and evening, and lowest in the afternoon

Movement frequency(Number/hour)
(0,0.2) [0.2,0.4) [0.4,0.6) [0.6,0.8)
[1.0,1.2) [2.2,2.4) [2.4,2.6)

Order of total duration of stay:
◎ > ◎ > ○ > ○ > ○

Figure 2-17 Movement frequency between the rooms and total duration of stay in certain room

2.5 Conclusion

In this chapter, the author showed a method to precisely identify the room use of one subject in the house. A series of survey methods was verified:

1) Wearing two tags on the collar may increase the probability of receiving signals, and ensure the subject is less burdened during a lengthy survey;
2) In order to improve the accuracy of location detection, readers in adjacent rooms should be located as far away as possible from each other, and the correct sensitivity parameter (Pk) of the reader should be set according to the size of room (e.g. 150 for a room of about 15 m^2);
3) The noise in the signals received could be reduced by summing up the number of signals from each room every minute and stating the room with the most signals as the room in which the subject stayed.

The characteristics of the room use of the subject during eight days were identified on the basis of the duration and frequency of stay in certain rooms, and the movement frequency between the rooms. The findings were shown as follows:

1) Throughout the whole survey period, the subject tended to stay most frequently (36% of the total frequency of stay) in the kitchen, but stayed for the longest duration (68% of the total duration of stay) in the living room. She moved most frequently (2.4 times per hour) between the living room and kitchen, and with the second highest frequency was between the kitchen and washing room (0.67 times per hour).

2) The average duration and frequency of stay in the rooms, and movement frequency between the rooms varied with time periods. The subject stayed in the kitchen and washing room during the morning over 1.2 times as frequently as in other periods, and she stayed in living room during the evening about 1.6 times as long as during the day. The movement frequency between the living room and kitchen and between the toilet and kitchen increased from the morning to the evening. Meanwhile, the movement frequency decreased between the living room and toilet, between the living room and washing room and between the washing room and kitchen from the morning to the evening.

3) The subject's stay was concentrated in one room or she stayed in multiple rooms but tended to stay in one of them during a certain period for 79% of the whole survey period. This showed that she had a specific schedule of stay in certain rooms for most of the day.

4) Taking both characteristics of stay and movement into account, it was clarified that, averagely, this subject aggregately stayed in the living room and kitchen for at least

40 minutes per hour, and moved between the two rooms for more than 40% of the total movement frequency between rooms in either time period.

In this chapter, the subject was found to stay longest in the living room, stay frequently in the kitchen, and move frequently between the two rooms. The above characteristics of stay in certain rooms and movement between the rooms were identified respectively.

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6) Atsushi Enta, Yuji Otsuka and Hitoshi Watanabe: Monitoring of Contact Behavior by using Ring-Tpe RFID Reader, J. Archit. Plann.Eviron.Eng., AIJ, No.646, pp2739-2744, 2009.12
7) Atsushi Enta, Kazuto Hayashida and Hitoshi Watanabe: Tracing of Human Walk by Using Slipper-Type RFID Reader. J. Archit. Plann.Eviron.Eng., AIJ,No.630, pp1847-1852, 2008.8

Chapter 3 Probabilistic Analysis of Room Use of the Elderly Living Alone in Detached House

3.1 Purpose

In chapter 2, the characteristics of the personal room use of a subject elderly was respectively identified by the duration of stay in certain rooms and the movement frequency among rooms, but a question was raised as to whether there is any relationship between these two factors. Because of the sensing technology, large amounts of room use data on a per-minute basis were obtained and this detailed data provided the possibility to explore more about this relationship.

This chapter focused on the complex relationship between duration of stay in certain rooms and in which room the subject stayed before or after this stay, which were associated with uncertainty, and a probabilistic model of data mining was said to be able to solve the similar problems[1) 2)]. Thus, the author chose to use the probabilistic model to analyze the data.

3.2 Method of data collection

3.2.1 Sensing devices

1) Active RFID devices

The components of the Active RFID devices were shown as follows:

① Active RFID tag (tag)
② Active RFID Reader (reader)
③ PC (platform)
④ LAN cable

The tag sent a signal with a unique ID on a per-second basis. Each reader was assigned a Static IP and installed in each room of the dwelling unit. LAN cables connected the PC and readers. The PC recorded the IP of the reader that had received signals from the tag, providing continuous data on when and in which room the subject was present.

2) Acceleration sensor

In order to fill in the missing values in the Active RFID data, the author also used an acceleration sensor that helped us judge whether the subject had moved. Fig. 3-1 shows the configuration of the device.

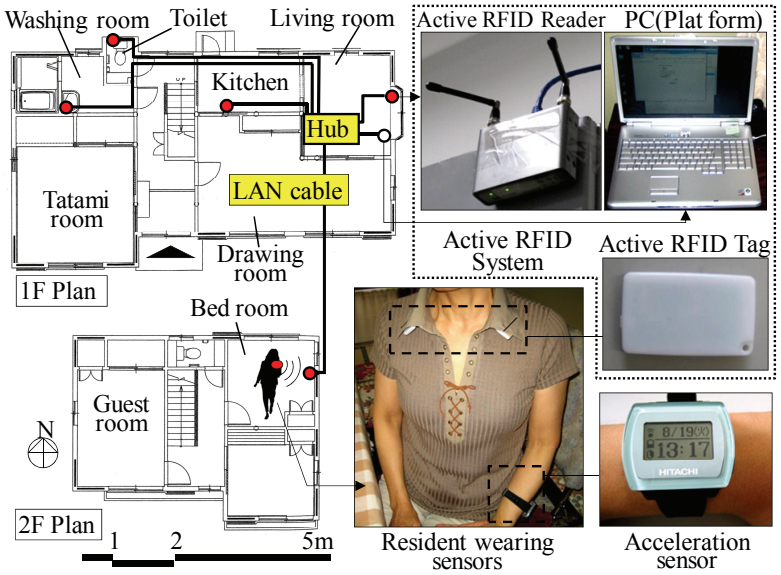


Figure 3-1 Configuration of device

3.2.2 Outline of the investigation

1) Investigation subject

An elderly woman, who lived alone and spent most of her time at home, was chosen as the subject. The basic information of the elderly subject and house is shown by Table 3-1, Fig. 3-2.

2) Investigation Flow

According to a short interview with the elderly woman, the author found that she always uses the living room, kitchen, washing room and toilet on the first floor in addition to the bedroom upstairs, and hardly uses the other rooms. Thus, five readers were installed respectively in the above rooms. Then, the investigator wore the Active RFID tags, moved among the rooms and adjusted the Pk of each reader according to the size of the room. The author made sure that in most cases each reader could detect the tag in the room where it was installed, and meanwhile the other reader in the adjacent room could hardly detect this tag. Then, the investigation started after investigators left. The elderly woman wore two tags under her collars and the acceleration sensor between getting up and going to bed and lived as usual for eight days, from the 24th of June to the 1st of July, 2008.

Table 3-1 Basic information of the subject

Subject resident		House	
Gender	Female	Location	Kurashiki, Okayama, Japan
Age	63	Site area	327.1㎡
Years of living alone	3	Construction area	Total:125.9㎡. First floor:82.1㎡.
Health status	good	Completion	1993
Profession	Housewif	Structure	2 story house by wood

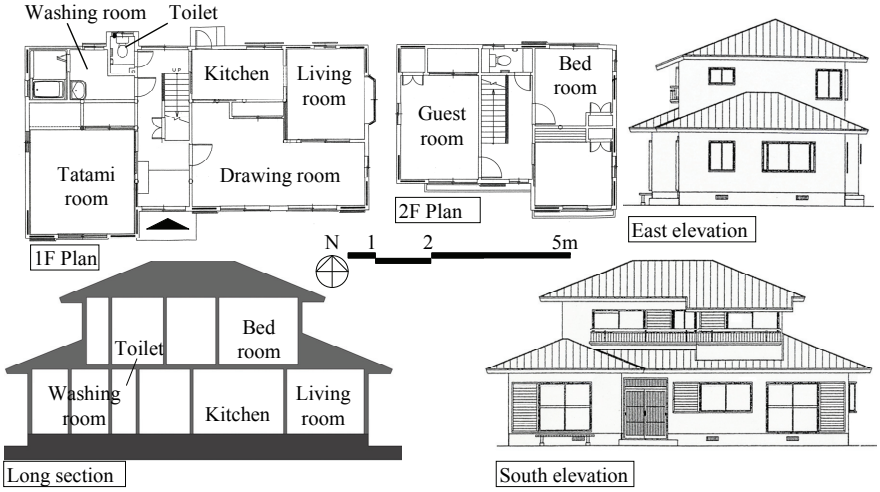


Figure 3-2 Plan, elevation and section of the house

3.3 Time series data obtained by Active RFID

After data correction, time series data could be expressed as illustrated in Fig.3-3. It showed the subject's movements and the time, duration, and room in which each subject stayed between rising in the morning and going to bed at night during the investigation period. The following analysis is based on the time series sequence.

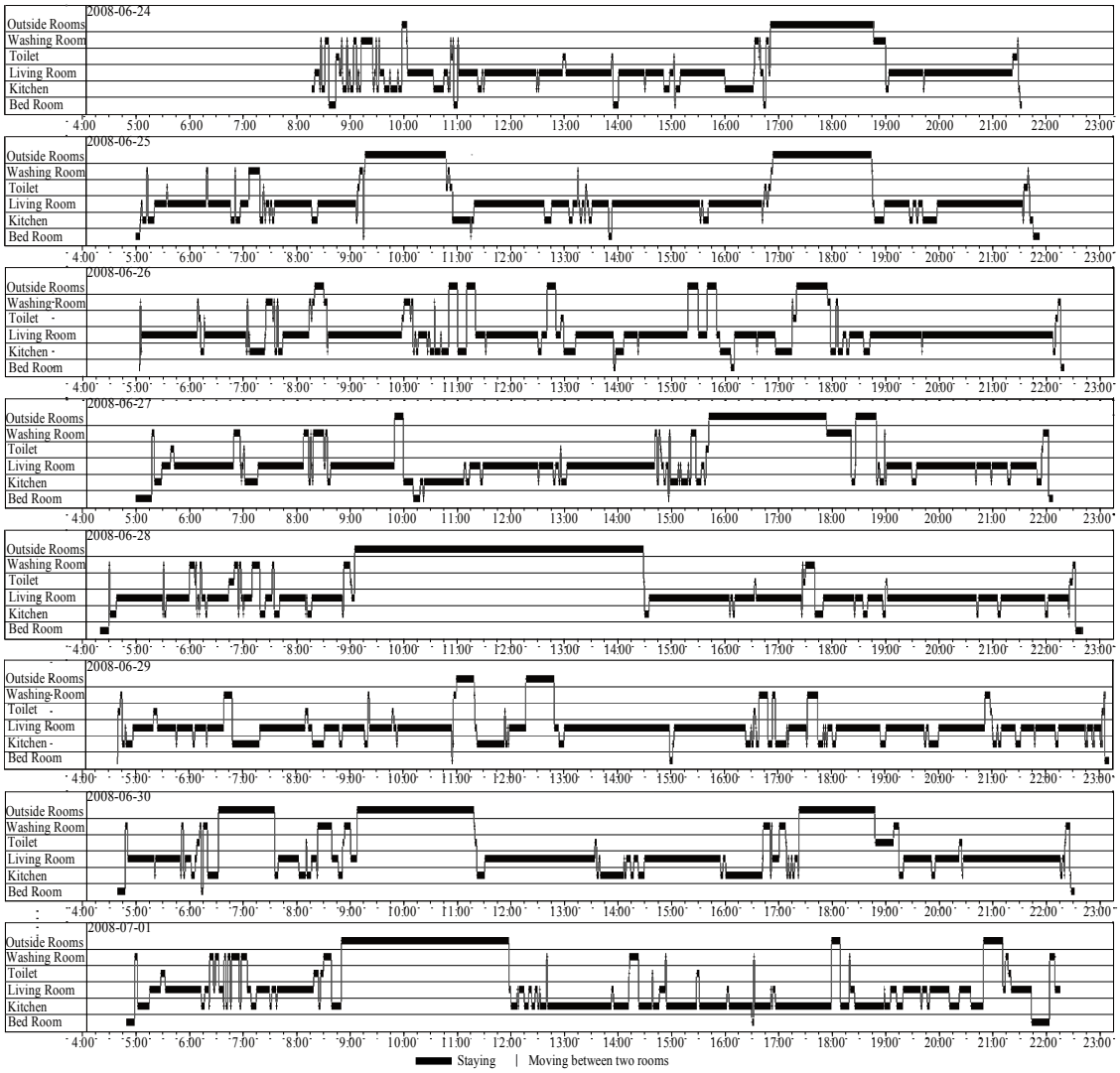


Figure 3-3 Time series sequence during waking hours from 24th Jun to 1st Jul

3.4 Probabilistic model built by Bayesian network

3.4.1 Bayesian network

Based on the introduction in reference 1), a Bayesian network is a directed and acyclic graph representing probability distributions. The network is composed of a set of nodes made up by variables, and directed arrows connecting pairs of nodes. If there is an arrow from node X to Y, X is called a parent of Y, which means X has a direct relationship with Y. This relationship is quantified by conditional probability distribution P(Y|X)(termed Probability Y given X).

Moreover, the joint probability distribution given more than one variables can be calculated by multiplying all the probabilities of variables given their parents, as

indicated in the following formula:

$$P(x_1,\ldots,x_n)= \prod_{i=1}^{n} P(x_i \mid \text{parents}(x_i))$$

The joint probability distribution of each note given all its parents is shown in a Conditional Probability Table (CPT) [1)].

3.4.2 Why Bayesian network was used

In probabilistic models, although full joint probability distribution may answer all the questions about variables (such as the probability that the subject moves from the living room to the kitchen, after staying in the living room for more than 60 minutes in the evening), the probability table may become quite large on the basis of the number of variables. For the purpose of this study, 5 nodes, which were *Period* (3 variables), *Previous room* (6 variables), *Present room* (6 variables), *Next room* (6 variables) and *Duration* (4 variables) would be set (Table 3-2 and 3-3), and the probability of each variable, given all the other variables needed to be specified. The full joint probability distribution would be represented as a 3×6×6×6×4 table with 2592 entries. In this probability table, many of the probability would be zero or quite little, since our database is not large enough. Therefore, instead of full joint probability distribution, the author used Bayesian Network, which can represent dependencies among variables and thus reduce the number of probabilities that need to be specified. In this way, the complex room use can be approximately described by a small model.

3.4.3 Database

This study aims to clarify the relationship among time, staying duration and moving order of the surveyed elderly. For the purpose of this study, corresponding nodes and variables in Bayesian network are determined (Table 3-2). A database including the information above is built (Table 3-3).

Table 3-2 Nodes and variables in Bayesian network

Factor	Items	Categories
Time	Node1: Period	Morning (rising~12:00), Afternoon (12:00~19:00) Evening (19:00~going to
Movement order	Node2: Present Room (Room/location where the elderly is staying)	Living Room Kitchen Washing Room Toilet Bed Room Outside Rooms
	Node3: Previous Room (Room/location that the resident stayed before moving to Present Room)	Living Room Kitchen Washing Room Toilet Bed Room Outside Rooms
	Node4: Next Room (Room/location that the resident stayed after leaving Present Room)	Living Room Kitchen Washing Room Toilet Bed Room Outside Rooms
Staying duration	Node5: Duration (staying duration in Present Room)	1-10(minutes) 10-30(minutes) 30-60(minutes) >60(minutes)

Table 3-3 Database

Period	Present Room	Previous Room	Next Room	Duartion (minute)
Morning	Living Room	Kitchen	Washing Room	1-10
Morning	Washing Room	Living Room	Bed Room	1-10
Morning	Bed Room	Washing Room	Toilet	1-10
⋮	⋮	⋮	⋮	⋮
Afternoon	Living Room	Kitchen	Kitchen	30-60
Afternoon	Kitchen	Living Room	Outside	1-10
⋮	⋮	⋮	⋮	⋮
Evening	Kitchen	Toilet	Bed Room	1-10

3.4.4 Building Model

Firstly, a lot of Bayesian network graphs were generated by searching methods or modified by hand in Weka-3-5*[1]. Then the models were evaluated by 10-fold Cross-validation*[2] and the model with highest correctly classified instance*[3] was chosen as the one for analysis (Fig. 3-4, Table 3-4).

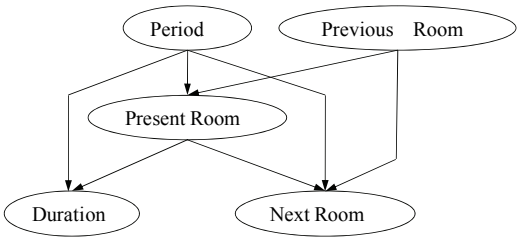


Figure 3-4 Network graph of the model

Table 3-4 Rate of correctly classified instance

	Duration	Present Room	Next Room
Correctly classified instances	74.21%	68.36%	58.57%
Incorrectly classified instances	25.79%	31.64%	41.43%

3.5 Analysis of room use based on a probabilistic model

3.5.1 Network graph of the model

According to the network graph of the model, *Present Room* related to *Period* and *Previous Room*. *Duration* related to *Period* and *Present Room*. The *Next Room* related to *Period*, *Present Room* and the *Previous Room*. There was no link between *Duration*, *Previous Room* and *Next Room*. It showed that the duration of stay in a certain room did not relate to which room the subject stayed before or after this stay, namely, the duration of stay in a certain room did not relate to the order of movement. (Fig. 3-4) .

3.5.2 Staying duration in each room

In either period, it was most probable for the elderly woman to stay for less than 10 minutes in the kitchen, toilet and washing room (the probability was higher than 0.75), but in the washing room, the probability of staying for 10 to 30 minutes increased in the afternoon (probability: 0.21, hereafter the number in the bracket refers to the probability).

In the living room, it was most probable for her to stay for less than 10 minutes in the afternoon (0.63). Though it was most probable for her to stay for less than 10 minutes in the morning (0.54), it was also probable for her to stay for 10-30 minutes during this period (0.26). It was most probable for her to stay there for 10-30 minutes in the evening (0.35), and it was also probable for her to stay even longer (probability of 30-60minutes: 0.21).

In the bedroom, it was most probable for her to stay for less than 10 minutes in the morning (0.73) and afternoon (0.85), and 10-30 minutes in the evening (0.52) (Table 3-5).

Table 3-5 Probability of *Duration* given *Period* and *Present Room* (for e.g., 0.26 in the row3, column 2 of the table, in the first table from the left, indicates that it is probable for the resident to stay between 10 to 30 minutes in 26 times out of 100 times she stayed in the living room in the morning.)

Morning		P(Duration | Period, Present Room)				Afternoon		P(Duration | Period, Present Room)				Evening		P(Duration | Period, Present Room)			
		1-10 (min)	10-30 (min)	30-60 (min)	> 60 (min)			1-10 (min)	10-30 (min)	30-60 (min)	> 60 (min)			1-10 (min)	10-30 (min)	30-60 (min)	> 60 (min)
Present Room	Bed Room	0.73	0.21	0.03	0.03	Present Room	Bed Room	0.85	0.05	0.05	0.05	Present Room	Bed Room	0.16	0.52	0.16	0.16
	Kitchen	0.84	0.11	0.04	0.01		Kitchen	0.78	0.13	0.06	0.03		Kitchen	0.86	0.12	0.01	0.01
	Living Room	0.54	0.26	0.13	0.07		Living Room	0.63	0.17	0.10	0.10		Living Room	0.28	0.35	0.21	0.16
	Toilet	0.94	0.02	0.02	0.02		Toilet	0.90	0.06	0.02	0.02		Toilet	0.88	0.04	0.04	0.04
	Washing Room	0.91	0.07	0.01	0.01		Washing Room	0.75	0.21	0.02	0.02		Washing Room	0.88	0.04	0.04	0.04
	Outside	0.12	0.42	0.04	0.42		Outside	0.04	0.42	0.19	0.35		Outside	0.16	0.52	0.16	0.16

3.5.3 Movement order

1) Probability level

With a given *Previous Room*, the probability distributes to the 6 variables (the living room, kitchen, toilet, washing room, bedroom and outside the rooms) in *Present Room*. If it distributes equally (probability=0.17=1/7), it means there is a probability that the subject will stay in either room. When one room's probability is more than 0.17, it means the subject is more probable to stay in this room than at least one of the other rooms. In this way, probability value is divided into six levels as below:

① Probability<0.17, the subject is more likely to stay in this room than none of the other rooms.

② 0.17<probability<=0.20, the subject is more likely to stay in this room than at least one of the other rooms.

③ 0.20<probability<=0.25, the subject is more likely to stay in this room than at least two of the other rooms.

④ 0.25<probability<=0.33, the subject is more likely to stay in this room than at least three of the other rooms.

⑤ 0.33<probability<=0.50, the subject is more likely to stay in this room than at least four of the other rooms.

⑥ 0.50<probability<=1, the subject is most likely to stay in this room.

The comparison of probability in the following analysis is based on the levels above.

2) Movement order between two rooms

The link and CPT among *Previous Room, Present Room* and *Next Room* showed

the relationship in connection to movement order. Characteristics of movement order between two rooms were shown by the probability of *Present Room* given *Previous Room**[4].

In either period, movements from the living room to the kitchen and movements from the kitchen to the living room kept a high probability. Movements from the toilet to the living room, from the toilet to the washing room, from the washing room to the kitchen, and from the bedroom to the washing room kept a probability higher than 0.17 in either period (Table 3-6)

In the evening, there were fewer movements with probability lower than 0.33, but the values of top level probabilities (0.50<probability<=1) were more than in other periods. It showed that the elderly woman was more inclined to move between certain fixed rooms in the evening.

No matter which period, most movements pointed to the living room, kitchen and washing room, which comprised the primary destination of movements in this house.

In the morning, there were more movements from other rooms with a probability higher than 0.17 to the kitchen than during the afternoon, but the value of the corresponding probability in the afternoon was higher than the morning. It showed movements to the kitchen were more diversified in the morning. There were more movements with probability higher than 0.17 to the living room in the afternoon than other periods. It showed movements to the living room were more diversified in the afternoon.

When the *Previous Room* was the living room or the kitchen, the most probable *Present Room* was the kitchen or the living room, and the probability increased from morning to the evening respectively (Probability of movement from the kitchen to the living room: 0.62(morning), 0.77(afternoon), 0.82 (evening). Probability of movement from the living room to the kitchen: 0.53(morning), 0.66(afternoon), 0.76 (evening)). It showed the connection between these two rooms became stronger from morning to the evening. In addition, according to the probability analysis, movements from the kitchen to the living room were more likely than the movements from the living room to the kitchen.

When the *Previous Room* was the living room or the kitchen, it was also probable for her to move to the washing room in the morning (Probability of movement from the kitchen to the washing room: 0.19, probability of movement from the living room to the washing room: 0.25).

When the *Previous Room* was the washing room, the most probable *Present*

Room was the kitchen in each period, and the probability was highest in the afternoon (0.52). When the *Previous Room* was the toilet, the most probable *Present Room* was the washing room in the morning and evening, and the kitchen in the afternoon. When the elderly woman was known to have stayed outside, she was likely to move to the washing room in the morning (0.38) and likely to move to the living room in the afternoon (0.34) and evening (0.35). When the elderly woman was known to have stayed at the bedroom, she was likely to move to the washing room in the morning (0.47) and evening (0.35), and she might go to the washing room, the living room or the kitchen in the afternoon (either probability was 0.29). (Table 3-6, Fig. 3-5)

Table 3-6 Probability of *Present Room* given *Period* and *Previous Room*

Morning	P(Present room | Period, Previous Room)					
Previous room	Bed room	Kitchen	Living room	Toilet	Washing room	Outside Rooms
Bed room	0.03	0.25	0.08	0.14	0.47	0.03
Kitchen	0.04	0.01	0.62	0.08	0.19	0.06
Living room	0.08	0.53	0.00	0.11	0.25	0.03
Toilet	0.02	0.21	0.32	0.02	0.41	0.02
Washing room	0.06	0.41	0.33	0.14	0.01	0.05
Outside Rooms	0.04	0.28	0.13	0.13	0.38	0.04

Afternoon	P(Present room | Period, Previous Room)					
Previous room	Bed room	Kitchen	Living room	Toilet	Washing room	Outside Rooms
Bed room	0.04	0.29	0.29	0.04	0.29	0.05
Kitchen	0.03	0.01	0.77	0.07	0.11	0.01
Living room	0.06	0.66	0.01	0.10	0.09	0.08
Toilet	0.10	0.32	0.27	0.02	0.19	0.10
Washing room	0.02	0.52	0.22	0.17	0.02	0.05
Outside Rooms	0.03	0.16	0.34	0.16	0.28	0.03

Evening	P(Present room | Period, Previous Room)					
Previous room	Bed room	Kitchen	Living room	Toilet	Washing room	Outside Rooms
Bed room	0.13	0.13	0.13	0.13	0.35	0.13
Kitchen	0.01	0.01	0.82	0.11	0.01	0.04
Living room	0.03	0.76	0.01	0.13	0.06	0.01
Toilet	0.03	0.09	0.28	0.03	0.54	0.03
Washing room	0.05	0.41	0.12	0.32	0.05	0.05
Outside	0.13	0.13	0.35	0.13	0.13	0.13

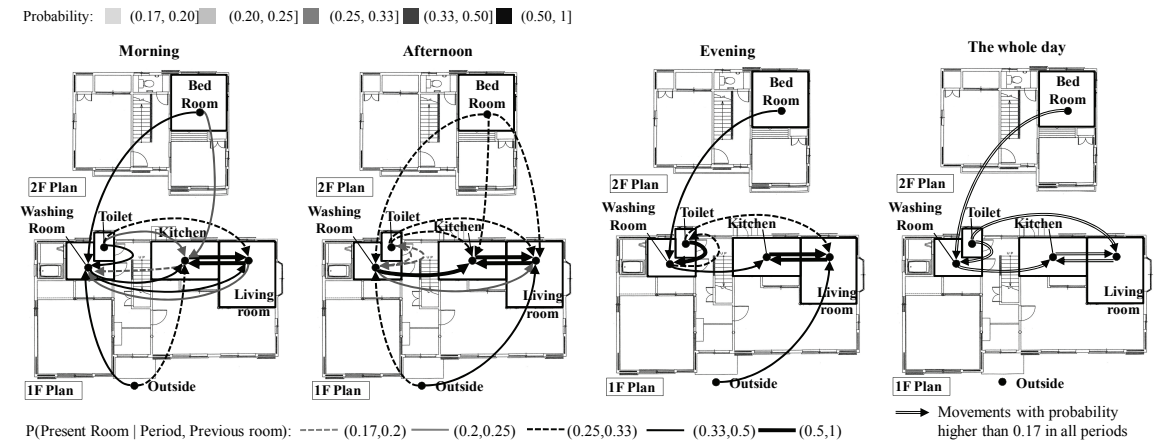


Figure 3-5 Movement from *Previous Room* to *Present Room* with relative high probability

3) Movement order among three rooms

Characteristics of movement order among three rooms were shown by Probability of *Next Room* given *Previous Room* and *Present Room*.

The round trip between the living room and the kitchen (living room→kitchen→ living room or kitchen→living room→kitchen) was obvious in any period and it becomes increasingly likely for the subject to move in this round trip from morning to evening. When the subject moves from the living room to the kitchen, the most probable *Next Room* was the living room(0.69(morning), 0.77(afternoon), 0.83

(evening)) and when she moves from the kitchen to the living room, the most probable *Next Room* was the kitchen (0.52(morning), 0.68 (afternoon), 0.78 (evening)).

In either period, when the elderly woman moved from any room to the kitchen, the most probable *Next Room* was the living room. When the elderly woman moved from any room to the living room, the most probable *Next Room* was the kitchen. But in the morning and afternoon, when she moved from the washing room to the kitchen or the living room, it was also probable for her to return to the washing room.

Moreover, in the morning, when she moved from the kitchen to the bedroom, she was very probable to return to the kitchen (0.60). In the evening, when she has moved from the living room to the toilet, the next most probable moving destination was the washing room (0.57), and it was also probable for her to return to the living room (0.19) (Table 3-7) .

3.6 Conclusion

In this chapter, the author analyzed the relationship among time, staying duration and movement order. The findings are as follows:

1) In the topology of the probabilistic model, *Present Room* related to *Period* and *Previous Room*. *Duration* related to *Period* and the *Present Room*. The *Next Room* related to *Period*, *Present Room* and Previous Room, and there was no link between *Duration* and *Next Room.* It showed that the duration of stay in a certain room did not relate to which room the subject stayed in before or after the present stay, namely, the duration of stay in a certain room did not relate to the order of movement.
2) The elderly woman was much more likely to stay for less than 10 minutes (probability>0.75) in the kitchen, toilet and washing room in either time period. She was likely to stay for less than 10 minutes in the living room and bed room during the day (probability>0.5), and to stay for more than 10 minutes during the evening. She was also likely to stay in the washing room for 10 to 30 minutes during the afternoon.

Table 3-7 Probability of *Next Room* given *Period*, *Present Room* and *Previous Room*

Morning		P(Next Room | Period, Previous room, Present room)					
Previous Room	Present Poom	Bed Room	Kitchen	Living Room	Toilet	Washing Room	Outside Rooms
Living Room	Kitchen	0.01	0.01	0.69	0.08	0.16	0.05
Kitchen	Bed Room	0.08	0.60	0.08	0.08	0.08	0.08
Washing Room	Kitchen	0.02	0.02	0.56	0.05	0.27	0.08
Washing Room	Living Room	0.02	0.56	0.02	0.10	0.25	0.05
Kitchen	Living Room	0.03	0.52	0.01	0.15	0.26	0.03
Living Room	Bed Room	0.04	0.14	0.14	0.14	0.50	0.04
Washing Room	Bed Room	0.07	0.07	0.07	0.21	0.51	0.07
Outside Rooms	Washing Room	0.07	0.07	0.51	0.21	0.07	0.07
Living Room	Toilet	0.04	0.17	0.46	0.04	0.25	0.04
Washing Room	Toilet	0.04	0.29	0.13	0.04	0.46	0.04
Toilet	Kitchen	0.15	0.05	0.45	0.25	0.05	0.05
Kitchen	Washing Room	0.07	0.43	0.33	0.07	0.03	0.07
Toilet	Living Room	0.04	0.42	0.04	0.04	0.35	0.11
Washing Room	Outside Rooms	0.08	0.08	0.08	0.25	0.43	0.08
Living Room	Washing Room	0.02	0.41	0.34	0.19	0.02	0.02
Bed Room	Washing Room	0.05	0.41	0.32	0.05	0.05	0.12
Bed Room	Living Room	0.13	0.35	0.13	0.13	0.13	0.13
Outside Rooms	Living Room	0.13	0.35	0.13	0.13	0.13	0.13
Outside Rooms	Toilet	0.13	0.13	0.13	0.13	0.35	0.13
Bed Room	Kitchen	0.21	0.07	0.37	0.07	0.21	0.07
Kitchen	Toilet	0.05	0.25	0.25	0.05	0.35	0.05
Toilet	Washing Room	0.22	0.34	0.16	0.16	0.03	0.09
Kitchen	Outside Rooms	0.06	0.31	0.31	0.06	0.20	0.06
Bed Room	Toilet	0.10	0.10	0.30	0.10	0.30	0.10
Living Room	Outside Rooms	0.08	0.26	0.08	0.25	0.25	0.08
Outside Rooms	Kitchen	0.25	0.08	0.26	0.08	0.08	0.25
Afternoon		P(Next Room | Period, Previous room, Present room)					
Previous Room	Present Poom	Bed Room	Kitchen	Living Room	Toilet	Washing Room	Outside Rooms
Living Room	Kitchen	0.04	0.01	0.77	0.08	0.08	0.02
Toilet	Kitchen	0.05	0.05	0.75	0.05	0.05	0.05
Kitchen	Living Room	0.06	0.68	0.01	0.09	0.09	0.07
Bed Room	Kitchen	0.08	0.08	0.60	0.08	0.08	0.08
Bed Room	Living Room	0.08	0.60	0.08	0.08	0.08	0.08
Washing Room	Kitchen	0.03	0.03	0.53	0.13	0.25	0.03
Toilet	Outside Rooms	0.10	0.10	0.10	0.10	0.50	0.10
Outside Rooms	Washing Room	0.07	0.51	0.21	0.07	0.07	0.07
Living Room	Outside Rooms	0.05	0.15	0.45	0.15	0.15	0.05
Outside Rooms	Living Room	0.06	0.44	0.06	0.19	0.06	0.19
Kitchen	Washing Room	0.04	0.42	0.27	0.19	0.04	0.04
Bed Room	Washing Room	0.08	0.43	0.25	0.08	0.08	0.08
Living Room	Washing Room	0.05	0.41	0.12	0.32	0.05	0.05
Kitchen	Toilet	0.05	0.39	0.17	0.05	0.17	0.17
Toilet	Living Room	0.05	0.39	0.05	0.28	0.17	0.06
Washing Room	Living Room	0.17	0.39	0.05	0.05	0.17	0.17
Kitchen	Outside Rooms	0.13	0.35	0.13	0.13	0.13	0.13
Living Room	Toilet	0.21	0.21	0.38	0.04	0.12	0.04
Washing Room	Outside Rooms	0.13	0.13	0.13	0.13	0.35	0.13
Toilet	Washing Room	0.07	0.37	0.21	0.07	0.07	0.21
Living Room	Bed Room	0.06	0.31	0.20	0.06	0.31	0.06
Washing Room	Toilet	0.06	0.19	0.19	0.06	0.31	0.19
Kitchen	Bed Room	0.10	0.10	0.30	0.10	0.30	0.10
Toilet	Bed Room	0.10	0.30	0.30	0.10	0.10	0.10
Outside Rooms	Kitchen	0.10	0.10	0.30	0.10	0.30	0.10
Outside Rooms	Toilet	0.10	0.30	0.10	0.10	0.30	0.10
Evening		P(Next Room | Period, Previous room, Present room)					
Previous Room	Present Poom	Bed Room	Kitchen	Living Room	Toilet	Washing Room	Outside Rooms
Living Room	Kitchen	0.01	0.01	0.83	0.10	0.01	0.04
Kitchen	Living Room	0.01	0.78	0.01	0.15	0.04	0.01
Living Room	Toilet	0.06	0.06	0.19	0.06	0.57	0.06
Kitchen	Toilet	0.07	0.07	0.21	0.07	0.51	0.07
Living Room	Washing Room	0.10	0.10	0.10	0.50	0.10	0.10
Toilet	Living Room	0.21	0.51	0.07	0.07	0.07	0.07
Washing Room	Toilet	0.08	0.25	0.43	0.08	0.08	0.08
Toilet	Washing Room	0.41	0.32	0.05	0.12	0.05	0.05
Bed Room	Washing Room	0.13	0.13	0.35	0.13	0.13	0.13
Kitchen	Outside Rooms	0.13	0.13	0.35	0.13	0.13	0.13
Living Room	Bed Room	0.13	0.13	0.13	0.13	0.35	0.13
Toilet	Kitchen	0.35	0.13	0.13	0.13	0.13	0.13
Washing Room	Living Room	0.13	0.35	0.13	0.13	0.13	0.13
Outside Rooms	Living Room	0.13	0.13	0.13	0.13	0.35	0.13
Washing Room	Kitchen	0.36	0.07	0.36	0.07	0.07	0.07

Probability:
(0.17, 0.20] (0.20, 0.25] (0.25, 0.33] (0.33, 0.50] (0.50, 1]

3) The living room, the kitchen and the washing room were the primary destination of movements in this house in either period. The subject was most likely to move between the living room and kitchen in each period, to move from the washing room to the kitchen during the afternoon and move from the toilet to the washing room during the evening (probability>0.5). The probability of movement between the living room and kitchen increased by 5% to 15% in every time period from the morning to the evening. Moreover, the subject was most likely to move from the kitchen to the living room and back to the kitchen, or move from the living room to the kitchen and then back to the living room in either time period. The probability of this movement also increased from the morning to the evening.

Since the findings showed the duration that the subject stayed in a certain room did not relate to which room she stayed in before or after the present stay, namely, the duration of stay in a certain room did not relate to the order of movement, the characteristics of duration of stay in a certain room and movement between rooms could be analyzed respectively, and a regular statistic method could be competent in doing this job. Thus, in the following chapters, the characteristics of duration of stay in a certain room and movement between rooms were analyzed respectively by a regular statistic method.

Notes

*1. WEKA is a collection of machine learning algorithms for data mining tasks. It is open source software.

*2. 10-fold Cross-validation is a technique for estimating the performance of a predictive model. It runs in the following ways (Referring to the introduction in reference 2):

(1) The data is divided into 10 partitions randomly

(2) Each part is held out in turn as test data and the learning scheme trained on the remaining nine-tenths (training data), then the error rate is calculated on the test data that is held out.

(3) The procedure is repeated 10 times and the results of these 10 evaluations are then aggregated to give overall cross-validation accuracy.

*3. Each instance is an individual, independent example of the concept to be learned. In other words, a row of data in the database is called an instance. The correctly classified instances of a Bayesian network model in 10-fold Cross-validation are calculated as

follows: in each of the 10 estimates, probability distribution is calculated based on nine-tenths of the data, and any instance in the test data to which the actual class is assigned a highest probability in the training data will be regarded as a correctly classified instance.(for e.g., if the *Present Room* is most probable to be the washing room when the *Previous Room* is the toilet during the morning according to the training data, then instances in the test data comprising (a) *Present Room:* the washing room, (b) *Previous Room:* toilet and (c) *Period*: morning are correctly classified instances, and other instances comprising the same (b) and (c), but different (a) are regarded as incorrectly classified instances) Then the procedure is repeated 10 times and the proportion of the overall correctly classified instances in all the instances is calculated as a correctly classified instance rate.

*4. Characteristics of movement order between two rooms could be shown by either the probability of *Present Room* for a given *Previous Room*, or the probability of *Next Room* for a given *Present Room*, which were two values that were almost the same. Thus, the author only analyzed the probability of *Present Room* for a given *Previous Room.*

References

1) Stuart J. Russell, and Peter Norvig: Artificial intelligence: a modern approach, 2nd ed, Prentice Hall, 2003
2) Ian H. Witten, Eibe Frank: Data mining: practical machine learning tools and techniques, 2nd ed, Morgan Kaufmann Publishers, 2005

Chapter 4 Elderly Couples' Room Use in Chinese Urban Apartment Houses

4.1 Purpose

The purpose of this chapter is to quantitatively identify the personal room use of Chinese elderly couples living in urban apartment houses in their daily life*[1] between rising in the morning and going to bed at night. the author precisely measured the room use of six ordinary elderly couples living in two typical dwelling unit types in the urban apartment houses of North China.

The author chose two typical types of dwelling units because the author were interested in ascertaining whether any relationship existed between the room layout and room use pattern observed in multiple cases. In order to study the factor of room use, the author focused on the duration of the couples' stay in certain rooms and their movement frequency between rooms for purposes other than to perform specific daily routine activities. Every couple was studied individually. A resident's room use is said to be concentrated in a certain room if he/she stays in the room for long durations, and from the same point of view, the fact that a resident moves frequently between two rooms shows the presence of a strong link between the rooms.

Therefore, the author attempted to clarify the characteristics of room use by identifying the following: (i) the room wherein the couples stayed for the longest duration (base), and (ii) the route between the pair of rooms that they passed through most frequently (main link) by continuously recording the elderly couples' stay in certain rooms and movement between the rooms in their daily life through Active RFID devices. The bases and main links during each time period (morning, afternoon and evening) were identified. Then, on the basis of the base and main link findings, the author interviewed the subjects to identify their specific needs regarding the room layout.

The author was interested in the following questions:

1) Which room is the base? Which rooms are linked by the main link? Which room(s) had a main link with most rooms (hub) for a specific couple?
2) Is the base identified by objective observation the same as the base self-identified by elderly couples?
3) Do they use the bases together or use them alone?
4) What is the relationship between the base and the hub of a couple?

4.2 Method of data collection

4.2.1 Sensing devices

1) Active RFID devices

The components of the Active RFID devices were as follows:

① Active RFID Tag (tag)

② Active RFID Reader (reader)

③ PC (platform)

④ Wireless Ethernet Converter (converter)

The tag sent a signal with a unique ID on a per-second basis. Each reader was assigned a Static IP and installed in each room of the dwelling unit. The converter connected the PC and readers though a wireless LAN. The PC recorded the IP of the reader that had received signals from the tag, providing continuous data on when and in

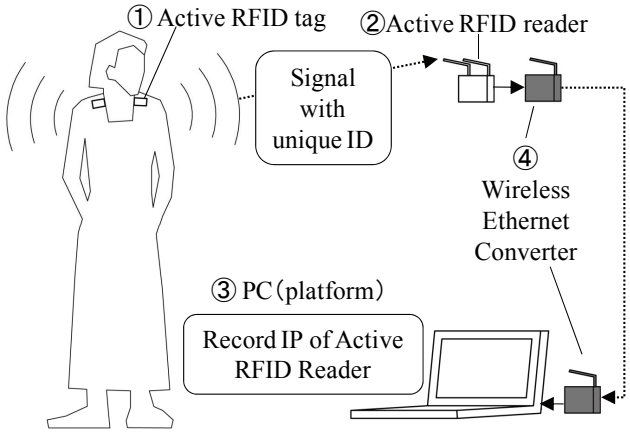


Figure 4-1 Composition of Active RFID devices

which room the subject was present. (Fig. 4-1)

2) Acceleration sensor

In order to fill in the missing values in the Active RFID data, the author also used an acceleration sensor that helped us judge whether the subject had moved. Figure 4-2 shows the configuration of the device.

4.2.2 Investigation subjects and period

The investigation was conducted in Tangshan*[2] and Beijing, two large cities in North China. For our study, the author chose dwelling units from the two dwelling unit types that are typically found in the apartment houses in North China: (i) the one with a

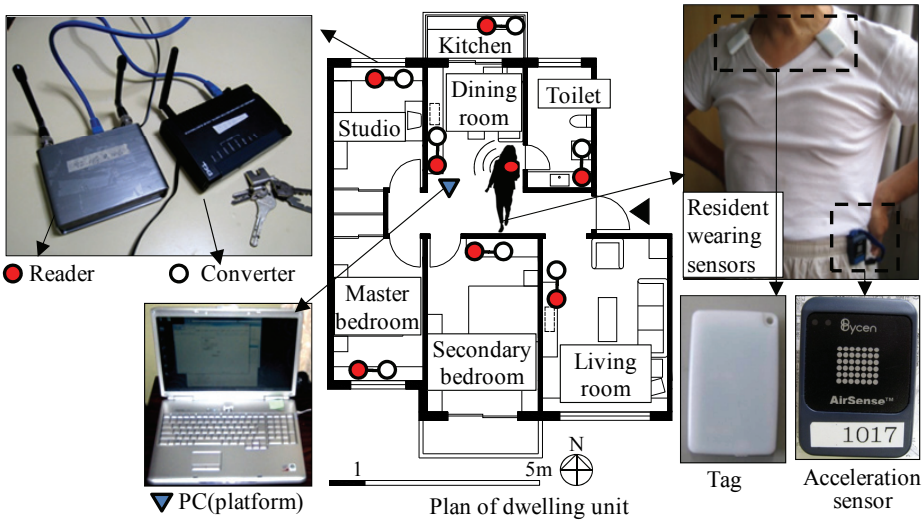
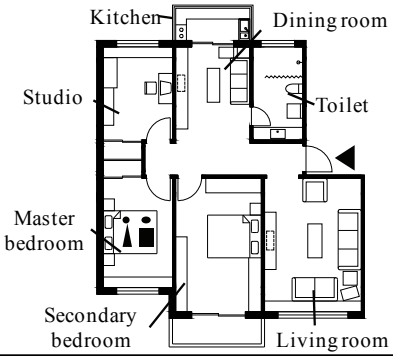
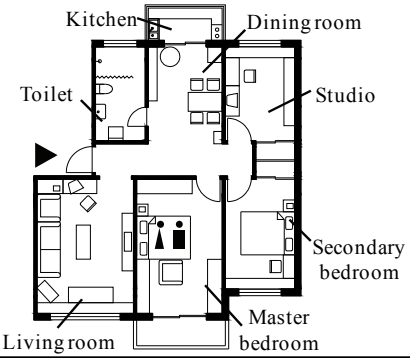
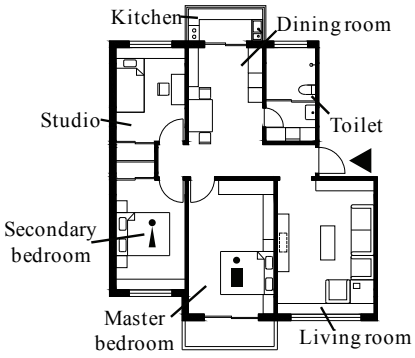
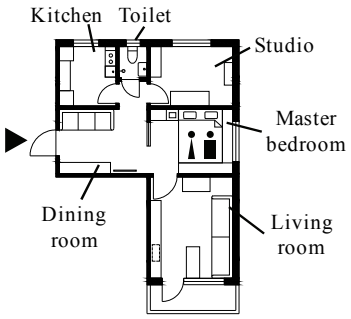
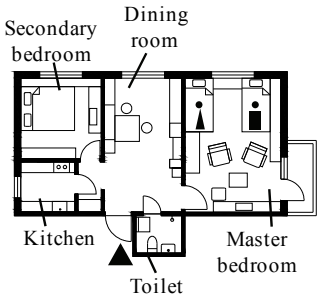
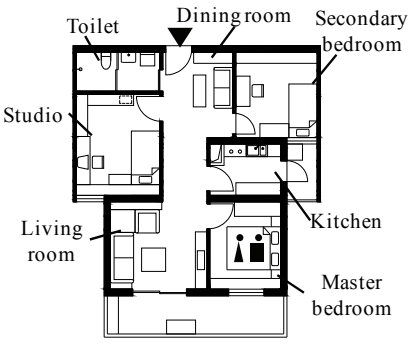


Figure 4-2 Configuration of device

small entrance hall (case A–C), and (ii) the one comprising a combined entrance hall and dining room (case D–F). The subjects of our study were six average, healthy, elderly couples, all over the age of 60 and living in the dwelling unit types described above (Fig. 4-3).

Each surveyed room was named on the basis of the subjects' description of its main function. The subjects received visitors and watched TV in the living room. The dining room was where they daily had dinner by themselves or with guests. In the case of most of the couples living in two bedroom apartment houses, the couple slept in the master bedroom at night while the secondary bedroom was used as a guest room. Couple C, however, slept in separate bedrooms. The author called the larger room—where the husband slept—the master bedroom, and the smaller one—where the wife slept—the secondary bedroom. The room having a bookshelf or PC, where the residents might read, nap, or do other activities, was designated as the studio. The toilet was the room comprising a close stool, washbasin, and shower nozzle. Some apartment houses also had a washer inside the toilet, thus making it a room for carrying out housework. The balcony was considered a part of the adjacent room through which it could be accessed *[3].

Couple A / At Tangshan	Couple B /At Tangshan
	
Area: 82.9m^2. 2nd fl/6 fls. Completion: 2000	Area: 82.9m^2. 3rd fl/6 fls. Completion: 2000
Husband: (61) Retired. Wife: (60) Part-time job Moved in: 2001. Started living by themselves: 2008	Husband: (60) Retired. Wife: (61) Retired Moved in: 2002. Started living by themselves: 2000
Survey period: 2009/6/20 19:50 - 6/23 19:50	Survey period: 2009/6/29 8:00 - 7/1 21:40
Couple C / At Tangshan	**Couple D / At Tangshan**
	
Area: 82.9m^2. 3rd fl/6 fls. Completion: 2000	Area: 42.4m^2. 2nd fl/6 fls. Completion: 1979
Husband: (70) Part-time job. Wife: (69) Retired Moved in: 2002. Started living by themselves: 2002	Husband: (73) Retired. Wife: (71) Retired Moved in: 1980. Started living by themselves: 1995
Survey period: 2009/7/3 8:00 - 7/5 16:00	Survey period: 2009/6/25 17:40 - 6/28 17:00
Couple E / At Beijing	**Couple F / At Beijing**
	
Area: 50.1m^2. 2nd fl/9 fls. Completion: 1984	Area: 66.3m^2. 15th fl/18 fls. Completion: 2000
Husband: (79) Retired. Wife: (80) Retired Moved in: 1986. Started living by themselves: 1994	Husband: (73) Retired. Wife: (79) Retired Moved in: 2000. Started living by themselves: 2000
Survey period: 2009/7/18 11:00 - 7/21 8:00	Survey period: 2009/7/21 10:30 - 7/24 16:40

Husband's bed room Wife's bed room The area refers to the area of usable living space 1 5m N

The dwelling plans above only show the layout and approximate size of the furniture based on the photos shot in the families studied. They did not show plants, dolls and decorations.

Figure 4-3 Basic information about the surveyed elderly couples and their dwelling units.

4.2.3 Investigation flow

1) The aforementioned readers were installed in every room of the dwelling unit.

2) The investigators wore the tags, moved among the rooms, and adjusted parameters of the devices to ensure the devices correctly recorded when and in which room the tag was.

3) Investigator instructed the residents when and how to wear the tags and acceleration sensors.

4) The investigation started after the investigators left. The residents wore the tags and acceleration sensors between getting up and going to bed when staying inside the house. They also recorded when and why they took the device off (going out, having a shower, and so on).

5) The investigation lasted three to four days and ended when the investigator retrieved the devices. A short interview was conducted. Each subject was asked which room or rooms he/she stayed in for the longest time, according to their memory.

4.2.4 Time series data

After correcting the Active RFID data*[4], a time series database was obtained. It showed the subject's movements and the time, duration, and room in which each subject stayed during the investigation period (Table 4-1, Fig. 4-4). In this study, the "staying duration" in a certain room was measured by the total number of minutes from when the resident entered the room until he/she entered another room."Movement" denotes a change of room. All the subjects took only a few seconds to move from one room to another, and so this duration was not counted*[5].

Table 4-1 Time series database

Serial number (i)	Date&Time to start staying (t_i)	Period	Gender	Couple	Room to stay	Staying duration[min] (t_{i+1}-t_i)	Rooms that the subject moved in between (In no particular order)
…	……	……	……	……	……	……	……
12	2009/7/22 7:46	Morning	man	F	Master bedroom	1	Toilet&Master bedroom
13	2009/7/22 7:47	Morning	man	F	Living room	43	Master bedroom&Living room
14	2009/7/22 8:30	Morning	man	F	Master bedroom	2	Master bedroom&Living room
…	……	……	……	……	……	……	……

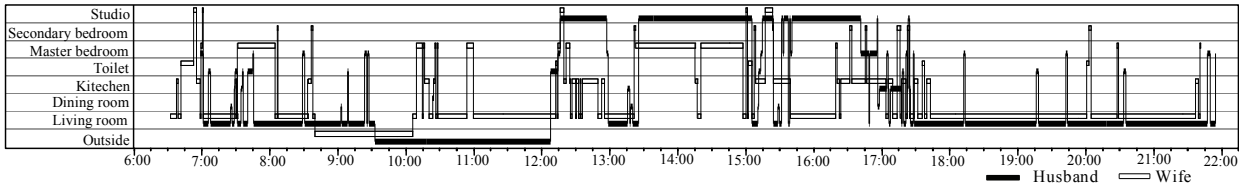


Figure 4-4 Time series graph, which shows when and in which room each of the subjects of couple F was staying on July 22nd.

Additionally, residents who had set a routine for their daily life tended to arrange their living activities by time, which could have caused a variation in the room use in each period of a day. In order to show this variation, each day was divided into morning (time of waking until 12:00), afternoon (from 12:00 till 19:00), and evening (from 19:00 till bed time).

4.3 Obtaining of base and main link for each subject in each period

The proportion of the total staying duration (P_T) in each room and movement frequency between every pair of rooms (P_M) for a given subject in a given period was calculated as below:

$$P_T[\%] = \frac{T_i}{\sum_{i=1}^{R} T_i} \times 100 \quad \text{.....(1)} \qquad P_M[\%] = \frac{M_j}{\sum_{j=1}^{C_2^R} M_j} \times 100 \quad \text{.....(2)}$$

T_i: Total staying duration of a given person in a given room (i) in a given period in the whole investigation period (3–4 days)

R: Total number of rooms in a given dwelling unit

M_j: Total movement frequency between given pair of rooms (j) for a given subject in a given period in the whole investigation period (3–4 days)

Although the author could have just appointed the room with the highest P_T as the base in the period, there were also some cases where the second highest P_T was very close to the highest one. Thus, the author set several intervals according to the relative ratio for a given number of factors, and appointed all the rooms with P_T in the highest interval as the base. For example, if a house had n rooms, when the proportion of staying duration was 100/n in each room, it meant the resident spent the same amount of time in each room. When the staying duration in one room was more than 100/n, it meant that the resident spent more time in this room than in at least one other room. In this way, the proportion (%) was divided into n intervals as below:

1) (0, 100/n]: Resident spent relatively little time in this room.
2) (100/n, 100/(n-1)]: resident spent more time in this room than in at least one other room.

⋮

n-1) (100/3, 100/2]: resident spent more time in this room than in at least (n-2) other rooms.

n) (100/2, 100]:resident spent most time in this room.

In the same way, the author defined the link(s) with the highest level of P_M as the main link(s). For example, take a dwelling unit with seven rooms. As there are 21 possible links between every pair of rooms, if a P_M is in the interval of (33.3, 50.0], it means this link is stronger than at least 19 other links. Tables 4-2 and 4-3 show a sample of how the author determined the bases and main links for the husband in couple F, and Fig. 4-5 shows the pattern of the bases and main links of each subject in each period.

Table 4-2 Total duration of stay and P_T for husband of couple F throughout the survey period

	Total staying duration[min](P_T[%])						
	Living room	Dining room	Master bedroom	Secondary bedroom	Studio	Kitchen	Toilet
Morning	373(58.6)*	19(3.0)	22(3.5)	0(0)	171(26.9)	21(3.3)	30(4.7)
Afternoon	469(43.0)*	24(2.2)	65(6.0)	5(0.4)	463(42.4)*	37(3.4)	28(2.6)
Evening	377(92.0)*	0(0)	6(1.4)	0(0)	0(0)	7(1.7)	20(4.9)

*: Base

Table 4-3 Movement frequency and P_M for husband of couple F in the morning throughout the survey period

	Movement frequency between pair of rooms(P_M[%])					
	Dining room	Kitchen	Toilet	Master bedroom	Secondary bedroom	Studio
Living room	16(16.7)	11(11.5)	20(20.8)*	18(18.8)	0	11(11.5)
Dining room	—	1(1.0)	1(1.0)	3(3.1)	0	3(3.1)
Kitchen	—	—	3(3.1)	1(1.0)	0	0
Toilet	—	—	—	2(2.1)	0	2(2.1)
Master bedroom	—	—	—	—	0	4(4.2)
Secondary room	—	—	—	—	—	0
Sum						96(100)

*: Main link

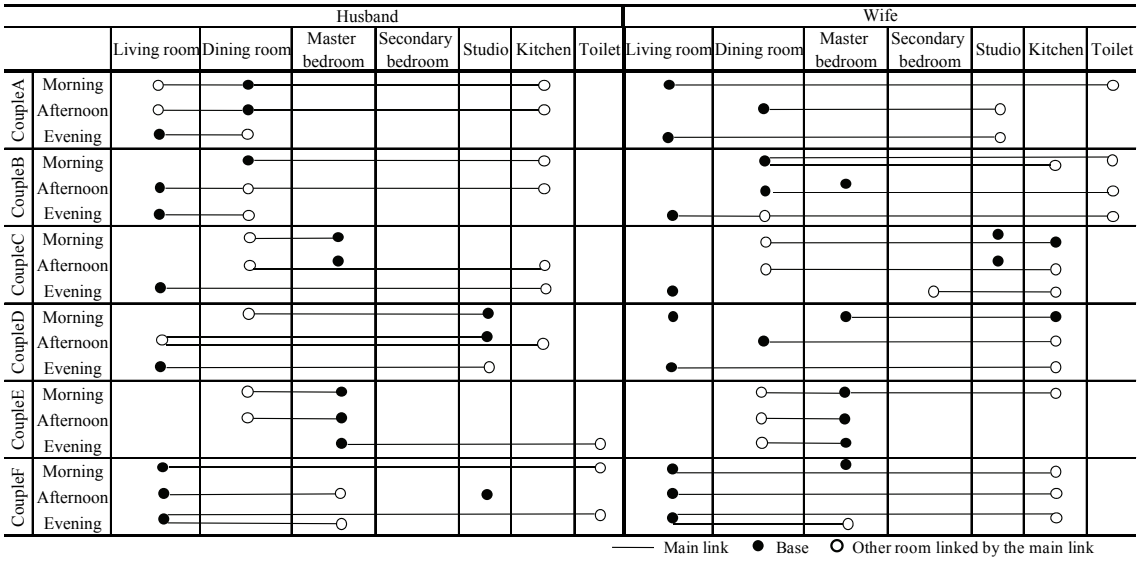


Figure 4-5 Pattern of the bases and main links of each subject in each period

4.4 Findings about the base

The total duration of stay, P_T and bases of all the subjects were shown in Table 4-4.

Table 4-4 Total duration of stay, P_T and bases of all the subjects

		Total staying duration of husband [min] (%)						
		Living room	Dining room	Master bedroom	Secondary bedroom	Studio	Kitchen	Toilet
Couple A	M.	115(18.6)	298(48.2)*	0(0)	40(6.5)	9(1.5)	113(18.3)	43(6.9)
	A.	370(29.1)	455(35.8)*	169(13.3)	49(3.8)	16(1.2)	137(10.8)	76(6.0)
	Evg.	372(82.3)*	45(10.0)	0(0)	14(3.1)	7(1.5)	5(1.1)	9(2.0)
	Sum	857(36.6)*	798(34.0)*	169(7.2)	103(4.4)	32(1.4)	255(10.9)	128(5.5)
Couple B	M.	127(31.3)	200(49.3)*	15(3.7)	1(0.2)	2(0.5)	35(8.6)	26(6.4)
	A.	454(59.0)*	215(28.0)	8(1.0)	1(0.1)	3(0.4)	72(9.4)	16(2.1)
	Evg.	392(79.9)*	56(11.4)	3(0.6)	0(0)	0(0)	3(0.6)	37(7.5)
	Sum	973(58.4)*	471(28.3)	26(1.6)	2(0.1)	5(0.3)	110(6.6)	79(4.7)
Couple C	M.	10(1.8)	61(10.9)	296(53.0)*	4(0.7)	66(11.8)	46(8.2)	76(13.6)
	A.	48(5.1)	124(13.1)	480(50.8)*	114(12.0)	11(1.2)	146(15.5)	22(2.3)
	Evg.	232(62.5)*	11(3.0)	52(14.0)	0(0)	7(1.9)	40(10.8)	29(7.8)
	Sum	290(15.5)	196(10.4)	828(44.2)*	118(6.3)	84(4.5)	232(12.4)	127(6.7)
Couple D	M.	281(22.7)	137(11.0)	43(3.5)	——	713(57.5)*	36(2.9)	30(2.4)
	A.	182(14.3)	85(6.6)	261(20.4)	——	628(49.2)*	101(7.9)	20(1.6)
	Evg.	219(67.8)*	25(7.7)	11(3.4)	——	29(9.0)	9(2.8)	30(9.3)
	Sum	682(24.0)	247(8.7)	315(11.1)	——	1370(48.3)*	146(5.1)	80(2.8)
Couple E	M.	——	21(3.5)	483(80.9)*	0(0)	——	88(14.7)	5(0.9)
	A.	——	81(6.8)	974(81.4)*	1(0.1)	——	91(7.6)	49(4.1)
	Evg.	——	4(1.1)	340(90.2)*	2(0.5)	——	0(0)	31(8.2)
	Sum	——	106(4.9)	1797(82.8)*	3(0.1)	——	179(8.3)	85(3.9)
Couple F	M.	373(58.6)*	19(3.0)	22(3.5)	0(0)	171(26.9)	21(3.3)	30(4.7)
	A.	469(43.0)*	24(2.2)	65(6.0)	5(0.4)	463(42.4)*	37(3.4)	28(2.6)
	Evg.	377(92.0)*	0(0)	6(1.4)	0(0)	0(0)	7(1.7)	20(4.9)
	Sum	1219(57.1)*	43(2.0)	93(4.3)	5(0.2)	634(29.7)	65(3.0)	78(3.7)
		Total staying duration of wife [min] (%)						
		Living room	Dining room	Bed room1	Bed room2	Studio	Kitchen	Toilet
Couple A	M.	96(47.5)*	29(14.4)	0(0)	12(5.9)	3(1.5)	12(5.9)	50(24.8)
	A.	9(3.8)	137(57.6)*	0(0)	1(0.4)	43(18.1)	37(15.5)	11(4.6)
	Evg.	423(66.3)*	130(20.4)	0(0)	3(0.5)	60(9.4)	4(0.6)	18(2.8)
	Sum	528(49.0)*	296(27.5)	0(0)	16(1.5)	106(9.8)	53(4.9)	79(7.3)
Couple B	M.	29(6.9)	187(44.3)*	49(11.6)	22(5.2)	11(2.6)	53(12.6)	71(16.8)
	A.	35(5.3)	296(44.5)*	231(34.7)*	17(2.6)	3(0.4)	30(4.5)	53(8.0)
	Evg.	312(67.0)*	62(13.3)	7(1.5)	0(0)	2(0.4)	10(2.1)	73(15.7)
	Sum	376(24.2)	545(35.1)*	287(18.5)	39(2.5)	16(1.0)	93(6.0)	197(12.7)
Couple C	M.	5(1.0)	83(17.2)	6(1.2)	42(8.7)	150(31.1)*	137(28.4)*	60(12.4)
	A.	229(23.9)	179(18.7)	90(9.4)	40(4.2)	258(26.9)*	109(11.4)	53(5.5)
	Evg.	234(56.4)*	7(1.7)	6(1.4)	39(9.4)	66(15.9)	21(5.1)	42(10.1)
	Sum	468(25.2)*	269(14.5)	102(5.5)	121(6.5)	474(25.5)*	267(14.4)	155(8.4)
Couple D	M.	180(26.9)*	120(17.9)	168(25.1)*	——	4(0.6)	191(28.5)*	7(1.0)
	A.	128(20.1)	366(57.6)*	95(14.9)	——	0(0)	39(6.1)	8(1.3)
	Evg.	190(58.7)*	6(1.8)	46(14.2)	——	0(0)	26(8.0)	56(17.3)
	Sum	498(30.6)*	492(30.2)*	309(19.0)	——	4(0.2)	256(15.7)	71(4.3)
Couple E	M.	——	51(7.5)	423(62.5)*	20(2.9)	——	167(24.7)	16(2.4)
	A.	——	57(4.5)	1095(86.8)*	12(0.9)	——	87(6.9)	11(0.9)
	Evg.	——	25(5.4)	389(82.4)*	3(0.6)	——	3(0.6)	52(11.0)
	Sum	——	133(5.5)	1907(79.1)*	35(1.4)	——	257(10.7)	79(3.3)
Couple F	M.	431(45.5)*	17(1.8)	323(34.1)*	3(0.3)	14(1.5)	133(14.0)	27(2.8)
	A.	476(41.6)*	6(0.5)	347(30.3)	24(2.1)	15(1.3)	257(22.4)	21(1.8)
	Evg.	425(80.0)*	1(0.2)	41(7.7)	2(0.4)	10(1.9)	26(4.9)	26(4.9)
	Sum	1332(50.7)*	24(0.9)	711(27.1)	29(1.1)	39(1.5)	416(15.9)	74(2.8)

M:Morning A: Afternoon Evg: Evening *: Base

4.4.1 Differences between husbands and wives in base choice

In the whole day, the average wife had more bases (1.3) than the average husband (1.2) during a day. This tendency was clearer in the morning, when the average wife had more bases (1.7) than the average husband (1) (Table 4-5). Moreover, in the morning, the proportion of total staying duration of the elderly wives in the base was much lower than the elderly husbands' (Fig.4-6). This suggests the elderly wives used more rooms in the morning. There were two cases in which the wives took the kitchen as base in the morning, but none of the elderly husbands took the kitchen as base.

Table 4-5 Average number of base per person

	Morning	Afternoon	Evening	Whole day
Husband	1.0	1.2	1.0	1.2
Wife	1.7	1.2	1.0	1.3

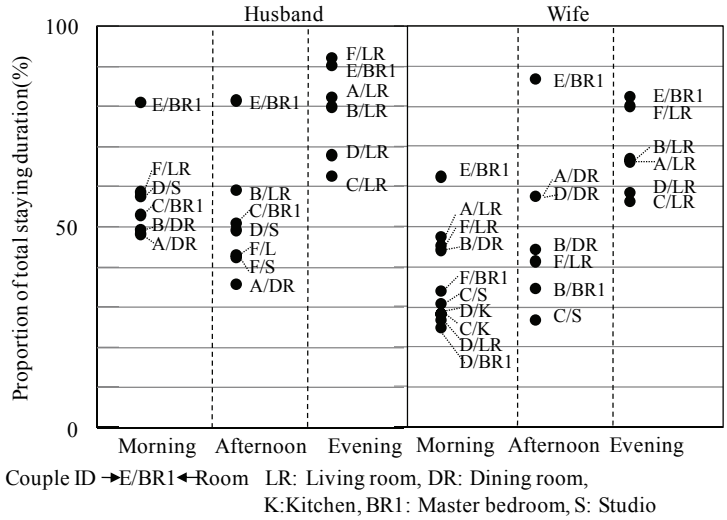


Figure 4-6 Proportion of total staying duration of elderly man and woman in each period

4.4.2 Difference between bases obtained by objective observation and those bases identified by subjects

The base obtained by calculating proportion of total staying duration (objective base) was compared with the base identified by the elderly couple (subjective base). For example, when the objective bases of a particular subject were the living room and dining room, but the subjective base that he/she identified was only the living room, the author marked "Accord" on the living room where objective and subjective base accord, and "Disaccord" on the dining room, which had been ignored by the subject. Then the

numbers of "Accord" and "Disaccord" were counted and the ratio of "Accord" (Ra) was calculated by the following formula:

$$Ra = \frac{N_{accord}}{N_{accord} + N_{disaccord}} \times 100\% \quad (3)$$

Ra: Ratio of "Accord"
$\mathbf{N_{accord}}$ **:** numbers of "Accord"
$\mathbf{N_{disaccord}}$ **:** numbers of "Disaccord"

Because in the interview, some responders could not clearly identify the room they stayed in for the longest duration during each period of a day, the question is simplified as to identify the room(s) they stayed in for the longest duration during the whole day. Thus, for each subject, only a subjective base for the whole day was obtained. Then, this subjective base for the whole day was compared with the objective base in each period in order to clarify in which period they accord more.

The results showed the objective and subjective bases in accord was more among the husbands (Ra: 85.7%) than in the wives (Ra: 37.5%) (Table 4-6). The objective and subjective bases in accord during the day was over one-and-a-half times more than during the evening for both husbands and wives. This shows that the base in the mind of the subjects indicated the room where they spent the most time during the day, although

Table 4-6 Counts of times that the objective and subjective Base accord and not.

ID	Husband					Wife				
	Subjectvie base	Objectvie Base in each period and the whole day				Subjectvie base	Objectvie Base in each period and the whole day			
		Morning	Afternoon	Evening	Whole day		Morning	Afternoon	Evening	Whole day
A	Dining room	Dining room*	Dining room*	Living room	Living room, Dining room*	Dining room	Living room	Dining room*	Living room	Living room
B	Living room	Dining room	Living room*	Living room*	Living room*	Master bedroom	Dining room	Dining room, Master bedroom*	Living room	Dining room
C	Master bedroom	Master bedroom*	Master bedroom*	Living room	Master bedroom*	Studio	Studio*, Kitchen	Studio*	Living room	Living room, Studio*
D	Studio	Studio*	Studio*	Living room	Studio*	Master bedroom	Living room, Master bedroom*, Kitchen	Dining room	Living room	Living room, Dining room
E	Master bedroom	Master bedroom*	Master bedroom*	Master bedroom*	Master bedroom*	Master bedroom	Master bedroom*	Master bedroom*	Master bedroom*	Master bedroom*
F	Living room	Living room*	Living room*, Studio	Living room*	Living room*	Living room	Living room*, Master bedroom	Living room*	Living room*	Living room*
	N_{accord}	5	6	3	6	N_{accord}	4	5	2	3
	Ra (%)	83.3	85.7	50.0	85.7	Ra (%)	40.0	71.4	33.3	37.5
		84.6					52.9			

*: Objective and subjective bases in accord

most of them spent most of the time in the living room during evening.

The Ra of the elderly husbands was high both in the morning (83.3%) and afternoon (85.7%). This might be because most elderly husbands stayed in the same room during the day, so it was easy for them to identify their base. The Ra of the wives was low in the morning (40.0%). This might be because since the wives used multiple rooms in the morning, their base for that period was not as clear to them as to the husbands. In the afternoon, the wives had fewer Bases and spent more time in a specific base, so it became easier for them to identify the base (Ra: 71.4%).

4.4.3 Spatial conditions of the base in each period

In the day, though more subjects chose a base facing south, almost half of them also happened to choose the dining room—which was a windowless room—as the base. The author asked Couples A and B and the wife in Couple D (5 person), who all used the dining room as the base, about why they stayed so long in a room with an orientation that is not ideal, and they answered that it was because it was cooler there (Table 4-7) .

Table 4-7 Counts of orientation of Base

	Dark	East	North	North, east	South	Sum
Morning	3	1	4	2	6	16
Afternoon	4	0	2	2	6	14
Evening	0	0	0	2	10	12

Dark: there is no window directly facing outside

The surveyed couples in Tangshan did not like to stay in an air-conditioned environment. Even if there was an air conditioner in the living room or bedroom, they seldom used it unless there was a guest. They preferred rooms that faced north or without windows during the day, but in the evening, when it got cool, they gathered in the living room. However, they were not satisfied with the room that faced north or without windows as it was a little dark in the day. This finding suggests that subjects who hardly use airconditioners in summer may need a base room that, though not necessarily facing south, should get a regular supply of natural light.

4.4.4 The room that the couples stayed in together or separately

Although how a certain subject allocated his/her time in each room was clarified, it was still not clear which base rooms the couples stayed in together and when. In order to clarify that, the room-use manner was divided into three types:

① Used alone by husband: Only the husband stayed in the room.

② Used alone by wife: Only the wife stayed in the room.

③ Used together: The couple stayed in the room at the same time.

Then the proportion of each room use manner (U) was calculated as below:

$$U = \frac{T_{w,r,p}}{\sum_{w}^{W} T_{w,r,p}} \times 100\% \quad (4)$$

$T_{w,r,p}$: Total staying duration of a given room use manner in a given room in given period in the whole investigation period(3-4 days)

w: Base use manner =(Used alone by the husband, Used alone by the wife, Used together)

W: Total number of base use manner

r: Room = (living room, . . . kitchen) the toilet and secondary bedroom that is hardly used together is excluded.

p: Period in a day = (morning, afternoon, evening)

For a certain room in a certain period, if there was only one room use with U > 50%, or 33.33 < U< = 50%, it was specified as the main room-use manner. If there were two room-use manner with 33.33 < U< = 50%, they were both specified as main room-use manners. For example, for couple A in Table 4-8, in the morning, the main room-use manner of the living room was ① used alone by husband, and in the evening, the main room uses of the living room were ② used alone by wife and ③ used together.

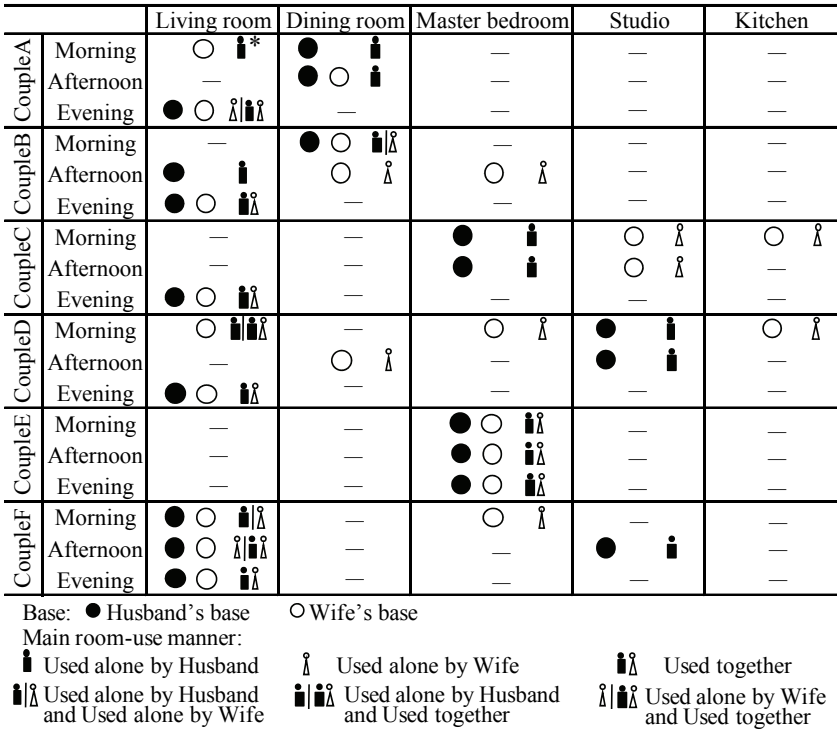
According to Figure 4-7, the rooms used as a base by both the husband and wife, was most likely to be used together, and the rooms used as a base by only one person in the couple was most likely to be used alone by that person. There were also two instances in which the living room or dining room were used as bases by both the husband and wife, but the couples stayed in these rooms alone at different times rather than together.

The rooms that the couples stayed in together or separately vary with the time period. Most subject couples (five couples) tended to use the same room- the living room- as the base and stayed there together during the evening. During the day, they tended to use different rooms- dining room, master bedroom, studio and kitchen- as bases and use 91% of the base rooms alone. There was also one subject couple, who tended to use the bedroom as their base and stayed together in that room during any given period.

Table 4-8 Room-use manner for each room

			Total duration [min] (%)				
			Living room	Dining room	Master bedroom	Studio	Kitchen
Couple A	Morning	Husband	110(53.4)**	298(91.1)**	0(0.0)	9(75.0)**	108(90.0)**
		Wife	91(44.2)	29(8.9)	0(0.0)	3(25.0)	7(5.8)
		Together	5(2.4)	0(0.0)	0(0.0)	0(0.0)	5(4.2)
		Sum	206(100.0)	327(100.0)	0(0.0)	12(100.0)	120(100.0)
	Afternoon	Husband	363(97.6)**	394(74.2)**	169(100.0)**	15(25.9)	115(75.7)**
		Wife	2(0.5)	76(14.3)	0(0.0)	42(72.4)**	15(9.8)
		Together	7(1.9)	61(11.5)	0(0.0)	1(1.7)	22(14.5)
		Sum	372(100.0)	531(100.0)	169(100.0)	58(100.0)	152(100.0)
	Evening	Husband	148(25.9)	28(17.7)	0(0.0)	7(10.4)	5(55.6)**
		Wife	199(34.9)*	113(71.5)**	0(0.0)	60(89.6)**	4(44.4)
		Together	224(39.2)*	17(10.8)	0(0.0)	0(0.0)	0(0.0)
		Sum	571(100.0)	158(100.0)	0(0.0)	67(100.0)	9(100.0)
Couple B	Morning	Husband	127(81.4)**	124(39.9)*	15(23.4)	2(15.4)	35(39.8)
		Wife	29(18.6)	111(35.7)*	49(76.6)**	11(84.6)**	53(60.2)**
		Together	0(0.0)	76(24.4)	0(0.0)	0(0.0)	0(0.0)
		Sum	156(100.0)	311(100.0)	64(100.0)	13(100.0)	88(100.0)
	Afternoon	Husband	446(92.7)**	147(33.1)	7(2.9)	3(50.0)*	69(69.7)**
		Wife	27(5.6)	228(51.5)**	230(96.6)**	3(50.0)*	27(27.3)
		Together	8(1.7)	68(15.4)	1(0.5)	0(0.0)	3(3.0)
		Sum	481(100.0)	443(100.0)	238(100.0)	6(100.0)	99(100.0)
	Evening	Husband	124(28.4)	45(42.1)*	3(30.0)	0(0.0)	3(23.1)
		Wife	44(10.1)	51(47.7)*	7(70.0)**	2(100.0)**	10(76.9)**
		Together	268(61.5)**	11(10.2)	0(0.0)	0(0.0)	0(0.0)
		Sum	436(100.0)	107(100.0)	10(100.0)	2(100.0)	13(100.0)
Couple C	Morning	Husband	10(66.7)**	50(37.6)	263(86.2)**	53(26.1)	45(24.7)
		Wife	5(33.3)	72(54.1)**	9(3.0)	137(67.5)**	136(74.7)**
		Together	0(0.0)	11(8.3)	33(10.8)	13(6.4)	1(0.6)
		Sum	15(100.0)	133(100.0)	305(100.0)	203(100.0)	182(100.0)
	Afternoon	Husband	8(3.3)	50(21.8)	466(92.1)**	5(1.9)	121(52.6)**
		Wife	189(79.8)**	105(45.9)*	26(5.1)	252(95.8)**	84(36.5)
		Together	40(16.9)	74(32.3)	14(2.8)	6(2.3)	25(10.9)
		Sum	237(100.0)	229(100.0)	506(100.0)	263(100.0)	230(100.0)
	Evening	Husband	60(20.4)	11(61.1)**	28(41.8)*	0(0.0)	37(63.8)**
		Wife	62(21.1)	7(38.9)	15(22.4)	59(89.4)**	18(31.0)
		Together	172(58.5)**	0(0.0)	24(35.8)*	7(10.6)	3(5.2)
		Sum	294(100.0)	18(100.0)	67(100.0)	66(100.0)	58(100.0)
Couple D	Morning	Husband	154(46.1)*	131(52.2)**	39(18.8)	713(99.4)**	28(12.8)
		Wife	53(15.9)	114(45.4)	164(79.3)**	4(0.6)	183(83.6)**
		Together	127(38.0)*	6(2.4)	4(1.9)	0(0.0)	8(3.6)
		Sum	334(100.0)	251(100.0)	207(100.0)	717(100.0)	219(100.0)
	Afternoon	Husband	115(47.3)*	51(12.2)	259(73.2)**	628(100.0)**	91(70.0)**
		Wife	61(25.1)	332(79.6)**	93(26.2)	0(0.0)	29(22.3)
		Together	67(27.6)	34(8.2)	2(0.6)	0(0.0)	10(7.7)
		Sum	243(100.0)	417(100.0)	354(100.0)	628(100.0)	130(100.0)
	Evening	Husband	76(28.6)	25(80.7)**	5(9.8)	29(100.0)**	0(0.0)
		Wife	47(17.6)	6(19.3)	40(78.4)**	0(0.0)	17(65.4)**
		Together	143(53.8)**	0(0.0)	6(11.8)	0(0.0)	9(34.6)
		Sum	266(100.0)	31(100.0)	51(100.0)	29(100.0)	26(100.0)
Couple E	Morning	Husband	—	19(27.1)	164(27.9)	—	84(33.5)
		Wife	—	49(70)**	104(17.7)	—	163(64.9)**
		Together	—	2(2.9)	319(54.4)**	—	4(1.6)
		Sum	—	70(100.0)	587(100.0)	—	251(100.0)
	Afternoon	Husband	—	73(56.2)**	110(9.1)	—	88(50.3)**
		Wife	—	49(37.6)	231(19.2)	—	84(48)
		Together	—	8(6.2)	864(71.7)**	—	3(1.7)
		Sum	—	130(100.0)	1205(100.0)	—	175(100.0)
	Evening	Husband	—	4(13.8)	40(9.3)	—	0(0.0)
		Wife	—	25(86.2)**	89(20.8)	—	3(100.0)**
		Together	—	0(0.0)	300(69.9)**	—	0(0.0)
		Sum	—	29(100.0)	429(100.0)	—	3(100.0)
Couple F	Morning	Husband	224(34.2)*	19(52.8)**	15(4.4)	171(92.4)**	17(11.3)
		Wife	282(43.1)*	17(47.2)	316(93.5)**	14(7.6)	129(86.0)**
		Together	149(22.7)	0(0.0)	7(2.1)	0(0.0)	4(2.7)
		Sum	655(100.0)	36(100.0)	338(100.0)	185(100.0)	150(100.0)
	Afternoon	Husband	185(26.0)	21(77.8)**	51(12.8)	449(96.8)**	27(9.5)
		Wife	240(33.9)*	3(11.1)	333(83.7)**	1(0.2)	247(87.0)**
		Together	284(40.1)*	3(11.1)	14(3.5)	14(3.0)	10(3.5)
		Sum	709(100.0)	27(100.0)	398(100.0)	464(100.0)	284(100.0)
	Evening	Husband	0(0.0)	0(0.0)	6(12.8)	0(0.0)	7(21.2)
		Wife	0(0.0)	1(100.0)**	41(87.2)**	10(100.0)**	26(78.8)**
		Together	377(100.0)**	0(0.0)	0(0.0)	0(0.0)	0(0.0)
		Sum	377(100.0)	1(100.0)	47(100.0)	10(100.0)	33(100.0)

Husband: Used alone by Husband, Wife: Used alone by wife, Together: Used together *: 33.33<U<=50% **: 50<U<100.0%



*: The base is the room with proportion of the total staying duration (P_T) in the highest interval for a given subject, and the main room-use manner is the room use with the highest proportion of time (U>1/3) for a given room. In the case of couple A during the morning and afternoon, the wife spent less time at home than the husband. Thus, according to the wife's time allocation in all the rooms, the living room and dining room were used by her as the base, however, based on the time allocation of room-use manner for the given rooms, the two rooms tended to be used by the husband alone.

Figure 4-7 Main room-use manner in the base room

4.5 Findings about pattern of bases and main links

4.5.1 Tendency of the base and main links for all the subjects

The author overlapped the pattern formed by the base and main links of each subject in each period to identify the general tendency of room use of all the subjects in the entire day (Fig. 4-8 shows an example of the overlapping process).

In this pattern, the author focused on what room is a base and where the main link between the rooms is. Even if some dwelling plans are different from others, e.g., the couple E has no living room, it was shown as non-use of the living room in the overlapped pattern. Thus, the room use pattern of subjects living in different plans can be overlapped into this pattern. In the author's opinion, the overlapped pattern is a method to identify the tendency in the room use of the studied subjects.

The author counted the number of instances of one room being used as the base (S_B) and number of main links between a given pair of rooms (N_{ML}) to show the room/route that subjects used the most. The author also counted the total number of main links that one room had (S_{ML}) to show how frequently this room was linked to

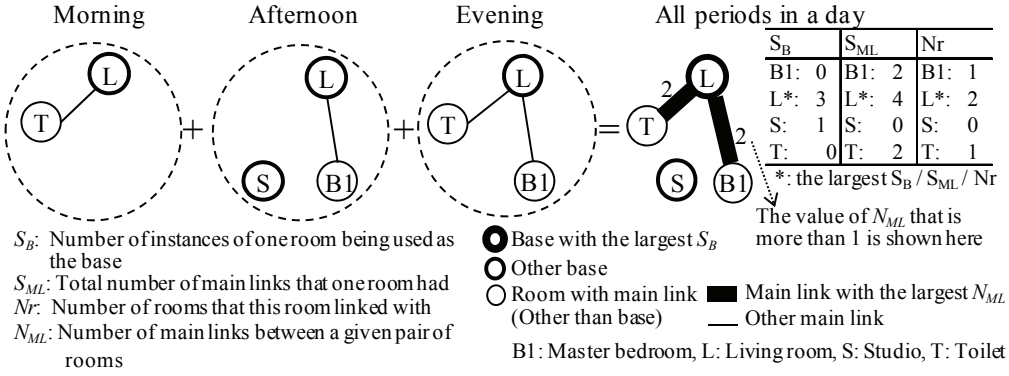


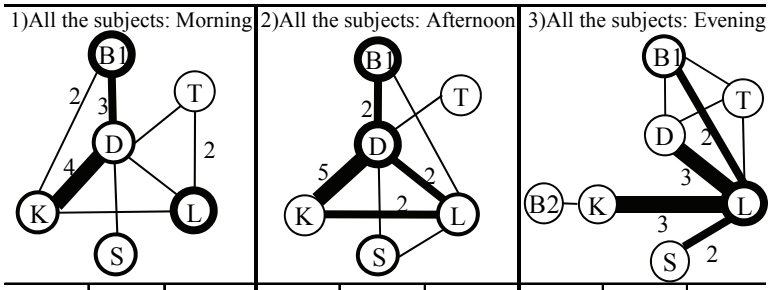
Figure 4-8 The patterns in each period were overlapped to obtain pattern for the subject in a day (husband in Couple F)

others and counted the number of rooms (*Nr*) that this room had a main link with (shortened as "linked with" henceforth) to show the range of rooms it was linked to. The room that was linked with the most rooms (highest *Nr*) was regarded as the hub.

In the morning, the subjects tended to use the living room and master bedroom as the base, and thereafter, moved frequently between the dining room and kitchen and between the dining room and master bedroom. The dining room was used as the hub (Fig. 4-9,1)). In the afternoon, the dining room, master bedroom, living room, and studio were used as the base. The maximum number of main links were concentrated between the dining room and kitchen. The dining room was still the hub, but the living room tended to be linked with more rooms and linked with these rooms more frequently in the afternoon than in the morning. Either the master bedroom, kitchen, or studio was linked to both the dining and living rooms, and the kitchen was linked with these two rooms more frequently than the master bedroom and studio (Fig. 4-9,2)). In the evening, the subjects tended to use the living room as both the base and hub. They tended to move frequently between the living room and kitchen and between the living room and dining room (Fig. 4-9,3)).

Depending on Fig. 4-9,4) and Fig. 4-9,5), for both the husband and wife, the use of the living room as the base was found to be highest, followed by the master bedroom. The summation of proportion of times that the two rooms were used as base was about 70% for the husband and 65% for the wife. Two cases of the subject wives took the kitchen as base in the morning, but none of the husbands did so. The dining room was frequently linked to the living room for the husband while for the wife, it was linked frequently to the toilet. The wife also tended to move more between the living room and kitchen. As compared with the husband, the kitchen was linked to more rooms and more frequently to these rooms in the wife's room use.

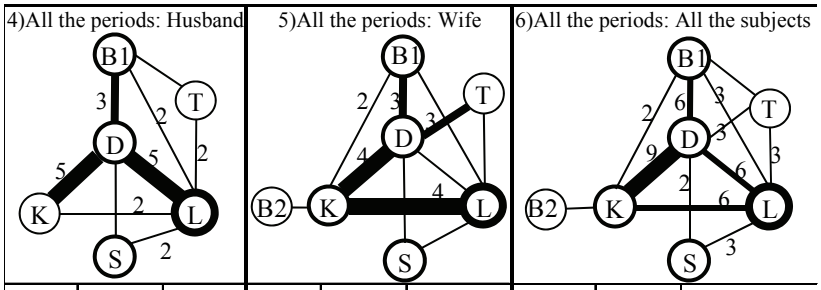
Throughout the day for all the subjects, the use of the living room as the base was found to be highest, followed by the master bedroom. The dining room and living rooms were linked frequently with each other and were both used as a hub, but the dining room was linked more frequently to rooms other than the living room. The kitchen was linked frequently to both the hubs, especially to the dining room



S_B	S_{ML}	Nr
L*: 5	L: 4	L: 3
D: 3	D*: 9	D*: 5
B1*: 5	B1: 5	B1: 2
B2: -	B2: -	B2: -
S: 2	S: 1	S: 1
K: 2	K: 7	K: 3
T: 0	T: 3	T: 2

S_B	S_{ML}	Nr
L: 3	L: 6	L: 4
D*: 4	D*: 11	D*: 5
B1*: 4	B1: 3	B1: 2
B2: -	B2: -	B2: -
S: 3	S: 2	S: 2
K: 0	K: 7	K: 2
T: 0	T: 1	T: 1

S_B	S_{ML}	Nr
L*: 10	L*: 11	L*: 5
D: 0	D: 5	D: 3
B1: 2	B1: 4	B1: 3
B2: 0	B2: 1	B2: 1
S: 0	S: 2	S: 1
K: 0	K: 4	K: 2
T: 0	T: 3	T: 3



S_B	S_{ML}	Nr
L*: 8	L: 13	L*: 5
D: 3	D*: 14	D: 4
B1: 5	B1: 6	B1: 3
B2: -	B2: -	B2: -
S: 3	S: 3	S: 2
K: 0	K: 7	K: 2
T: 0	T: 3	T: 2

S_B	S_{ML}	Nr
L*: 9	L: 8	L*: 5
D: 4	D*: 12	D*: 5
B1: 6	B1: 6	B1: 3
B2: 0	B2: 1	B2: 1
S: 2	S: 2	S: 2
K: 2	K: 11	K: 3
T: 0	T: 4	T: 2

S_B	S_{ML}	Nr
L*: 17	L: 21	L*: 5
D: 7	D*: 26	D*: 5
B1: 12	B1: 12	B1: 4
B2: 0	B2: 1	B2: 1
S: 5	S: 5	S: 2
K: 2	K: 18	K: 3
T: 0	T: 7	T: 3

B1: Master bedroom, B2: Secondary bedroom, D: Dining room, L: Living room, K:Kitchen, S: Studio, T: Toilet

Base with the largest S_B
Other base
Room that had main links (Other than Base)
Main link with the largest N_{ML}
Main link with the second largest N_{ML}
Other main link
The number next to the main link shows the N_{ML} that is more than one.

S_B: Number of instances of one room being used as the base
S_{ML}: Total number of main links that one room had
Nr: Number of rooms that this room linked with
N_{ML}: Number of main links between a given pair of rooms, the number that is over 1 is shown on the main link

*: The largest $S_B / S_{ML} / Nr$

Figure 4-9 Overlapped pattern of bases and main links

(9/45=20% of the main links). The dining room was also linked frequently with the master bedroom. Either the studio or toilet tended to be linked to both the living and dining rooms (Fig. 4-9,6)).

4.5.2 Reasons for typical room use

Depending on Fig 4-10, the kitchen was linked frequently with the dining room in 4 cases of the elderly families. The author also interviewed Couples A, B, C, D, and E about why they moved frequently between the dining room and kitchen, to which they replied that this was because their kitchen was too small to enable two persons to prepare dinner together, thus forcing one person to work in the dining room. The kitchen was also to small to accommodate all the appliances for cooking, such as the refridger and the microwave oven, which had to be located in the dining room. This resulted in their having to move frequently between the two rooms. This finding suggests that for couples jointly preparing dinner, enlarging the size of their kitchen would prove convenient.

4.5.3 Grouping of the room use pattern of the subjects

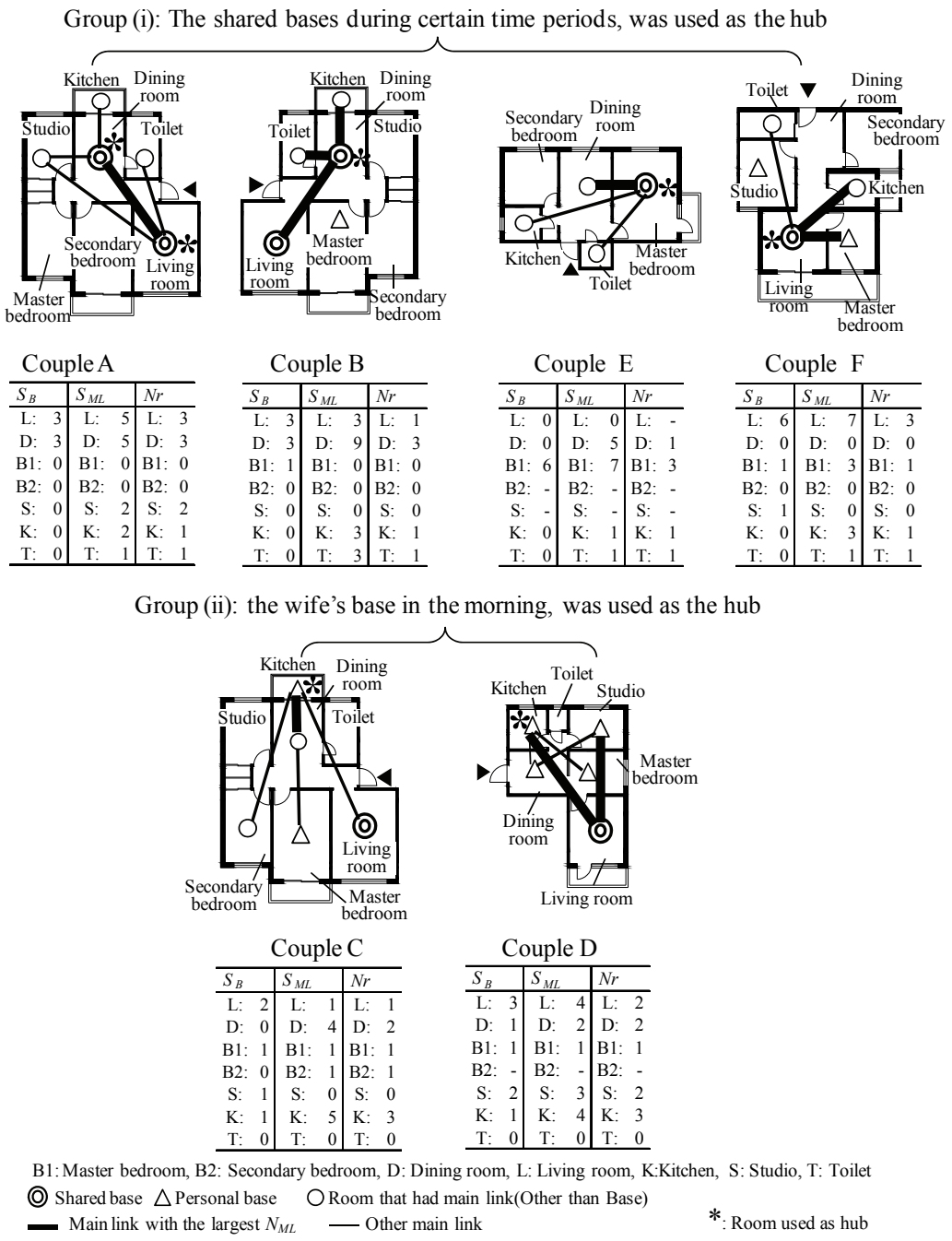
The room use of a studied couple comprises the room use of both the husband and wife. In order to show the characteristics of each couple's room use, the author overlapped the pattern in this regard of the two persons making up a couple during the survey period and obtained the room use patterns for the room used as the base by both husband and wife (shared base), the room used as the base by either of the two (personal base), and the main links among the rooms. The shared base showed the characteristic pattern of the couple's stay in the various rooms, and the room used as the hub by the couple showed the characteristics of their movement. According to the general assumption, the shared base is characterized by a good orientation and appropriate size, whereas the hub is located at the center of the house, from where the residents can conveniently access other rooms. A particular couple's use or non-use of the shared base as the hub could be taken to reflect different needs in connection with the room layout. In order to show this diversity in room use, the author grouped the subjects on the basis of whether they used the shared base as the hub.

One group of subjects(Couples A, B, E and F) used the shared base as the hub. Couple A used the dining and living rooms as both the shared base and hub, and tended to move most frequently between the two. Both the rooms were linked with the studio and the kitchen and toilet, respectively. Couple E used the master bedroom as the hub

and moved frequently between it and the kitchen, toilet, and dining room. Couple F used the living room as the hub and moved frequently between it and the kitchen, toilet, and master bedroom. Couple B used both the dining and living rooms as the shared base, and the dining room as the hub. In this group, the shared base appeared to have a close relationship with the other rooms in the whole room use pattern.

The other group (Couples C and D) did not use the shared base as the hub. Couples C and D both used the living room as the shared base, but used the kitchen as the hub. As for Couple C, their shared base was only linked with one other room. In this group, the link between the shared base and the other rooms was weak.

In addition, the couples living in the same dwelling unit type (Couples A, B, and C, whose dwelling units were all of type (i) the one with a small entrance hall) sometimes displayed different patterns of room use. Conversely, the room use pattern of subjects living in different dwelling unit types was at times found to be similar (Couples A, B, E and F, whose dwelling units were of type(i) and (ii) the one comprising a combined entrance hall and dining room, respectively). The grouping of room use pattern did not correspond to the dwelling unit type (Fig. 4-10).



Couple A

S_B	S_{ML}	Nr
L: 3	L: 5	L: 3
D: 3	D: 5	D: 3
B1: 0	B1: 0	B1: 0
B2: 0	B2: 0	B2: 0
S: 0	S: 2	S: 2
K: 0	K: 2	K: 1
T: 0	T: 1	T: 1

Couple B

S_B	S_{ML}	Nr
L: 3	L: 3	L: 1
D: 3	D: 9	D: 3
B1: 1	B1: 0	B1: 0
B2: 0	B2: 0	B2: 0
S: 0	S: 0	S: 0
K: 0	K: 3	K: 1
T: 0	T: 3	T: 1

Couple E

S_B	S_{ML}	Nr
L: 0	L: 0	L: -
D: 0	D: 5	D: 1
B1: 6	B1: 7	B1: 3
B2: -	B2: -	B2: -
S: -	S: -	S: -
K: 0	K: 1	K: 1
T: 0	T: 1	T: 1

Couple F

S_B	S_{ML}	Nr
L: 6	L: 7	L: 3
D: 0	D: 0	D: 0
B1: 1	B1: 3	B1: 1
B2: 0	B2: 0	B2: 0
S: 1	S: 0	S: 0
K: 0	K: 3	K: 1
T: 0	T: 1	T: 1

Couple C

S_B	S_{ML}	Nr
L: 2	L: 1	L: 1
D: 0	D: 4	D: 2
B1: 1	B1: 1	B1: 1
B2: 0	B2: 1	B2: 1
S: 1	S: 0	S: 0
K: 1	K: 5	K: 3
T: 0	T: 0	T: 0

Couple D

S_B	S_{ML}	Nr
L: 3	L: 4	L: 2
D: 1	D: 2	D: 2
B1: 1	B1: 1	B1: 1
B2: -	B2: -	B2: -
S: 2	S: 3	S: 2
K: 1	K: 4	K: 3
T: 0	T: 0	T: 0

Figure 4-10 Room use pattern of each studied couple

4.6 Conclusion

Chapter four clarified, by studying individual cases, the personal room use in urban apartment houses of Chinese elderly couples in their daily life. The room use was identified on the basis of the room in which they stayed the longest (base), the route between the pair of rooms that they passed through most frequently (main link), and the

room that had a main link with most rooms (hub). Findings regarding the use of base are as follows:

1) Throughout the day, the objective and subjective bases in accord was over twice as many for the husband as for the wife. For both the husband and wife, the ratio of objective and subjective bases in accord during the day was over one-and-a-half times more than during the evening. This shows that the base, in the mind of the subjects, indicated the room where they spent the most time during the day. The base where they spent the evening, which made less of an impression on the subjects, was the living room, where they stayed together for the whole evening;
2) The rooms that the couples stayed in together or separately vary with the time period. Most subject couples (five of them) tended to use the same room- the living room- as the base during the evening and different rooms- dining room, master bedroom, studio and kitchen-as bases during the day. There was also one subject couple, who tended to use the bedroom as their base during any given period. This finding suggests that it is important to satisfy the elderly couple's individual use of different rooms during the day in the room layout planning for them;
3) Throughout a day, for both the husband and wife, the use of the living room as the base was found to be highest, followed by the master bedroom. The summation of proportion of times that the two rooms were used as base was 70% for the husband and 65% for the wife. Two subject wives took the kitchen as base in the morning, but none of the husbands did so;
4) As per general assumptions, the subjects should have always chosen a south-facing room as the base, but actually, almost half of them (5/12) also happened to choose the dining room—which was a windowless room—as the base. In the interview, Couples A and B and the wife in Couple D, who all used the dining room as the base, said that they preferred to stay there as this room remained cool even in the summer (they did not like to use an airconditioner), but they were not satisfied with the room as it was a little dark in the day. This finding suggests that subjects who hardly use airconditioners in summer may need a base room that, though not necessarily facing south, should get a regular supply of natural light.

Findings regarding the main link are as follows:

1) The kitchen was linked frequently with the dining room in four out of the six couples. The author also interviewed Couples A, B, C, and D about why they moved frequently between the dining room and kitchen, to which they replied that

this was because their kitchen was too small to enable two persons to prepare dinner together, thus forcing one person to work in the dining room. The kitchen was also to small to accommodate all the appliances for cooking, such as the refridger and the microwave oven, which had to be located in the dining room. This resulted in their having to move frequently between the two rooms. This resulted in their having to move frequently between the two rooms.

2) The main links between the dining room and kitchen were found to be most (20%), followed by those between the dining room and living room, between the dining room and bed room, and between the living room and kitchen.

Findings regarding the main link between base and other rooms are as follows:

1) The author overlapped the patterns of main links of the two persons in a couple during all time periods and clarified the room that had a main link with most other rooms (hub) for each couple. Four out of the six couples used living room, dining room or bed room, the bases of both the husband and wife in certain time periods, as the hub and the other two couples used the kitchen, the wife's base in the morning, as the hub. This finding suggests that the position of shared base room or kitchen in a dwelling plan is important for the elderly couples studied. Room layout plans with the shared base room or kitchen located at the center would be convenient for them.

Notes

*1. Although accommodating guests forms a possible part of the life of the elderly who live by themselves, in this study, the author chose to focus on the normal daily life of the elderly between rising in the morning and going to bed at night, without having guests stay over in the house.

*2. Tangshan, an industrial city in Hebei province, located southeast of Beijing. The area is 13,472 km^2, and the population is 7.35 million (to 2009.6).

*3. The balcony was not regarded as an important space in which the subjects stayed for long because it faced south and was enclosed by glass, and was thus hot in the summer and seldom used by the residents unless they were airing clothes or watering plants. Moreover, an Active RFID reader needs to connect to the power supply, but the studied balconies did not have any power supply. Considering the feasibility of the survey, the author had to give up installing Active RFID readers in the balconies. Therefore, in this study, the balcony is considered as a part of the

adjacent room from which it can be accessed.

*4. According to the specific location of the resident, the reader in the adjacent room might receive signals sporadically, which the author regarded as noise. In order to reduce noise, RFID data was filtered every minute. The number of signals received by each reader in a minute was counted, and the room in which the reader received the most signals in a minute was specified as the resident's "staying room" in that minute (Fig. 4-13). Then the author needed to fill missing values in the data. Though the tag sent a signal every second, sometimes the reader failed to receive the signal when the tag kept stable. Therefore, the author needed to judge whether this was because the resident was simply in a stable position, although wearing the tags, or had taken them off and forgotten to record why. Based on the acceleration data, when the sensor judged "there is no movement" and "keep flat" successively, the subject was judged as having taken the device off and gone outside, and the missing values were completed by entering "Outside" in the relevant fields and the other cases were completed in the context of the staying room (Fig. 4-14).

*5. Since the balcony was considered a part of the adjacent room, the movement from a certain room to the balcony was taken as a movement between rooms and the

Before correction

	Counts of received signals in each room			Missing signals	Sum
Time	Living room	Kitchen	Dining room		
8:28:00	1	3	50	6	60
8:29:00		45	2	13	60

→

After correction

Time	Staying room
8:28:00	Dining room
8:29:00	Kitchen

Figure 4-11 Example of correction of data

Date and time	Staying room obtained by Active RFID	Status of acceleration sensor	
		whether there is movement	whether keep flat
2009/6/26 11:20	Living room	Yes	No
2009/6/26 11:21	Living room	Yes	No
2009/6/26 11:22	Living room	Yes	No
2009/6/26 11:23	Living room	No	No
2009/6/26 11:24	Living room	Yes	No
2009/6/26 11:25	Outside	No	Yes
2009/6/26 11:26	Outside	No	Yes
2009/6/26 11:27	Outside	No	Yes
2009/6/26 11:28	Outside	No	Yes
2009/6/26 11:29	Outside	No	Yes

The empty cells above are missing values

Figure 4-12 Complete the missing values

duration was not counted.

*6. A shared base is the base used by both the husband and wife, not necessarily the base used by the husband and wife simultaneously

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3) Lin Wenjie, Nishimura Shin-Ya, Takahashi Yuzumi, Noguchi Takahiro, Lu Wei, Tsukidate Toshiei, Morishita Mitsuru, Zhou Bo: The Living Style of Elderly Couples in Collective Housing in Da-lian and Harbin, China: A study on the planning of living spaces for elderly living in urban areas. J. Archit. Plann.Eviron.Eng., AIJ, No.599, 2006.1, pp.1-7

Chapter 5 Father-Child Communication in Chinese Urban Apartment Houses

5.1 Purpose

There are three major ways to impart meaning to face-to-face communication among humans: body language, voice tonality, and words)[1)]. In face-to-face communication, looking at each other is the most important precondition, and talking is an important part of the process. In this study, the author regarded instances where a parent and child stayed in the same room or adjacent rooms that opened to each other (hereafter referred to as "connected rooms") as events that had a high probability of visual and verbal contact (this kind of stay is hereafter referred to as "staying together" or "spending time together"). Thus, the probability of face-to-face communication was quantified by the duration and frequency of a parent and child staying in the same room or connected rooms and the duration of speech that occurred during that period. The use of certain rooms was quantified by the duration and frequency that subjects stayed there. The duration and frequency of stays or speech were obtained by a continuous recording of each family member's stay and speech in each room for seven individual cases using Active RFID and an audio recorder.

On the basis of the relationship between the amount of time spent in rooms and the communication that took place in each case, it is possible to determine a layout that might increase the probability of father-child communication among the subjects.

In this chapter, the author aimed at clarifying the relationship between room use and father-child communication among Chinese urban one-child family dwelling units by using Active RFID devices and an audio recorder. The author was interested in the following questions:

1) In which room (or connected rooms) do the father and child tend to stay together and talk?
2) In which room do they tend to stay when they are separated (both stay in different rooms that are not connected)?
3) Who is the main speaker when they stay in the same room?

5.2 Method of data collection

5.2.1 Devices

1) Active RFID devices

The components of the Active RFID devices were as follows:

① Active RFID Tag (tag)

② Active RFID Reader (reader)

③ PC (platform)

④ Wireless Ethernet Converter (converter)

The tag sent a signal with a unique ID on a per-second basis. Each reader was assigned a Static IP and installed in each room of the dwelling unit. The converter connected the PC and readers though a wireless LAN. The PC recorded the IP of the reader that had received signals from the tag, providing continuous data on when and in which room the subject was present.

2) Acceleration sensor

In order to fill in the missing values in the Active RFID data, the author also used an acceleration sensor that helped us judge whether the subject had moved.

3) Audio recorder

An audio recorder was used to record the speech of the subjects. Then, the recorded audio files were transformed into data that only shows whether the subjects talked without knowing the content of their speech. The survey was conducted after all subjects understood the above details and agreed to cooperate. Fig. 5-1 shows the configuration of the device.

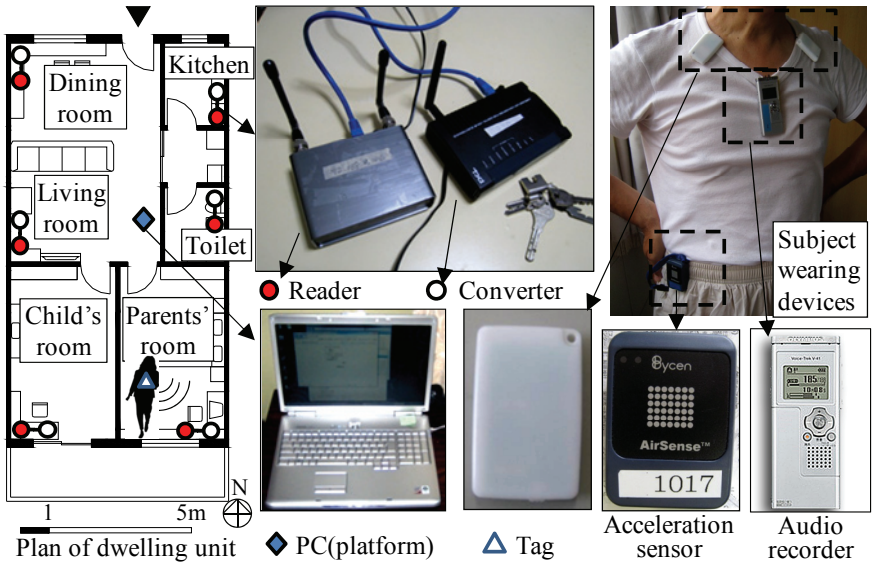


Figure 5-1 Configuration of Device

5.2.2 Investigation subjects and period

The investigation was conducted in Tangshan*[1] and Beijing, two prefecture-level cities in North China. Seven ordinary one-child families with adolescent children—four boys and three girls aged 13 to 19 years (subjects were identified by

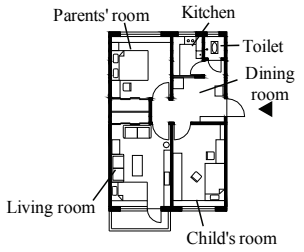
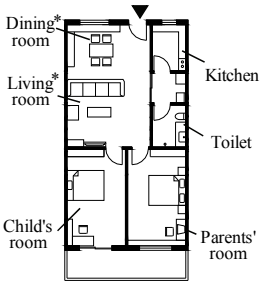
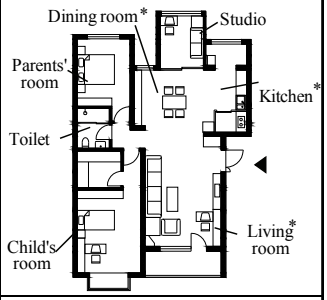
gender)—cooperated in our survey. Since the current study is a case study rather than a study that aims to clarify the universal characteristics of adolescents or compare adolescents at different ages, no regard was given to the age of an adolescent when choosing a subject*[2].

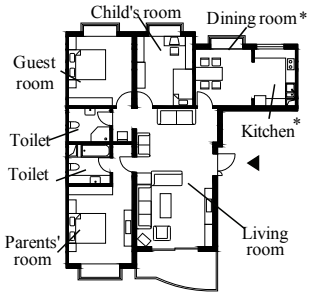
The subject dwelling units were common types found in the urban apartment houses of North China. Each subject dwelling unit had a living room, dining room, parents' room, child's room, kitchen, and toilet, and in some cases, a studio. On the basis of Chinese residents' general concept of rooms, the rooms in this study are described as a space, the main function of which is different from that of the adjacent space, regardless of whether it was enclosed by partitions. Thus, rooms in an open space were regarded as different rooms rather than a single room, and they are referred to as connected rooms in this paper (e.g., the living and dining rooms in the dwelling of Boy 2 in Fig. 5-2).

It is interesting that although there was only one child, the child's room was larger and was better orientated than the parents' room in more than half of the subject families (Boy 1, Boy 3, Girl 2, and Girl 3). The parents said that this was because they wanted their child to have a more wholesome study environment.

5.2.3 Investigation flow

1) Readers were installed in every room of the dwelling unit.
2) An investigator wore the Tags and moved among the rooms, adjusting the parameters of the devices to ensure that they correctly recorded which room the Tag was in and when.
3) The investigator instructed the residents on when and how to wear the devices.
4) The investigation started after the investigator left. Every family member wore the Tag, acceleration sensor, and audio recorder between rising and going to bed when inside the house. They also wrote down when they took the device off.
5) The investigation lasted two to four days and ended when the investigator withdrew the devices.
6) When the author clarified the room in which subjects tended to stay, the author asked them about the main activities that they participated in there through a short interview.

ID/Location	Boy 1 / Tangshan	Boy 2 / Beijing	Boy 3 / Beijing
Plan			
Dwelling unit	55.8m^2, 2F/6F, completion: 1981	79.9m^2, 8F/9F, completion: 1997	95.9m^2, 3F/5F, completion: 2006
Subjects' age	Father: (45) Mother: (45) Boy: (19)	Father: (46) Mother: (46) Boy: (19)	Father: (45) Mother: (45) Boy: (17)
Survey period	2009/7/5 (Sun.) 19:30~7/8 (Wen.) 17:30	2009/7/15 (Wen.) 11:00~ 7/17 (Fri.) 21:00	2009/7/28 (Tue.) 11:00~ 7/31 (Fri.) 22:30

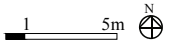
ID/Location	Boy 4 / Beijing
Plan	
Dwelling unit	103.9m^2, 4F/6F, completion: 2000
Subjects' age	Father: (46) Mother: (47) Boy: (18)
Survey period	2009/8/1 (Sat.) 11:50~ 8/3 (Mon.) 22:30

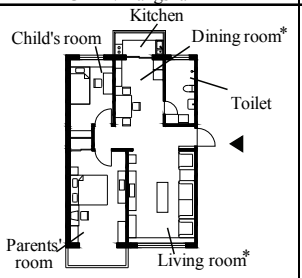
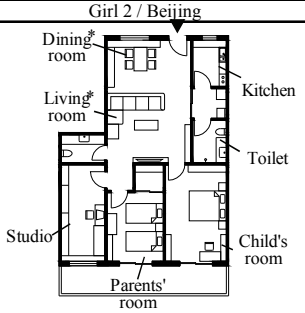
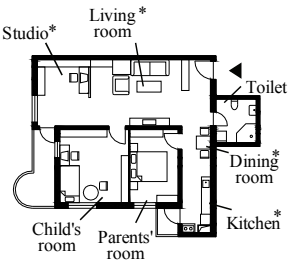
Each surveyed room was named on the basis of the subjects' description of its main function.

Living room: where Residents received visitors, watched TV, and relaxed.
Dining room: the room where the residents had dinner daily or with guests.
Child's room: the bedroom of the child
Parents' room: the bedroom of the parents.
Studio: the room with a bookshelf or PC where the residents might work or do other activities.
Toilet: the room with a close stool, washbasin, and shower nozzle. Some residents also had a washer inside and made it a room for housework.

*: Connected rooms

The area refers to the area of usable living space



ID/Location	Girl 1 / Tangshan	Girl 2 / Beijing	Girl 3 / Beijing
Plan			
Dwelling unit	71.5m^2, 5F/6F, completion: 2000	97.3m^2, 8F/9F, completion: 1997	78.9m^2, 4F/15F, completion: 2001
Subjects' age	Father: (40) Mother: (38) Girl: (13)	Father: (60) Mother: (55) Girl: (18)	Father: (48) Mother: (47) Girl: (18)
Survey period	2009/7/8 (Wen.) 20:40~ 7/11(Sat.) 21:00	2009/7/12 (Sun.) 17:30~ 7/13 (Mon.) 19:30	2009/8/4 (Tue.) 8:00~ 8/6 (Thu.) 20:30

The dwelling plans above only show the layout and approximate size of the furniture based on the photo shot in the families studied. They did not show plants, dolls and decorations.

Figure 5-2 Basic Information about the Surveyed Families

5.2.4 Time series data

The database included location data and vocal duration. The location data was obtained by correcting the Active RFID data*[3], and it showed which room the residents stayed in and what time they stayed there between rising and going to bed. The duration that the subject stayed at home between rising and going to bed hereafter referred to as "stayed at home".

Vocal duration is the number of seconds in a minute during which the subject talked, which was judged by calculating the average sampling value that showed the

intensity of the sound per second in the recorded audio file by using a software tool*[4]. The voice of the speaker could be identified in all rooms except the kitchen, where the noise created in the process of cooking Chinese food was too loud. Thus, the author did not calculate vocal duration in the kitchen. Fig. 5-3 illustrates a sample of the database.

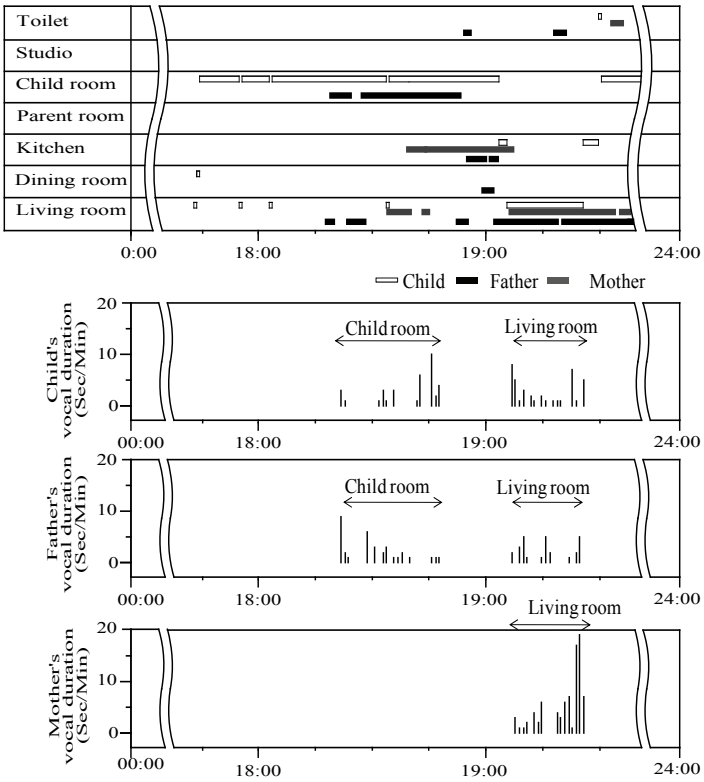


Figure 5-3 A sample of the Location Data and the Vocal Duration during the Period when Parent and Child Stayed Together (Boy 4 on Aug 3, 2009)

5.3 Findings about the communication in room use

5.3.1 Comparison of time spent together and speech between the child and their father and mother

The author calculated the proportion of the duration that a child stayed together with their father (P_{DF}), their mother (P_{DM}), and with both of them (P_{DP}), respectively, for the total duration that s/he had stayed together with a parent.

The girls tended to stay together with their mother and spent very little time with both parents, whereas the boys tended to stay together with both parents, except for Boy 1, who stayed together with his mother for a relatively longer period. For all subjects, the duration that a child stayed together with their father tended to be less than the duation that s/he stayed together with their mother ($P_{DF} < P_{DM}$ in 6 out of 7 cases,

hereafter expressed as 6/7).

Considering that the duration that both the father and child stayed at home (*DFH*) tended to be shorter than that of the mother (*DMH*) (5/7), the author also calculated the proportion of the duration that a child stayed together with the father (P_{DFH}) or the mother (P_{DMH}) for the total duration that the child and the parent were both at home and found that in five out of seven cases, the P_{DFH} was 1.6%~43.6% smaller than P_{DMH}. This shows that the father tended to stay together with his child for a lesser duration than the mother (Table 5-1). On average, the duration that the child and father stayed separately (*DFS*) represented 80.6% of the total time that both of they stayed at home.

The author also compared the vocal duration of the father and mother by using the proportion of the vocal duration of the father (P_{VF}) or that of the mother (P_{VM}) for the total vocal duration that occurred in the period s/he stayed together with the child. For six out of seven cases, the father talked 11.4%~62.8% less than the mother. Averagely, the father talked about 20% less than the mother (Table 5-2).

Table 5-1. Duration that Child and Parent Stayed Together

ID	Survey period [Day]	*DF* [Min]	*DM* [Min]	*DP* [Min]	*DS* [Min]	P_{DF} [%]	P_{DM} [%]	P_{DP} [%]	*DFH* [Min]	*DMH* [Min]	P_{DFH} [%]	P_{DMH} [%]	*DFS* [Min]	P_{DFS} [%]
Boy 1	4	22	135	88	245	9	55.1	35.9	535	1377	4.1	9.8	425	79.4
Boy 2	3	26	30	64	120	21.7	25	53.3	335	407	7.8	7.4	245	73.1
Boy 3	4	120	155	352	627	19.1	24.7	56.2	2486	2416	4.8	6.4	2014	81
Boy 4	3	53	18	189	260	20.4	6.9	72.7	972	959	5.5	1.9	730	75.1
Girl 1	4	200	448	43	691	29	64.8	6.2	780	878	25.6	51	537	68.8
Girl 2	2	9	111	6	126	7.1	88.1	4.8	149	224	6	49.6	134	89.9
Girl 3	3	1	67	6	74	1.4	90.5	8.1	204	464	0.5	14.4	197	96.6
Average	3.3	61.6	137.7	106.9	306.4	15.4	50.7	33.9	780.1	960.7	7.9	20.1	611.7	80.6

DF: duration that only child and father stayed together
DM: duration that child and mother stayed together
DP: duration that child and parents stayed together
$DS=DF+DM+DP$
$P_{DF}=DF\times 100/DS$, $P_{DM}=DM\times 100/DS$, $P_{DP}=DP\times 100/DS$

DFH: duration that child and father both stayed at home
DMH: duration that child and mother both stayed at home
$P_{DFH}=DF\times 100/DFH$, $P_{DMH}=DM\times 100/DMH$
DFS: duration that child and father stayed separately
$DFS=DFH-DF-DP$ $P_{DFS}=DFS\times 100/DFH$

Table 5-2. Vocal Duration when Child and Parent Stayed Together

ID	Survey period [Day]	*VF* [Second]	*VM* [Second]	*VC* [Second]	*VS* [Second]	P_{VF} [%]	P_{VM} [%]	P_{VC} [%]
Boy 1	4	93	684	164	941	9.9	72.7	17.4
Boy 2	3	900	672	429	2001	45	33.6	21.4
Boy 3	4	522	870	1078	2470	21.1	35.2	43.7
Boy 4	3	655	872	264	1791	36.6	48.7	14.7
Girl 1	4	1292	2436	3680	7408	17.4	32.9	49.7
Girl 2	2	37	66	151	254	14.6	26	59.4
Girl 3	3	66	515	556	1137	5.8	45.3	48.9
Average	3.3	509.3	873.6	903.1	2286.0	21.5	42.1	36.5

VF: Father's vocal duration in the period when he stayed together with the child
VM: Mother's vocal duration in the period when she stayed together with the child
VC: Child's vocal duration in the period when (s)he stayed together with at least one parent
$VS=VF+VM+VC$ $P_{VF}=VF\times 100/VS$, $P_{VM}=VM\times 100/VS$, $P_{VC}=VC\times 100/VS$

5.3.2 The distribution of the rooms that the father and child stayed in and the duration

Depending on the specific activities of the father and child, they may stay in the same or different rooms during a specific period. Fig. 5-4 shows the rooms that they stayed in and their duration of staying there when they are both at home for the whole survey period. Whether or not the mother was present is not shown. The number at the crossing of the row and column in the table of Fig. 5-4 shows the duration (percentage) that the father and child stayed in the same room or given pairs of rooms at the same time. For example, for Boy 1, the number of "11.9[min/hour] (19.8[%])" at the crossing of row one and column one indicates the average minutes and the percentage that the father and child stayed together in the living room per hour over the whole period that they were home (8.9 hours). Further, "42.2[min/hour] (70.3[%])" indicates the average duration and percentage that the child stayed in the child's room while the father stayed in the living room.

The child and father of each subject family had a tendency to stay in a certain pair of rooms during the period that they stayed in different rooms. The proportion of the longest duration that the father and child stayed in different rooms was 30.0–81.4%. The subjects could be classified into two groups according to the room that the father stayed in:

① Father stayed in the living room (all boy subjects and Girl 1):

In this group, Boy 1, Boy 3, and Boy 4 had the same tendencies regarding room use. The child tended to stay in the child's room when the father was in the living room, which was also the room that they tended to stay in together. On the other hand, Boy 2 and Girl 1 tended to stay in the parents' room when their father stayed in the living room. In the interview, they answered that this was because the only PC in the house was in the parents' room and they were allowed to play PC games during the summer vacation when the survey was conducted. This kind of stay, in which the father stayed in the living room and the child stayed in the child's room or parents' room, occupied 30%~70.3% of the time when the father and child both stayed at home.

② Father stayed in other rooms (Girl 2 and Girl 3):

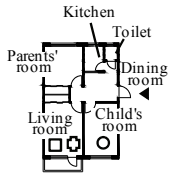
Compared with group ①, the children in this group spent less time with their father in the same room. Girl 2 tended to stay in the living room, but her father tended to stay in the studio. Girl 3 tended to stay in the child's room when her father stayed in the dining room, and they only met for totally three minutes in the living room. Depending on the result of interview, the two fathers indicated that they stayed in that

Duration of stay of the father [min/hour](%)

Duration of stay of the child [min/hour](%)

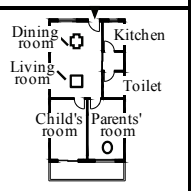
Boy 1	Living room	Dining room	Kitchen	Parents' room	Child's room	Studio	Toilet
Living room	11.9(19.8)**	0.6(1.0)	0.7(1.2)	0.4(0.7)	42.2(70.3)*	-	1.0(1.7)
Dining room	0.1(0.2)	0	0	0	0.2(0.3)	-	0
Kitchen	0	0	0	0	1.2(2.0)	-	0
Parents' room	0	0	0	0	1.0(1.7)	-	0
Child's room	0	0	0	0	0.5(0.8)	-	0
Toilet	0	0	0	0	0.2(0.3)	-	0

Survey days:4 Both at home:8.9[hour](100) Stayed in connected rooms: -



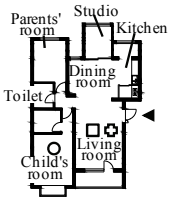
Boy 2	Living room	Dining room	Kitchen	Parents' room	Child's room	Studio	Toilet
Living room	5.5(9.2)	0.2(0.3)+	0	18.0(30.0)*	1.6(2.7)	-	0.2(0.3)
Dining room	1.8(3.0)+	7.5(12.5)**	0.5(0.8)	6.6(11.0)	0.2(0.3)	-	0.2(0.3)
Kitchen	3.0(5.0)	0.9(1.5)	0.4(0.7)	9.7(16.2)	1.1(1.8)	-	0.4(0.7)
Parents' room	0.2(0.3)	0	0	0.7(1.2)	0	-	0
Toilet	0.4(0.7)	0	0	0.9(1.5)	0	-	0

Survey days:3 Both at home:5.6[hour](100) Stayed in connected rooms: 2[min/hour](3.3)



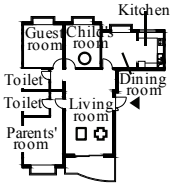
Boy 3	Living room	Dining room	Kitchen	Parents' room	Child's room	Studio	Toilet
Living room	7.4(12.3)**	0.7(1.2)+	0	0	34.5(57.5)*	0	0.6(1.0)
Dining room	0.8(1.3)+	1.2(2.0)	0.2(0.3)+	0	4.8(8.0)	0	0.1(0.2)
Kitchen	0.2(0.3)	0.1(0.2)+	0	0	4.5(7.5)	0	0.1(0.2)
Parents' room	1.9(3.2)	0.1(0.2)	0	0	0.5(0.8)	0	0
Child's room	0.1(0.2)	0	0	0	1.1(1.8)	0	0
Studio	0	0	0	0	0.2(0.3)	0	0
Toilet	0.6(1.0)	0	0	0	0.3(0.5)	0	0

Survey days:4 Both at home:41.4[hour](100) Stayed in connected rooms: 1.8[min/hour](3.0)



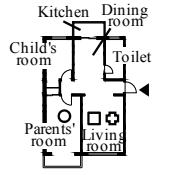
Boy 4	Living room	Dining room	Kitchen	Parents' room	Child's room	Studio	Toilet
Living room	10.6(17.6)**	0.1(0.2)	1.1(1.8)	0	38.6(64.3)*	-	0.1(0.2)
Dining room	0.1(0.2)	0	0	0	0.6(1.0)	-	0.1(0.2)
Kitchen	0.1(0.2)	0	0.1(0.2)	0	1.9(3.2)	-	0
Parents' room	0	0	0	0	0.2(0.3)	-	0
Child's room	0.1(0.2)	0.1(0.2)	0	0	4.4(7.3)	-	0
Toilet	0.4(0.6)	0	0.1(0.2)	0	1.3(2.1)	-	0

Survey days:3 Both at home:16.2[hour](100) Stayed in connected rooms: -



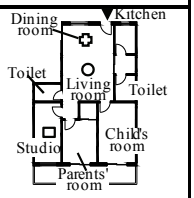
Girl 1	Living room	Dining room	Kitchen	Parents' room	Child's room	Studio	Toilet
Living room	9.7(16.2)**	2.4(4.0)+	0.1(0.2)	23.3(38.8)*	1.6(2.7)	-	0.9(1.5)
Dining room	3.9(6.5)+	1.9(3.2)	0	0.7(1.2)	3.4(5.7)	-	0.5(0.8)
Kitchen	0.7(1.2)	1.1(1.8)	0.1(0.2)	0.2(0.3)	0.3(0.5)	-	0.7(1.2)
Parents' room	1.5(2.5)	0.5(0.8)	0	0.4(0.7)	0	-	0
Child's room	0.3(0.5)	0.2(0.3)	0	0.7(1.2)	0.2(0.3)	-	0
Toilet	1.6(2.7)	0.5(0.8)	0	1.8(2.9)	0.8(1.3)	-	0

Survey days:4 Both at home:13[hour](100) Stayed in connected rooms: 6.3[min/hour](10.5)



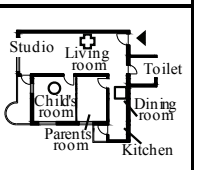
Girl 2	Living room	Dining room	Kitchen	Parents' room	Child's room	Studio	Toilet
Living room	2(3.3)	1.2(2)+	0.4(0.7)	0	0.4(0.7)	3.2(5.3)	0
Dining room	0+	2.8(4.7)**	0.4(0.7)	0	0.8(1.3)	0.4(0.7)	0
Kitchen	1.6(2.7)	2(3.3)	0	0	0.8(1.3)	0.4(0.7)	0
Parents' room	1.2(2.0)	0	0	0	0	0.8(1.3)	0
Studio	32.4(54.0)*	3.6(6.0)	2.4(4.0)	0	1.6(2.7)	0	0.8(1.3)
Toilet	0.8(1.3)	0	0	0	0	0	0

Survey days:2 Both at home:2.5[hour](100) Stayed in connected rooms: 1.2[min/hour](2.0)



Girl 3	Living room	Dining room	Kitchen	Parents' room	Child's room	Studio	Toilet
Living room	0.9(1.5)**	0	0	0	4.4(7.3)	1.2(2.0)+	0.3(0.5)
Dining room	0.6(1.0)	0	0	0	48.8(81.4)*	2.3(3.8)	1.2(2.0)
Toilet	0	0	0	0	0.3(0.5)	0	0

Survey days:3 Both at home:3.4[hour](100) Stayed in connected rooms: 1.2[min/hour](2.0)



*: The longest duration that father and child stay in separate rooms.
**: The longest duration that father and child stay in one room
+: Duration in connected rooms

○ The room that the child tended to stay when the father and child stay at home.
□ The room that the father tended to stay when the father and child stay at home.
✿ The room that the father and child tended to stay together.

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Figure 5-4 Distribution of the rooms that the father and child stayed in and the duration of their stay during the period when they were both at home

room not because they preferred quiet or solitude, but because they could install their PC on the table and work there. Although there was a studio in the house of Girl 3, it

was occupied by the mother. This kind of stay, in which the fathers stayed in the studio or dining room in order to work, while their children stayed in the living room or child's room, occupied over 50% of the time when the father and child both stayed at home.

The duration that the child and father stayed in connected rooms in the survey period was not long for all the subjects who had connected rooms in their respective dwellings (no more than 5% for Boy 2, Boy 3, Girl 2, and Girl 3) except for Girl 1 (10.5%).

However, for Girls 2 and 3, who did not stay together with their fathers long, this kind of stay might be meaningful. This kind of stay was observed when the fathers stayed in the living room (Girl 2 and Girl 3 were staying in the dining room and studio, respectively). This indicates that the father might have had more opportunities to meet the child if he had stayed in the living room.

5.3.3 Duration and frequency of time spent together and speech between the child and the father

In this chapter, there are four ways in which a child stays together with his/her father:

① The child stays with the father in the same room.

② The child stays with both the father and mother in the same room.

③ The child and father stay in connected rooms (Such as when the child stays in the living room and the father stays in the dining room in the house of Boy 2), and the mother is absent.

④ The child and father stay in connected rooms, and the mother stays with either of them.

The average duration (*D*) and frequency (*F*) of the father and child staying together per hour that they both stayed at home over the whole survey period were calculated. The author also calculated the average duration (*Dt* [Min]) and frequency (*Ft* [times]) that either the child or the father spoke per hour of the time they both stayed at home.

When ① or ② occurred, most subjects tended to stay and talk in one room (either of *D*, *F*, *Dt*, or *Ft* was highest in this room), and they tended to talk every time they stayed there ($F_1 = Ft_1$, $F_2 = Ft_2$). ② for Girl 2 was the exception: she tended to stay in the dining room longer but also stayed frequently and talked in the living room. When ① occurred, Girl 2 and her father tended to stay and talk in both the living and dining rooms.

Table 5-3 Duration and Frequency of Time Spent Together and Speech in ①

	Living room		Dining room		Kitchen		Parents' room		Child's room		Sum	
	$D_1(F_1)$	Dt_1 (Ft_1)	$D_1(F_1)$	Dt_1 (Ft_1)	$D_1(F_1)$	Dt_1 (Ft_1)	$D_1(F_1)$	Dt_1 (Ft_1)	$D_1(F_1)$	Dt_1 (Ft_1)	$D_1(F_1)$	Dt_1 (Ft_1)
Boy 1	2*(0.7**)	0.8*(0.7**)	0(0)	0(0)	0(0)	-	0(0)	0(0)	0.5(0.3)	0.4(0.3)	2.5(1)	1.2(1)
Boy 2	1.6(0.7)	1.3(0.7)	2.3*(0.9**)	2.1*(0.9**)	0.4(0.4)	-	0.7(0.5)	0.5(0.5)	0(0)	0(0)	5(2.5)	3.9(2.5)
Boy 3	2.3*(0.5**)	1.3*(0.5**)	0.2(0.1)	0.2(0.1)	0(0)	-	0(0)	0(0)	0.9(0.4)	0.7(0.4)	3.4(1.1)	2.2(1.1)
Boy 4	0.2(0.2)	0.2(0.2)	0(0)	0(0)	0.1(0.1)	-	0(0)	0(0)	3*(0.7**)	1.8*(0.7**)	3.3(1)	2(1)
Girl 1	9.2*(2.3**)	9.1*(2.3**)	1.5(0.4)	1.3(0.4)	0.1(0.1)	-	0.2(0.2)	0.2(0.2)	0.2(0.1)	0.2(0.1)	11.2(3)	10.8(3)
Girl 2	1.2*(0.4**)	0.4*(0.4**)	1.2*(0.4**)	0.4*(0.4**)	0(0)	-	0(0)	0(0)	0(0)	0(0)	2.4(0.8)	0.8(0.8)
Girl 3	0.3*(0.3**)	0.3*(0.3**)	0(0)	0(0)	0(0)	-	0(0)	0(0)	0(0)	0(0)	0.3(0.3)	0.3(0.3)

D_1 [min/hour]: average duration that the child and father stayed in same room per hour that they stayed at home *: the longest duration

F_1 [times/hour]: average frequency that the child and father stayed in same room per hour that they stayed at home **: the highest frequency

Dt_1 [min/hour]: average duration that the child and father stayed in same room and either of them had talked per hour that they stayed at home

Ft_1 [times/hour]: average frequency that the child and father stay in same room and either of them had talked per hour that they stayed at home

Table 5-4 Duration and Frequency of Time Spent Together and Speech in ②

	Living room		Dining room		Kitchen		Parents' room		Child's room		Sum	
	$D_2(F_2)$	$Dt_2(Ft_2)$	$D_2(F_2)$	$Dt_2(Ft_2)$	$D_2(F_2)$	$Dt_2(Ft_2)$	$D_2(F_2)$	$Dt_2(Ft_2)$	$D_2(F_2)$	$Dt_2(Ft_2)$	$D_2(F_2)$	$Dt_2(Ft_2)$
Boy 1	9.9*(0.7**)	5.2*(0.7**)	0(0)	0(0)	0(0)	-	0(0)	0(0)	0(0)	0(0)	9.9(0.7)	5.2(0.7)
Boy 2	3.9(0.2)	3.8(0.2)	5.2*(0.7**)	5.2*(0.7**)	0(0)	-	0(0)	0(0)	0(0)	0(0)	9.1(0.9)	8.9(0.9)
Boy 3	5*(0.6**)	3.3*(0.6**)	1(0.2)	0.8(0.2)	0(0)	-	0(0)	0(0)	0.2(0)	0.2(0)	6.3(0.9)	4.3(0.9)
Boy 4	10.3*(1**)	7.9*(1**)	0(0)	0(0)	0(0)	-	0(0)	0(0)	1.4(0.1)	1.2(0.1)	11.7(1.2)	9.1(1.2)
Girl 1	0.5*(0.3**)	0.5*(0.3**)	0.4(0.1)	0.4(0.1)	0(0)	-	0.2(0.1)	0.2(0.1)	0(0)	0(0)	1.1(0.5)	1.1(0.5)
Girl 2	0.8(0.8**)	0.4*(0.4**)	1.6*(0.4)	0(0)	0(0)	-	0(0)	0(0)	0(0)	0(0)	2.4(1.2)	0.4(0.4)
Girl 3	0.6*(0.3**)	0.6*(0.3**)	0(0)	0(0)	0(0)	-	0(0)	0(0)	0(0)	0(0)	0.6(0.3)	0.6(0.3)

D_2 [min/hour]: average duration that the child and parents stayed in same room per hour that they stayed at home *: the longest duration

F_2 [times/hour]: average frequency that the child and parents stayed in same room per hour that they stayed at home **: the highest frequency

Dt_2 [min/hour]: average duration that the child and parents stayed in same room and either child or father had talked per hour that they stayed at hom

Ft_2 [times/hour]: average frequency that the child and parents stayed in same room and and either child or father had talked per hour that they stayed at home

Boy 1, Boy 3, Girl 1, and Girl 3 tended to stay together with their fathers and talk in the living room when ① or ② occurred. Boy 2 tended to stay together with his father and talk in the dining room when ① or ② occurred. Boy 4 tended to stay together with his father and talk in the child's room in ①, and they tended to stay and talk in the living room in ②.

The living room was the first most-used room and the dining room was the second most-used room, in which the child and the father stayed together and talked (Tables 5-3 and 5-4).

When staying together in connected rooms (③ and ④), the subjects tended to stay and talk in the living and dining rooms that were connected to each other. The subjects talked almost every time they stayed in connected rooms, with the exception of Boy 3, whose duration and frequency of speech were less than those in the period during which they stayed in connected rooms (Tables 5-5 and 5-6).

The author compared the summation of duration and frequency of time spent together and speech in ① and ③, which focus on time spent between the child and

Table 5-5 Duration and Frequency of Time Spent Together and Speech in ③

	Living room and Dining room		Dining room and kitchen		Living room and Studio		Sum	
	$D_3(F_3)$	Dt_3 (Ft_3)	$D_3(F_3)$	Dt_3 (Ft_3)	$D_3(F_3)$	Dt_3 (Ft_3)	$D_3(F_3)$	Dt_3 (Ft_3)
Boy 1	-	-	-	-	-	-	-	-
Boy 2	0.6(0.2)	0.6(0.2)	-	-	-	-	0.6(0.2)	0.6(0.2)
Boy 3	0.1(0.1)	0.1(0.1)	0.1(0.1)	-	-	-	0.2(0.2)	0.1(0.1)
Boy 4	-	-	0	-	-	-	0	-
Girl 1	4.8(2.2)	4.7(2.2)	-	-	-	-	4.8(2.2)	4.7(2.2)
Girl 2	1.2(0.4)	1.2(0.4)	-	-	-	-	1.2(0.4)	1.2(0.4)
Girl 3	-	-	0	0	0	0	0	0

D_3 [min/hour]: average duration that the child and father stayed in connected rooms per hour that they stayed at home
F_3 [times/hour]: average frequency that the child and father stayed in connected rooms per hour that they stayed at home
Dt_3 [min/hour]: average duration that the child and father stayed in connected rooms and at least one of them had talked per hour that they stayed at home
Ft_3 [times/hour]: average frequency that the child and father stayed in connected rooms and at least one of them had talked per hour that they stayed at home
— : There was no such space in the subject house

Table 5-6 Duration and Frequency of Time Spent Together and Speech in ④

	Living room and Dining room		Dining room and kitchen		Living room and Studio		Sum	
	$D_4(F_4)$	Dt_4 (Ft_4)	$D_4(F_4)$	Dt_4 (Ft_4)	$D_4(F_4)$	Dt_4 (Ft_4)	$D_4(F_4)$	Dt_4 (Ft_4)
Boy 1	-	-	-	-	-	-	-	-
Boy 2	1.4(0.9)	1.4(0.9)	-	-	-	-	1.4(0.9)	1.4(0.9)
Boy 3	1.4(0.6)	1(0.5)	0.2(0.1)	-	-	-	1.6(0.7)	1 (0.5)
Boy 4	-	-	0	-	-	-	0	-
Girl 1	1.5(0.5)	1.5(0.5)	-	-	-	-	1.5(0.5)	1.5(0.5)
Girl 2	0	0	-	-	-	-	0	0
Girl 3	-	-	0	0	1.2(0.9)	1.2(0.9)	1.2(0.9)	1.2(0.9)

D_4 [min/hour]: average duration that the child and father stayed in connected rooms per hour that they stayed at home(mother stayed in either room)
F_4 [times/hour]: average frequency that the child and father stayed in connected rooms per hour that they stayed at home(mother stayed in either room)
Dt_4 [min/hour]: average duration that the child and father stayed in connected rooms and at least one of them had talked per hour that they stayed at home(mother stayed in either room)
Ft_4 [times/hour]: average frequency that the child and father stayed in connected rooms and at least one of them had talked per hour that they stayed at home(mother stayed in either
— : There was no such space in the subject house

father, with ② and ④, which focus on the time that both the child and father spent in the presence of the mother. For the boys, the duration and frequency of staying and talking in ③ and ④ tended to be less than that in ① and ②, respectively, and the duration of staying and talking in ③ and ④ were less than 1/4 of that in ① and ②. Boy 2 in ④ was an exception, and the frequency of his stays and talks was equal to that in ②. For the girls who spent time in ③ and ④, the duration and frequency of stays and talks for Girl 1 in ③ was less than that in ①. The duration of stays and talks of the two girls in ④ was more than that when ② occurred (Tables 5-3, 5-4, 5-5, and 5-6).

5.3.4 Comparison of vocal duration when child and father stayed together

In order to know who was more vocal when the father and child stayed together, the author compared their vocal duration. Owing to the fact that when the child stayed together with both parents, the vocal duration might include speech with the mother, the author only compared the vocal duration for the period when the child stayed together with the father only.

It is regarded as one case that a certain child stayed together with his father in a certain room and either of them had talked. In over half of the cases when the child stayed together with the father in common rooms (living room, dining room, or the space where the living room connected with the dining room), the child spoke over 1.6 times more than the father. However, in the individual rooms (parents' room or child's room), especially in the child's room, the child always spoke less than the father, and the duration of child's speech is less than 70% of that of the father (Table 5-7).

Table 5-7 Average vocal duration in the period that child and father stayed together during the whole survey period

ID	Common room									Individual room					
	Stay in the same room						Stay in connected rooms			Stay in the same room					
	Living room			Dining room			Living room and dining room			Parents' room			Child's room		
	Vc	*Vf*	*Vc/Vf*	*Vc*	*Vf*	*Vc/Vf*	*Vc*	*Vf*	*Vc/Vf*	*Vc*	*Vf*	*Vc/Vf*	*Vc*	*Vf*	*Vc/Vf*
Boy 1	0.7	1.8	0.4	-	-	-	-	-	-	-	-	-	0.6	0.9	0.7
Boy 2	6.3	7	0.9	11.3	35	0.3	7.1	3.8	1.9	0.5	3.2	0.2	-	-	-
Boy 3	4.2	1.6	2.6	0.8	0.2	4	0	0.1	0	-	-	-	1.3	3.6	0.4
Boy 4	1.3	0.8	1.6	-	-	-	-	-	-	-	-	-	2.7	4	0.7
Girl 1	41	58.6	0.7	6.5	8	0.8	34.1	14.1	2.4	1.2	2.2	0.5	0.1	1	0.1
Girl 2	7.6	13.2	0.6	0.8	0	∞	5.2	0	∞	-	-	-	-	-	-
Girl 3	6.8	1.2	5.7	-	-	-	-	-	-	-	-	-	-	-	-
Vf<*Vc*	3			2			3			0			0		
Vf>*Vc*	4			2			1			2			4		

Vc [second/hour]: Child's average vocal duration per hour when both the father and child stayed at home
Vf [second/hour]: Father's average vocal duration per hour when both the father and child stayed at home
— : The child did not stay together with the father in this room/space

5.4 Conclusion

In chapter five, the author identified which rooms the father and child tended to stay in together and talk, and which rooms they stayed in separately by using Active RFID devices and an audio recorder. The reasons they stayed there were obtained by conducting short interviews. The findings are as follows:

1) The father tended to stay in the same room or connected rooms with the child for less time than the mother. On average, when with the child, the duration of father's

speech is about 20% shorter than the mother.

2) The instances in which child and father stayed in different rooms fell into two groups: i) five of the seven subject fathers tended to stay in the living room, whereas the children stayed in the child's room or in the parents' room in order to use PC; ii) there were also two subject fathers who stayed in the studio or dining room in order to work, while their children stayed in the living room or the child's room. For both groups, the duration of these periods of stay covered 30.0–81.4% of the time when both the father and child stayed at home.

3) The father stayed together with the child for 0.5-25% of the time when both the father and child were at home. The use of the living room as the place, in which the child stay with the father and either of them had talked, was found to be the highest (five out of seven families), followed by the dining room and the child's room. They also stayed and talked in living rooms and dining rooms that were connected to each other. For the boys, the duration of this kind of time spent together tended to be less than 1/4 of that if they stayed with the father in the same room.

4) In over half of the cases in which the child stayed with the father in the living room or dining room, the child spoke over 1.6 times more than the father. However, in all cases in individual rooms, particularly the child's room, the child always spoke less than the father, and the duration of the child's speech was less than 70% of that of the father.

Based on the detailed room use analyzed above, it is regarded that the following points are important for the room layout planning for the only-child families studied:

1) The child was likely to speak more than his father in the common rooms, which are therefore considered to be places where equal levels of conversation might occur and a better place for communication than the individual rooms. Thus, in order to improve father-child communication, it is important to increase their time spent together in the common rooms, particularly in the living room.
2) The reason that the living room is often not used is the lack of PC or space to work. Thus, the use of the living room can be increased by increasing the spatial attraction of the living rooms, such as spaces where the father could work and the child could use PC.

Notes

*1. Tangshan is an industrial city in Hebei province, located southeast of Beijing. The area is 13,472 km^2 and the population is 7.35 million (as of 6/2009).

Before correction

	Counts of received signals in each room			Missing signals	Sum
Time	Living room	Kitchen	Dining room		
8:28:00	1	3	50	6	60
8:29:00		45	2	13	60

→

After correction

Time	Staying room
8:28:00	Dining room
8:29:00	Kitchen

Figure 5-5 Example of correction of data

*2. Since the previous research (references 20 and 21 in chapter 1) indicated that the problem of fathers communicating with their children less frequently than mothers occurred among adolescents in general rather than among adolescents of a certain age, the author did not limit the subjects to senior or middle school students. Additionally, in our opinion, since our purpose is not a comparison between senior and middle school students but rather a clarification of the characteristics of individual cases, it does not matter if the author use subject girls aged 13, 17, or 19 years. According to the results, though the subject girl aged 13 (Girl 1) stayed with her father longer and more frequently than the older subjects, she faced the same problem as the other subjects in that she stayed with the father for a lesser duration than the mother. This indicates that this does not conflict with our purpose.

*3. Depending on the specific location of the resident, the reader in the adjacent room might receive signals sporadically, which the author regarded as noise. In order to reduce noise, RFID data was filtered every minute. The signals received by each reader in a minute were counted, and the room in which the reader received the most signals in a minute was specified as the resident's "staying room" in that minute (Fig. 5-5).

*4. The software that can identify vocal duration was designed by Sun Miqin.

References

1) Mehrabian and Ferris: Inference of Attitude from Nonverbal Communication in Two Channels, J. Couns. Psy, Vol. 31, 1967, pp.248-252

Chapter 6 Conclusions

6.1 Summary of the findings in each chapter

The uniqueness of this research lies in the clarification of the use of rooms in dwellings belonging to elderly couples living independently and one-child families in time series, in terms of the residents' actual movements between rooms, the rooms which multiple family members occupy together and talk, and the rooms in which they stay separately, which are factors which have not been studied objectively or precisely in the past. This has provided a deeper understanding of the space-time relationship in the dwellings of families comprised of multiple members, and formed a basis for designing room layout, in terms of the number and size of rooms and their relative location.

6.1.1 The validity of continuous recording by sensing technology

In chapter two, the author verified the position and parameter setting of the sensing device most likely to improve the accuracy of location detection and gave a method to precisely identify how the subject made use of the rooms in the house.

On one hand, a series of survey methods was verified:

1) Wearing two tags on the collar may increase the probability of receiving signals, and ensure the subject is less burdened during a lengthy survey;
2) In order to improve the accuracy of location detection, readers in adjacent rooms should be located as far away as possible from each other, and the correct sensitivity parameter (Pk) of the reader should be set according to the size of room (e.g. 150 for a room of about 15 m^2);
3) The noise in the signals received could be reduced by summing up the number of signals from each room every minute and stating the room with the most signals as the room in which the subject stayed.

In the other method, the characteristics of the room use of one single elderly woman over eight days were identified on the basis of the duration and frequency of stay in certain rooms and the frequency of movement between the rooms. The subject stayed for the longest duration (68% of the total time of stay) in the living room. She stayed in the living room 1.6 times more in duration during the night than during the day. The subject had stayed most frequently (36% of the total frequency of stay in certain rooms) in the kitchen. The author also recorded the subject moved between the living room and the kitchen 2.4 times per hour in average, which is at least 3.6 times more frequently than movements between other rooms. During either the morning,

afternoon or evening, she spent at least forty minutes per hour in the living room and kitchen, and moved between the two for more than 40% of the total movement which occurred between rooms. The author also found that the subject tended to stay in one room or in multiple rooms but would usually stay in one of them during a certain period for 79% of the whole survey period. This showed that she had a specific schedule of stay in certain rooms for most of the day.

Chapter three attempted to clarify the relationship between duration of stay in certain rooms and the room which the subject stayed in before or after this stay, using a probabilistic model. The findings showed that the duration for which the subject stayed in a certain room did not relate to the room which she occupied before or after the present stay; therefore, the duration of stay in certain rooms did not relate to the order of movement. Therefore, the characteristics of the duration of stay in certain rooms and the movement between rooms should be analyzed independently.

6.1.2 Findings concerning the room use by elderly couples living independently

Chapter four clarified, by studying individual cases, the daily personal room use in urban apartment houses belonging to Chinese elderly couples. The room use was identified on the basis of the room in which they stayed the longest (the base), the route between the pair of rooms that they passed through most frequently (the main link), and the room that had main links with the most other rooms (the hub). The main findings about their room use are as follows:

1) Throughout the day, the objective and subjective bases in accord was over twice as many for the husband as for the wife. For both the husband and wife, the ratio of objective and subjective bases in accord during the day was over one-and-a-half times more than during the evening. This shows that the base, in the mind of the subjects, indicated the room where they spent the most time during the day. The base where they spent the evening, which made less of an impression on the subjects, was the living room, where they stayed together for the whole evening;
2) The rooms that the couples stayed in together or separately vary with the time period. Most subject couples (five of them) tended to use the same room- the living room- as the base during the evening and different rooms- dining room, master bedroom, studio and kitchen-as bases during the day. There was also one subject couple, who tended to use the bedroom as their base during any given period;
3) Moreover, the author overlapped the patterns of main links of the two persons in a couple during all time periods and clarified the room that had a main link with most

other rooms (hub) for each couple. Four out of the six couples used living room, dining room or bed room, the bases of both the husband and wife in certain time periods, as the hub and the other two couples used the kitchen, the wife's base in the morning, as the hub.

The findings above suggest that the following points are important for the room layout planning for the elderly couples studied:

1) Reasonable number of rooms for the elderly people's individual use during the day;
2) Centralized position of the shared base room or the kitchen in a dwelling plan.

6.1.3 Findings concerning the communication of one-child families in rooms

In chapter five, the author identified which rooms a father and child tended to stay in together and talk, and which rooms they stayed in separately. The reasons they stayed there were obtained by conducting short interviews.

1) The instances in which child and father stayed in different rooms fell into two groups: i) five of the seven subject fathers tended to stay in the living room, whereas the children stayed in the child's room or in the parents' room in order to use PC; ii) there were also two subject fathers who stayed in the studio or dining room in order to work, while their children stayed in the living room or the child's room. For both groups, the duration of these periods of stay covered 30.0–81.4% of the time when both the father and child stayed at home.
2) The father stayed together with the child for 0.5-25% of the time when both the father and child stayed at home. The use of the living room as the place in which the child stay with the father and talk was found to be highest (five out of seven families), followed by the dining room and the child's room.
3) In over half of the cases in which the child stayed with the father in the living room or dining room, the child spoke over 1.6 times more than the father. However, in all cases in individual rooms, particularly the child's room, the child always spoke less than the father, and the duration of the child's speech was less than 70% of that of the father.

The findings above suggest that in order to improve father-child communication, it is important to increase their time spent together in the living room. It can be achieved by increasing the spatial attraction of the living rooms, such as spaces where the father could work and the child could use PC.

6.2 The findings of this dissertation

Dwellings with common and individual rooms, in which ordinary Chinese people who receive a salary usually live, have improved during the sustained economic growth of the last thirty years. In the time of welfare housing allocation, when the average usable living area per person was extremely low, controlling the dwelling area within limits had been the most important principle for designing room layout of a room. With commercialization and an increase in the area allowed for an urban apartment house, the ways in which a family makes use of the rooms have become a bigger priority in planning the layout. An increasing number of elderly couples living alone and one-child families have specific uses for rooms, which mean there are specific needs to be met in terms of the improvement of room layout planning.

Thus, this research used sensing technology to acquire and analyze precise survey data in the behaviors of specific families in the room use, including residents' movement frequency between rooms, the rooms in which multiple family members would stay together and talk or stay separately and the time when these activities happened. These factors can be hardly recorded continuously without imposing extra burden to the subjects if the sensing technology is not used.

In the experiments, the author identified and approved an optimized wearing position of the tag on research subject's body, in which way the readers may achieve good signal receptions, as well as it is convenient for the subject to wear the tag continuously. Then the author identified the relationship between the sensitivity parameter and detection range and accuracy of the readers. Furthermore, by using a probabilistic model, the author showed that the duration of stay in certain rooms does not relate to the room which the subject occupied previously or directly afterwards.

The main findings about room use of elderly couples living alone, identified by the sensing technology, are shown as follows:

The rooms that the couples stay in together or separately vary with the time period. Most subject couples (five out of six couples) tended to use a common room (living room) together during the evening and different rooms independently during the day. The movement between the room that both the husband and wife stayed in for the longest duration and other rooms was clarified. Four out of the six couples used living room, dining room or bed room, the bases of both the husband and wife in certain time periods, as the hub, from which they moved frequently to other rooms. The other two couples did not use this kind of room as the hub, but used the kitchen, a certain person's base in a certain time period, as the hub.

Based on the detailed room use analyzed above, it is regarded that the following points are important for the room layout planning for the elderly couples studied:

1) Reasonable number of rooms for the elderly people's individual use during the day;
2) Centralized position of the shared base room or the kitchen in a dwelling plan.

The main findings about room use of a father and child in a one-child family, identified by the sensing technology, are shown as follows:

When the child and the father occupied separate rooms, five out of seven subject fathers tended to stay in the common room (living room), whereas the child stayed in an individual room (the child's room or parents' room), where there was a PC. There were also two subject fathers who stayed in the studio or dining room in order to work, while their children stayed in the living room or the child's room. The duration of these periods of stay covered 30.0–81.4% of the time when both the father and child stayed at home. The father stayed together with the child in certain rooms for 0.5-25% of the time when both the father and child stayed at home. The use of the living room as the place in which the child stayed with the father and talked was found to be highest (five out of seven families), followed by the dining room and the child's room. In over half of the cases when staying with the father in a common room (living or dining room), the child spoke over 1.6 times more than the father. However, in all cases, in individual rooms, particularly in the child's room, the child always spoke less than the father, and the duration of child's speech was less than 70% of that of the father.

Based on the detailed room use analyzed above, it is regarded that the following points are important for the room layout planning for the only-child families studied:

1) The child was likely to speak more than his father in the common rooms, which are therefore considered to be places where equal levels of conversation might occur and a better place for communication than the individual rooms. Thus, in order to improve father-child communication, it is important to increase their time spent together in the common rooms, particularly in the living room.
2) The reason that the living room is often not used is the lack of PC or space to work. Thus, the use of the living room can be increased by increasing the spatial attraction of the living rooms, such as spaces where the father could work and the child could use PC.

The main results of this research are shown as follows:

1) The author propose methods that use sensing technology to acquire and analyze precise survey data in residents' daily behavior in room use, including their stay

and talk in certain rooms and movements between rooms.

2) Despite the subjects studied were based on specific and individual cases, by using the methods above, the author showed the characteristics of daily room use of subject families, as the basis for the improvement of dwelling layout for these families.

6.3 Future research

This research has clarified, by studying individual cases, the room use in precise time series, in aspects of residents' movement between rooms, variation of stay in certain rooms in each time period within the day and communication throughout all the rooms.

With the development of sensing technology, it is possible to obtain more detailed data about residents' location and daily routine, which has a great deal of relevance to design layout. Although rooms are the basic components of a dwelling, a resident's location within certain rooms- such as beside a window, on a sofa, or beside a certain table-indicates the spaces preferred by that specific individual.

In addition, in this research, the collective periods of stay in rooms as well as movement caused by daily living activities during the survey period, regardless of the nature of the activities themselves, were recorded through the Active RFID devices, and these data were regarded as the total room use. The nature of the activities during the periods of stay in certain rooms was not taken into account in this research, but the relationship between specific daily routine activities (relaxing, cooking, receiving guests, and so on) and dwelling space is also an important factor that needs to be clarified in future studies.

Furthermore, since the identification of the way in which a particular individual makes use of rooms is a significant step towards identifying the manner in which the general population makes use of rooms, it is necessary to conduct a survey examining the relationship between residents' detailed location and daily routine, using a sizable number of subjects.

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Chapter 2

屈小羽，松下大輔：アクティブ RFID タグを用いた住宅における部屋滞在行動観測手法(OBSERVATION ON ROOM-STAYING BEHAVIOR BY USING ACTIVE RFID)，日本建築学会計画系論文集(Journal of Architecture and Planning, Transactions of AIJ), Vol. 75, No. 650, 2010.04, pp.797-804 (published)

Chapter 3

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Chapter 4

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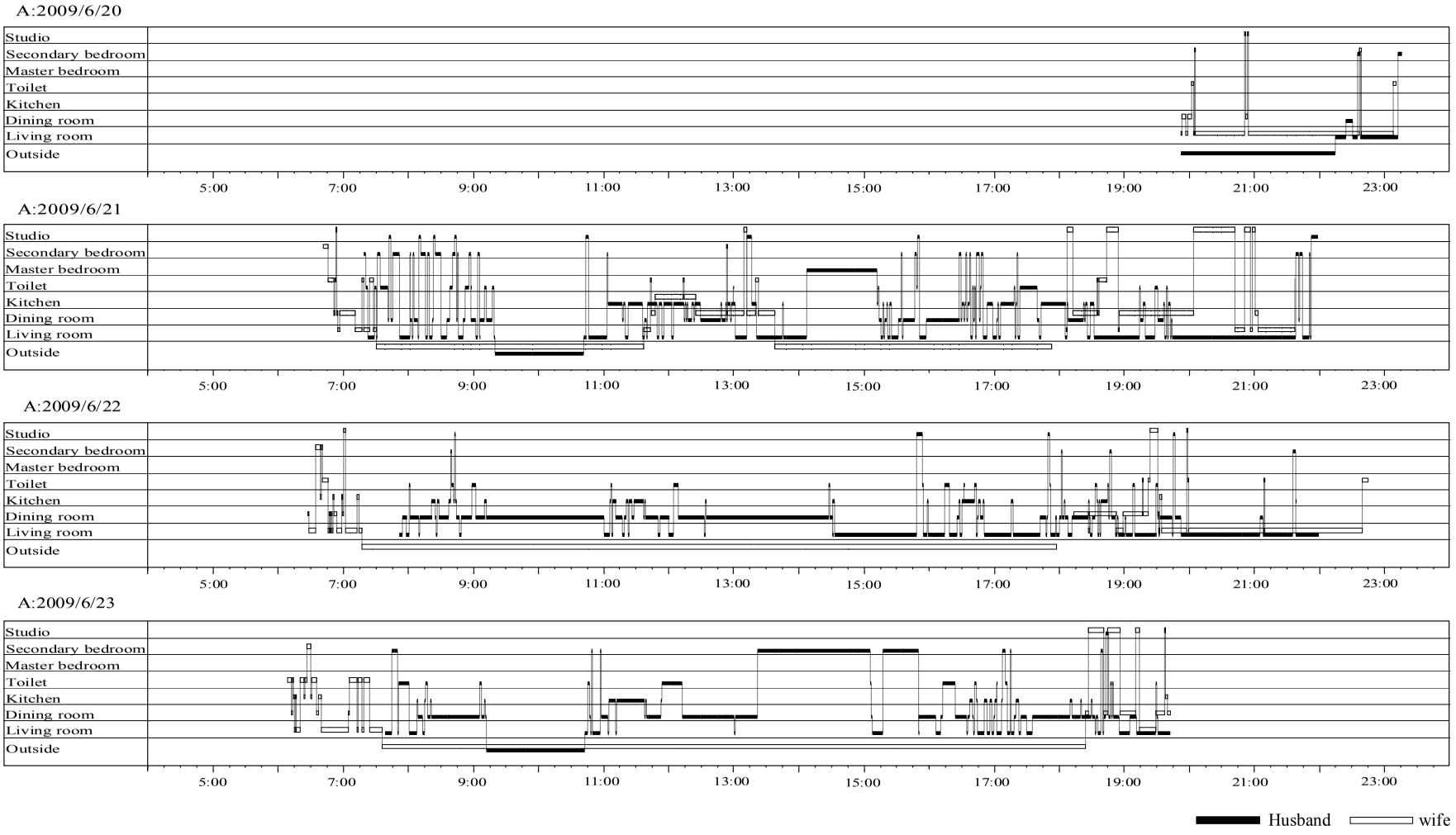
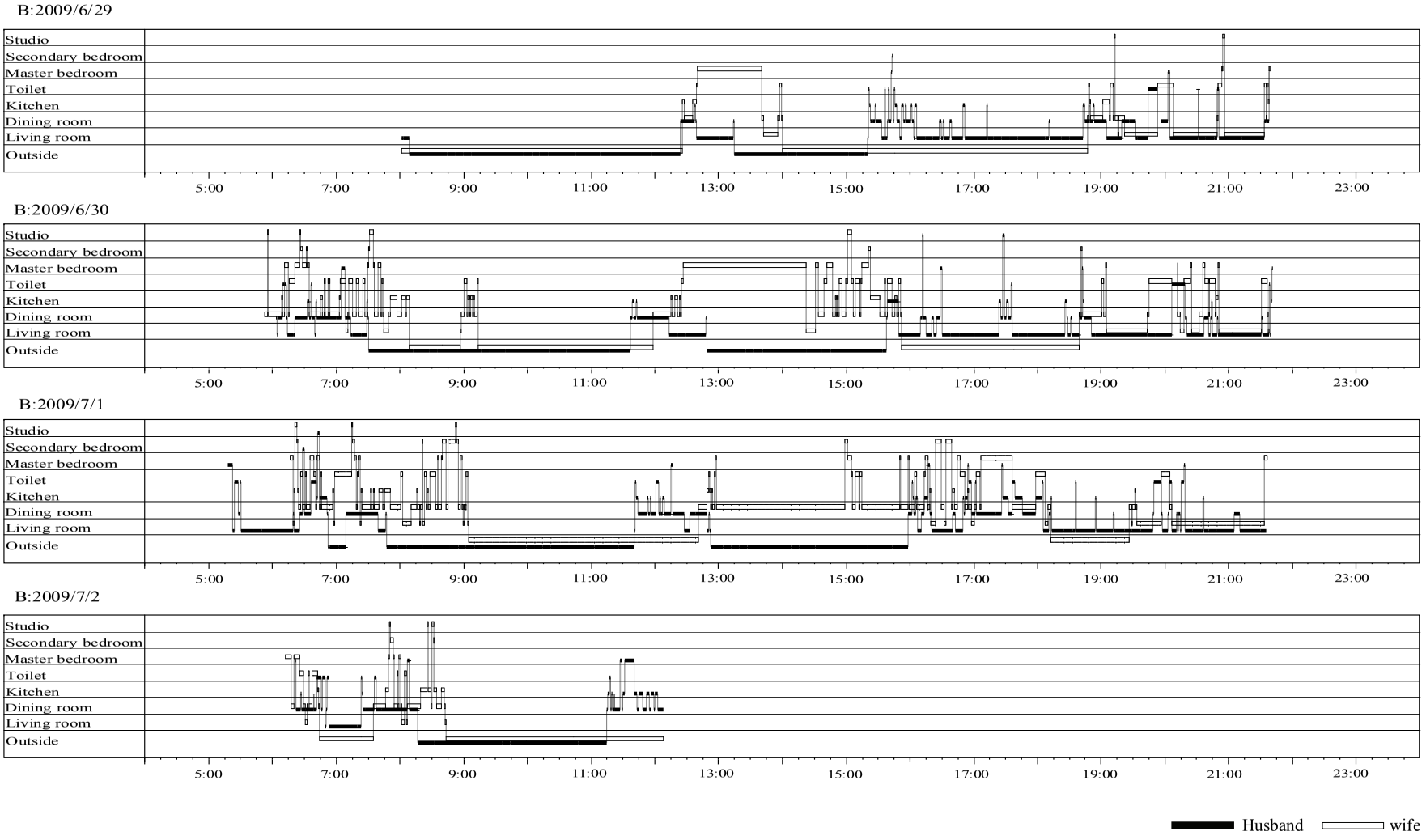
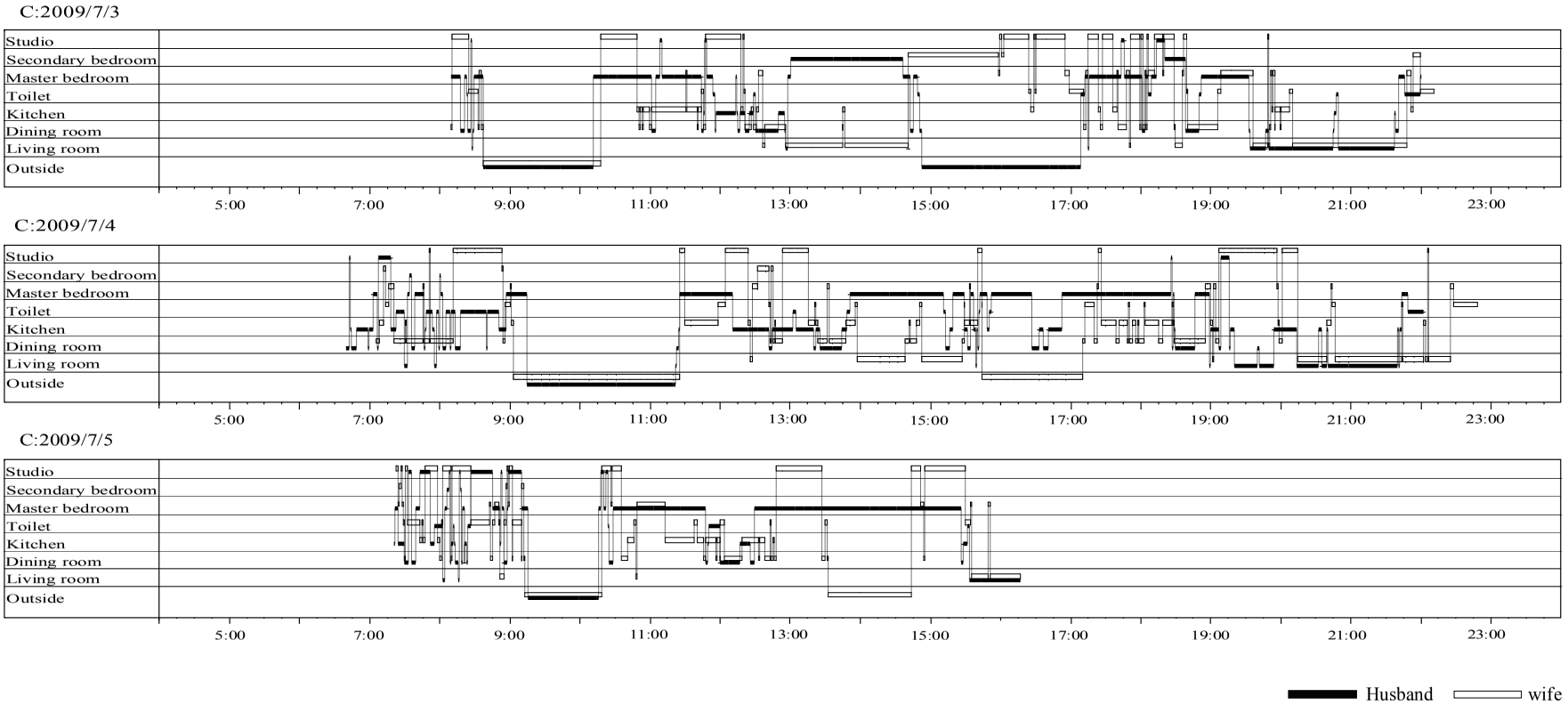
Appendix 1: Time series data of elderly couples during waking hours



Subject couple A



Subject couple B



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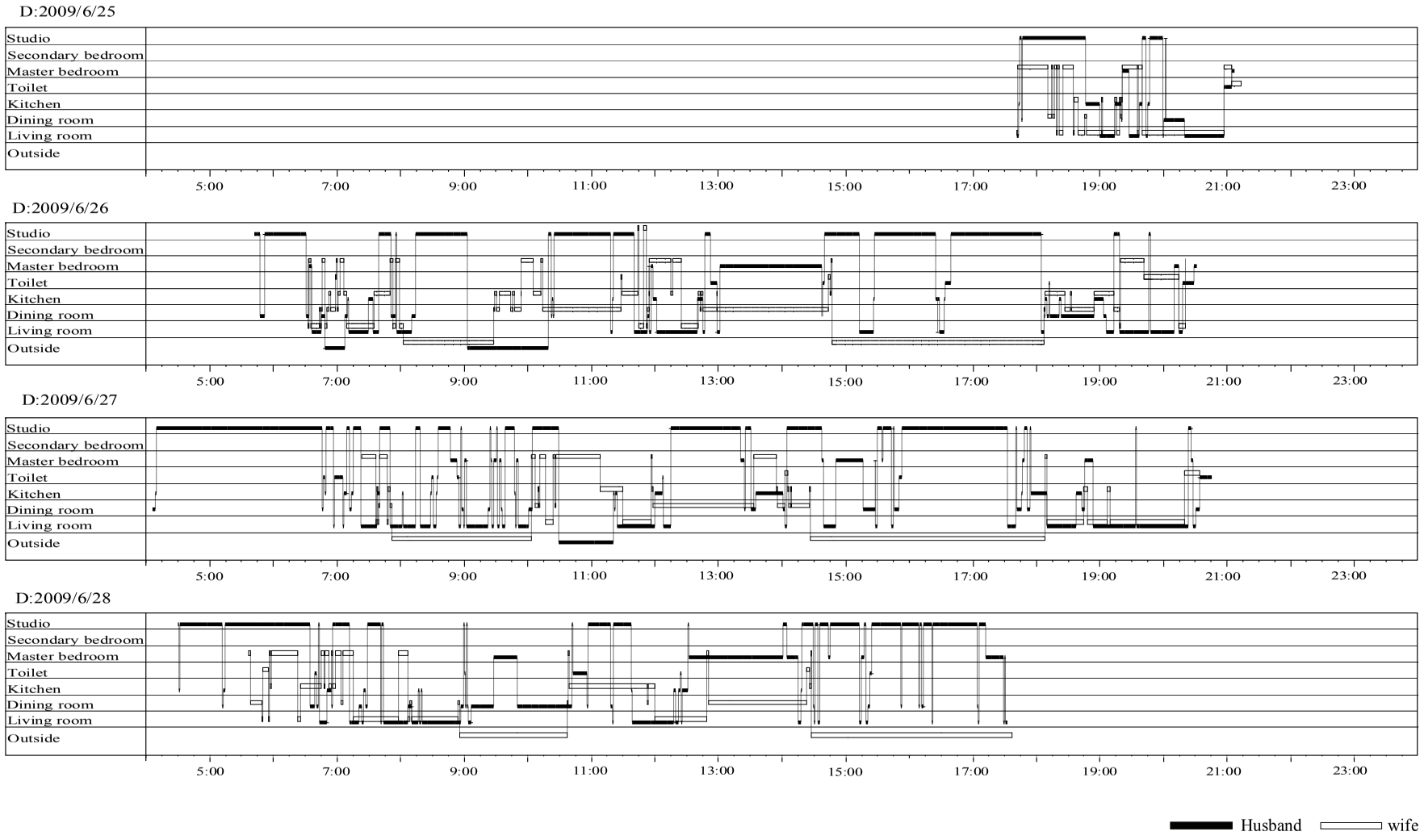

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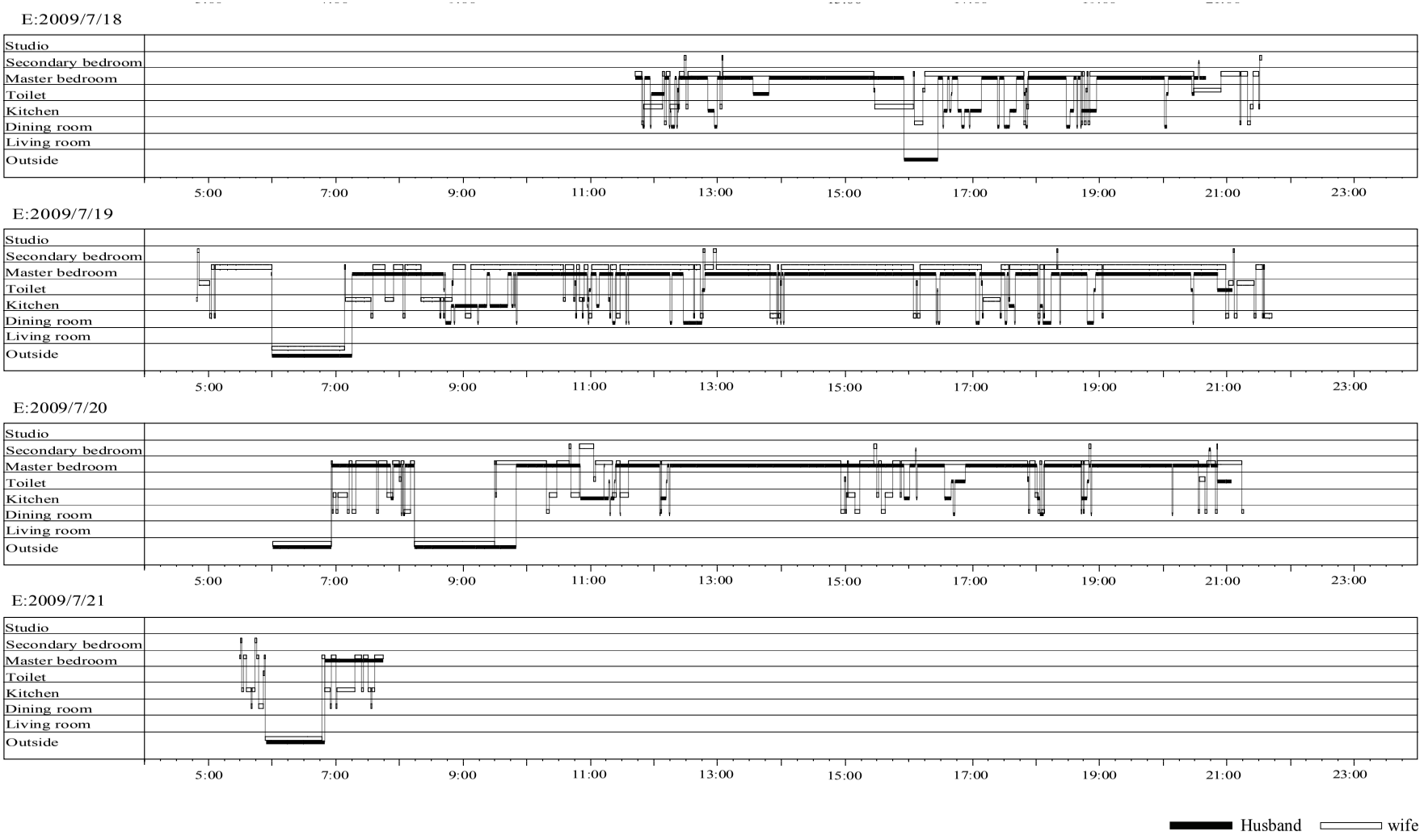
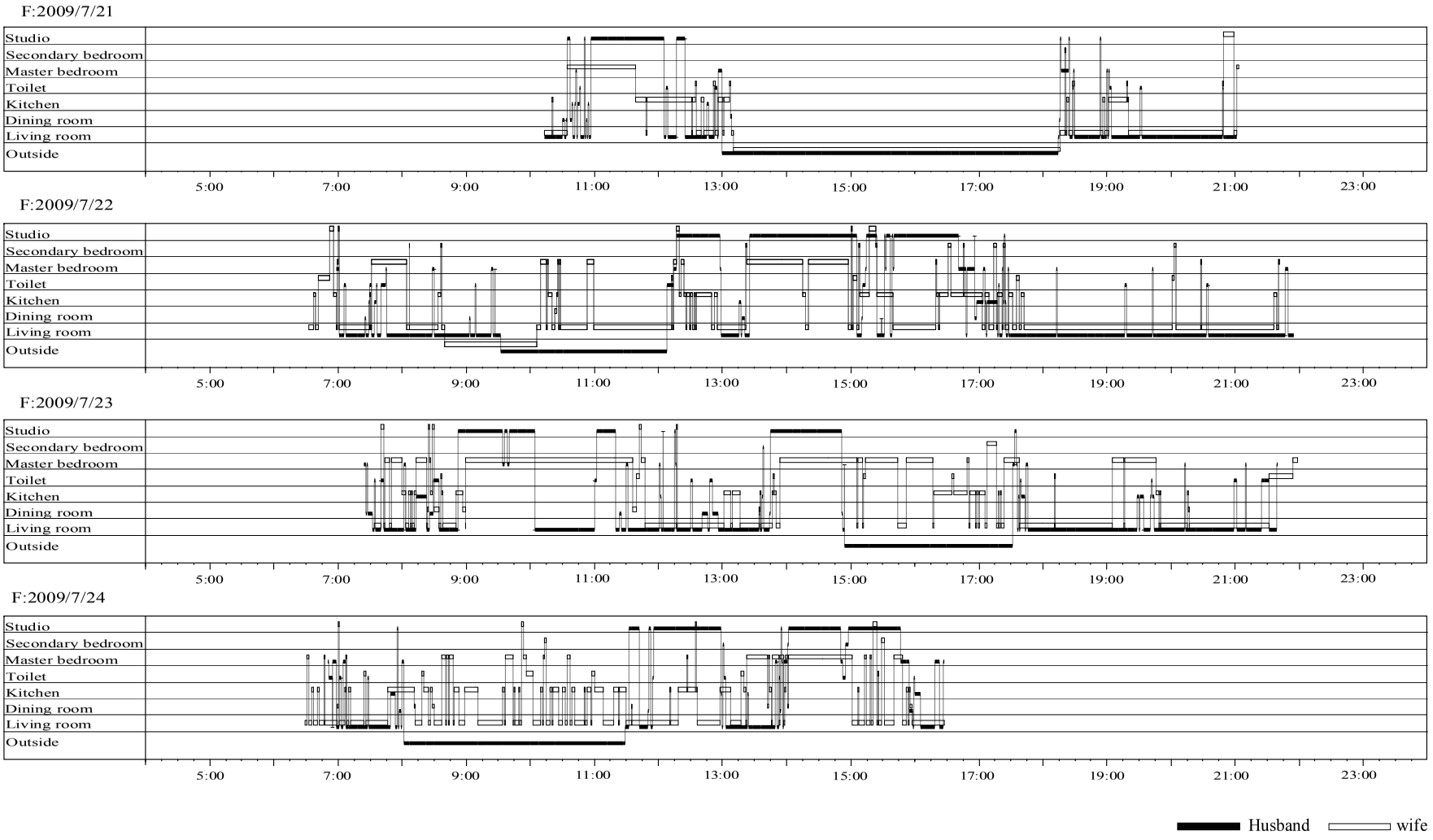
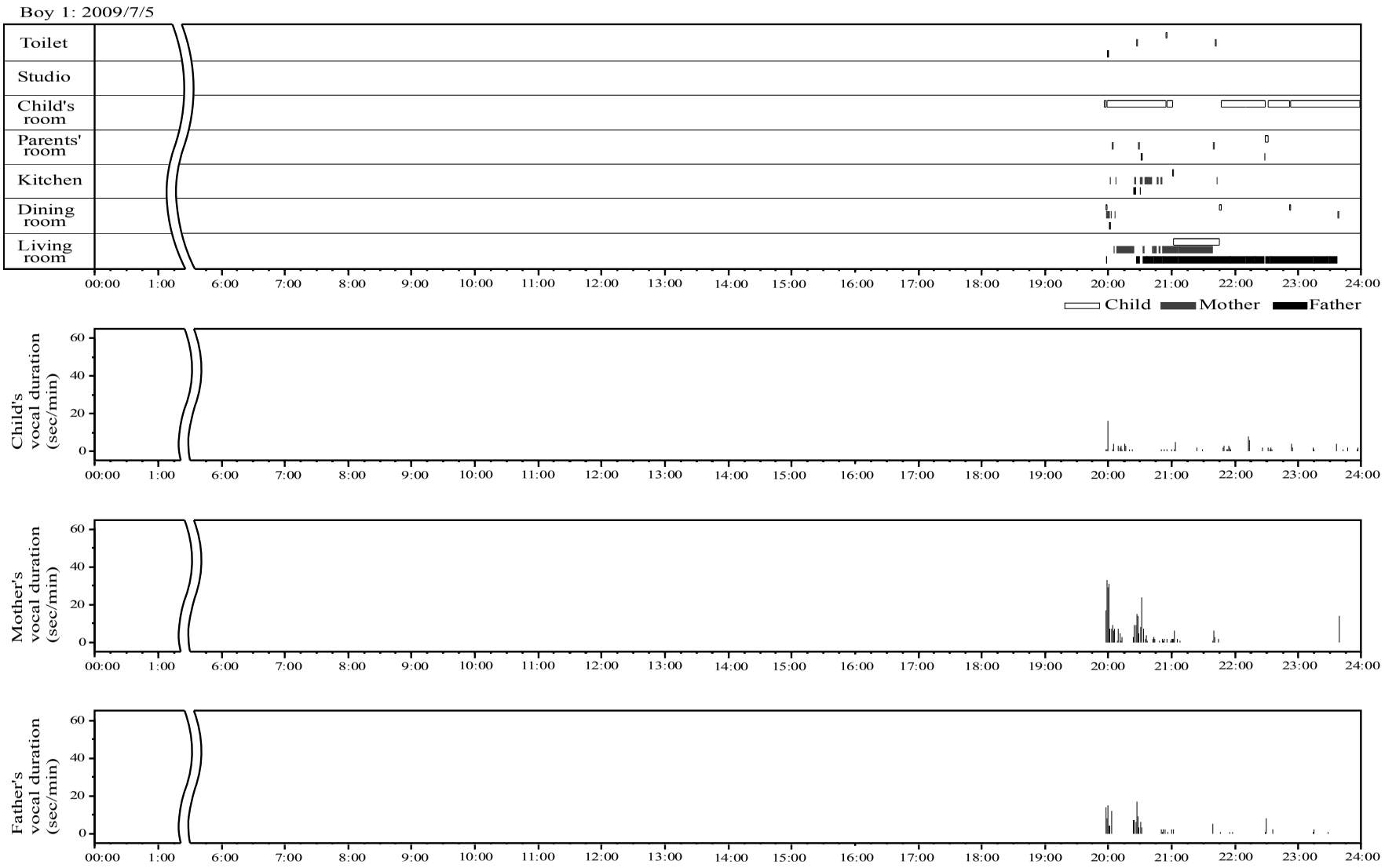


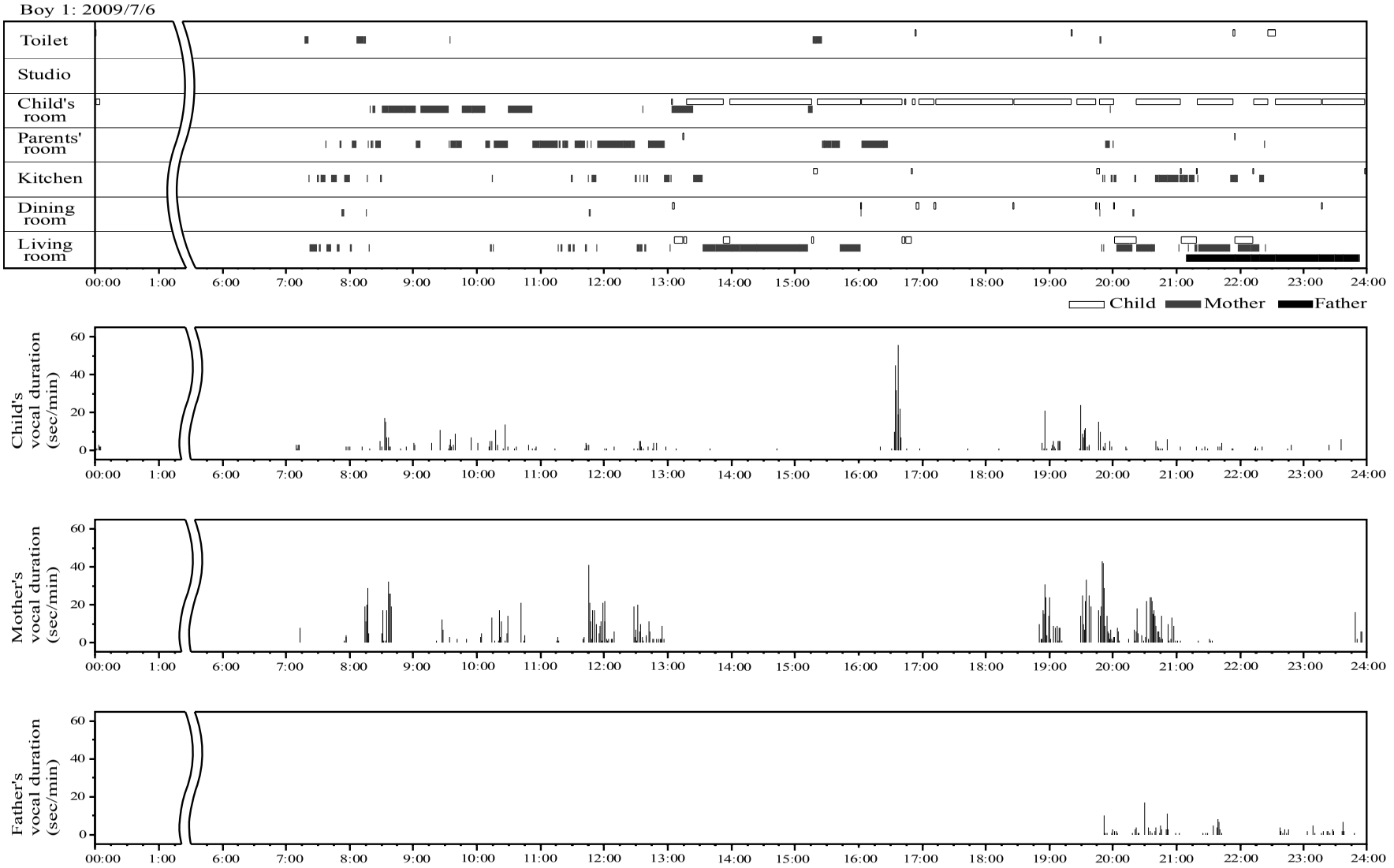
Subject couple E

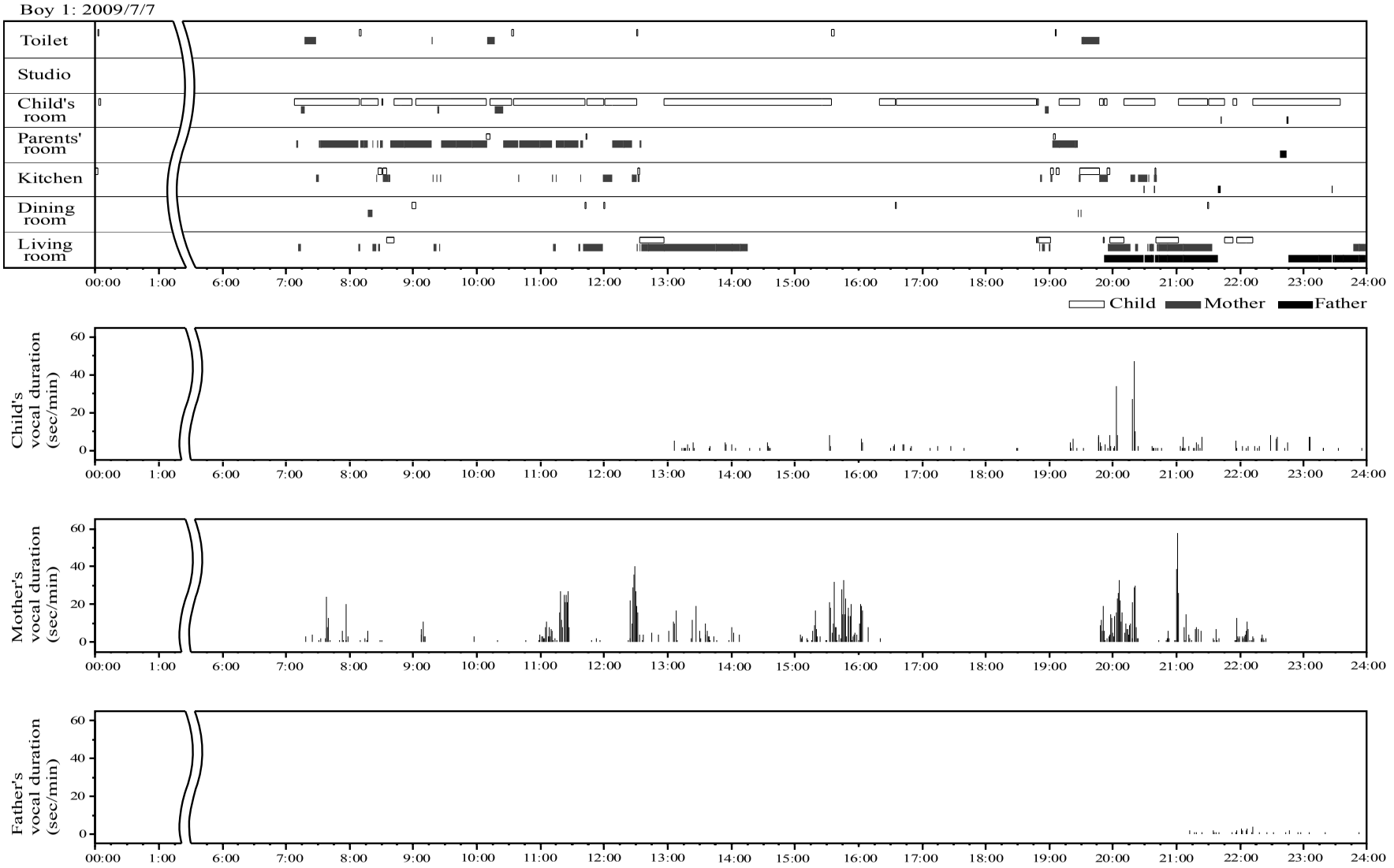


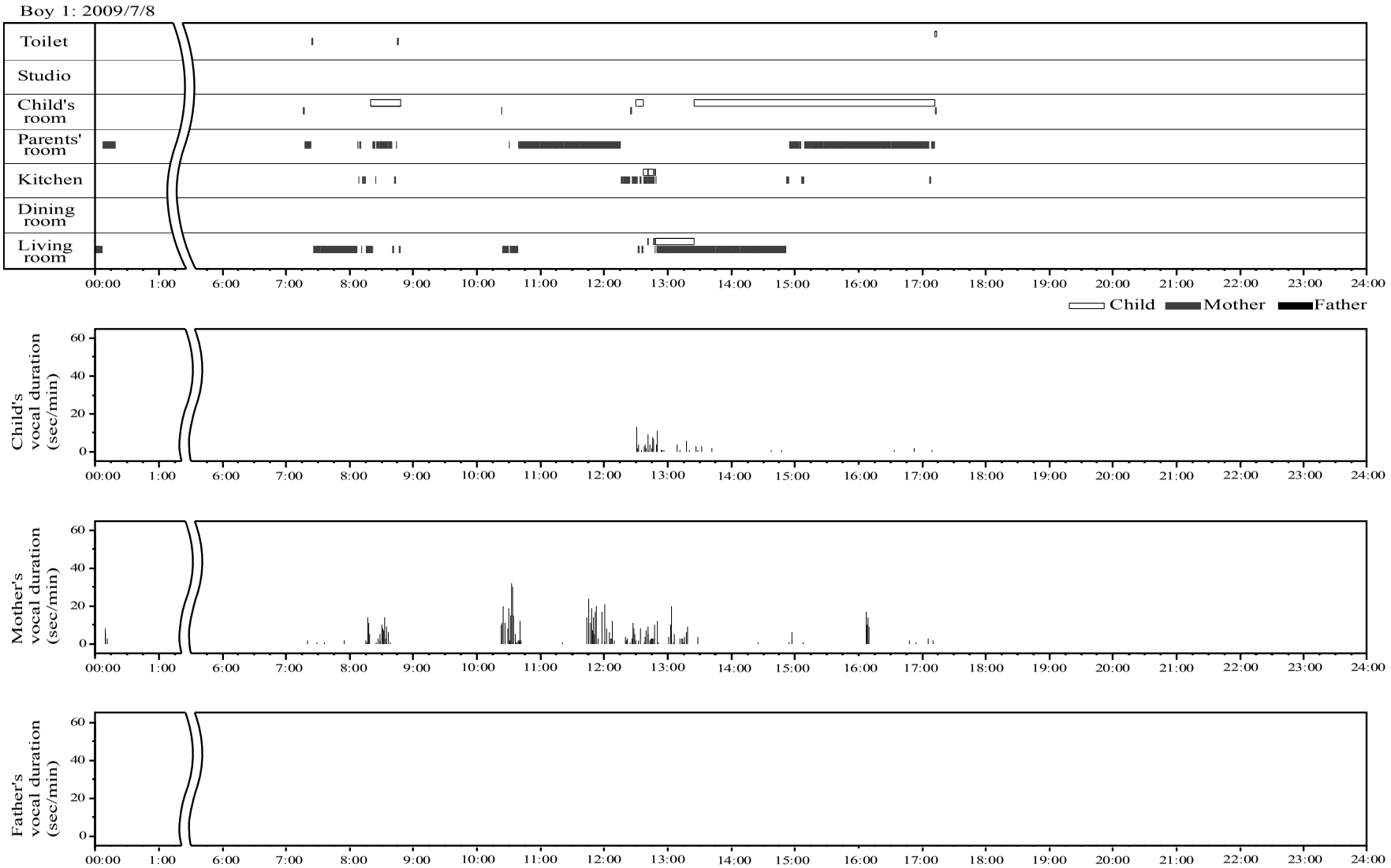
Subject couple F

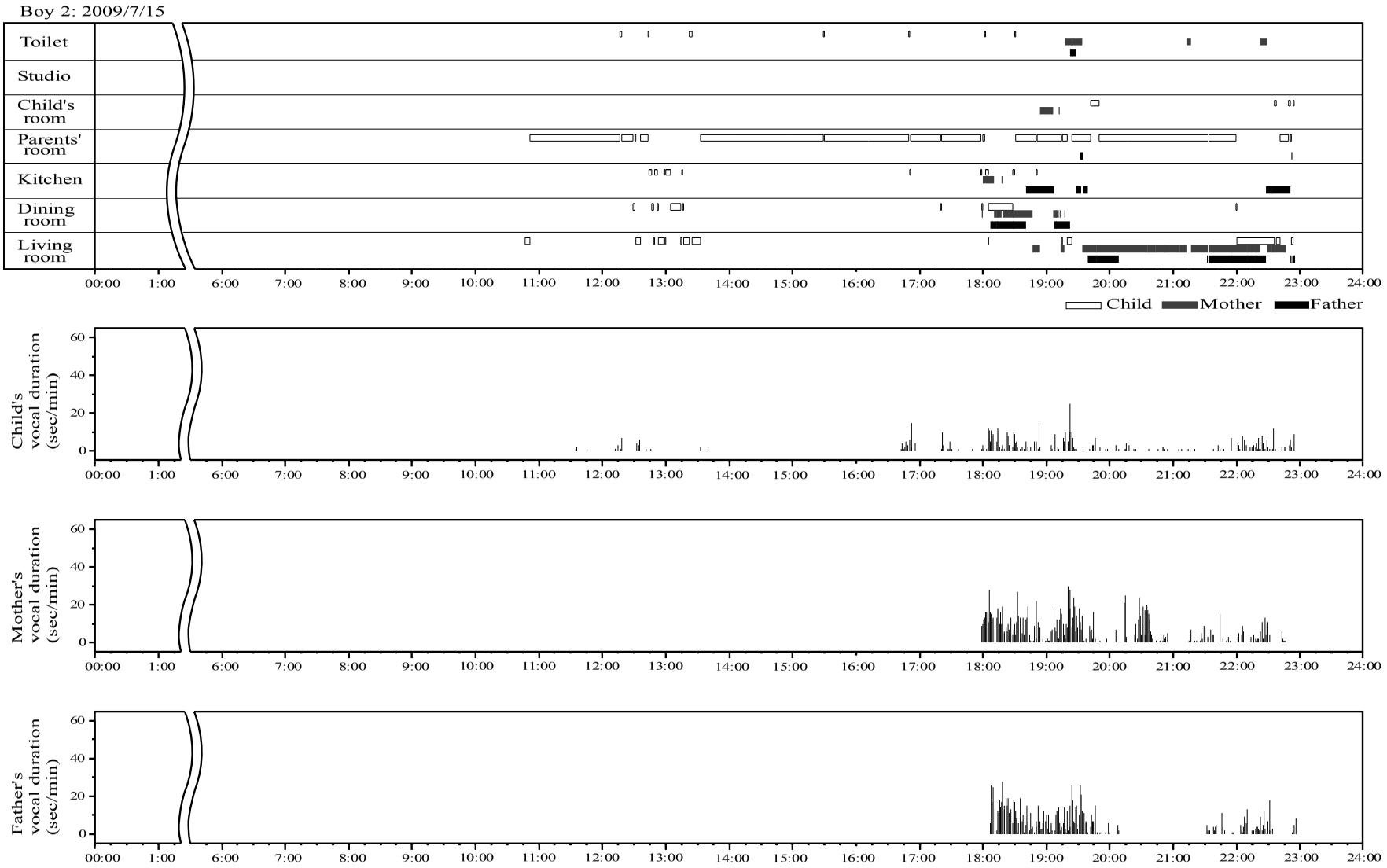
Appendix 2: Time series data of one-child families during waking hours

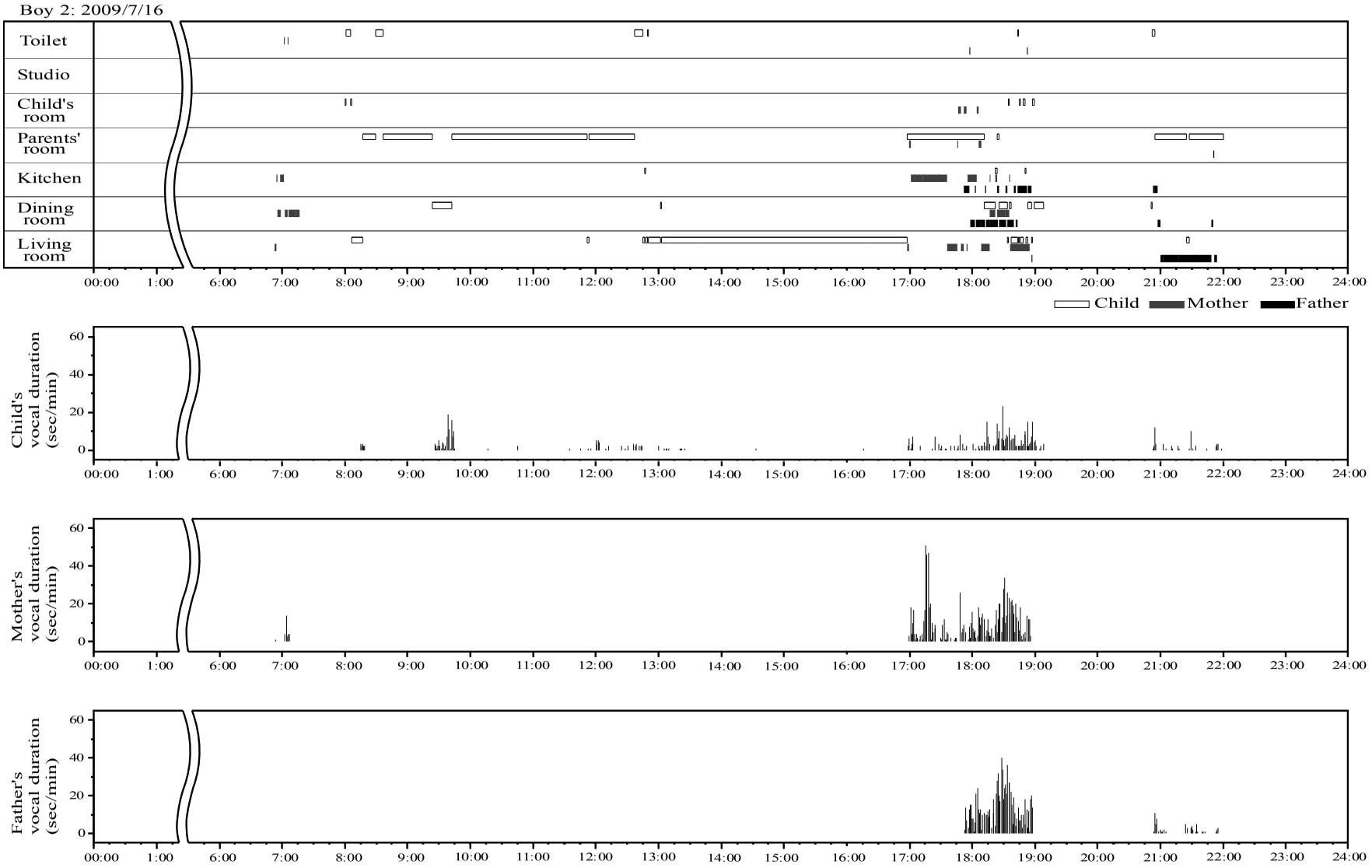

Boy 1: 2009/7/5
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

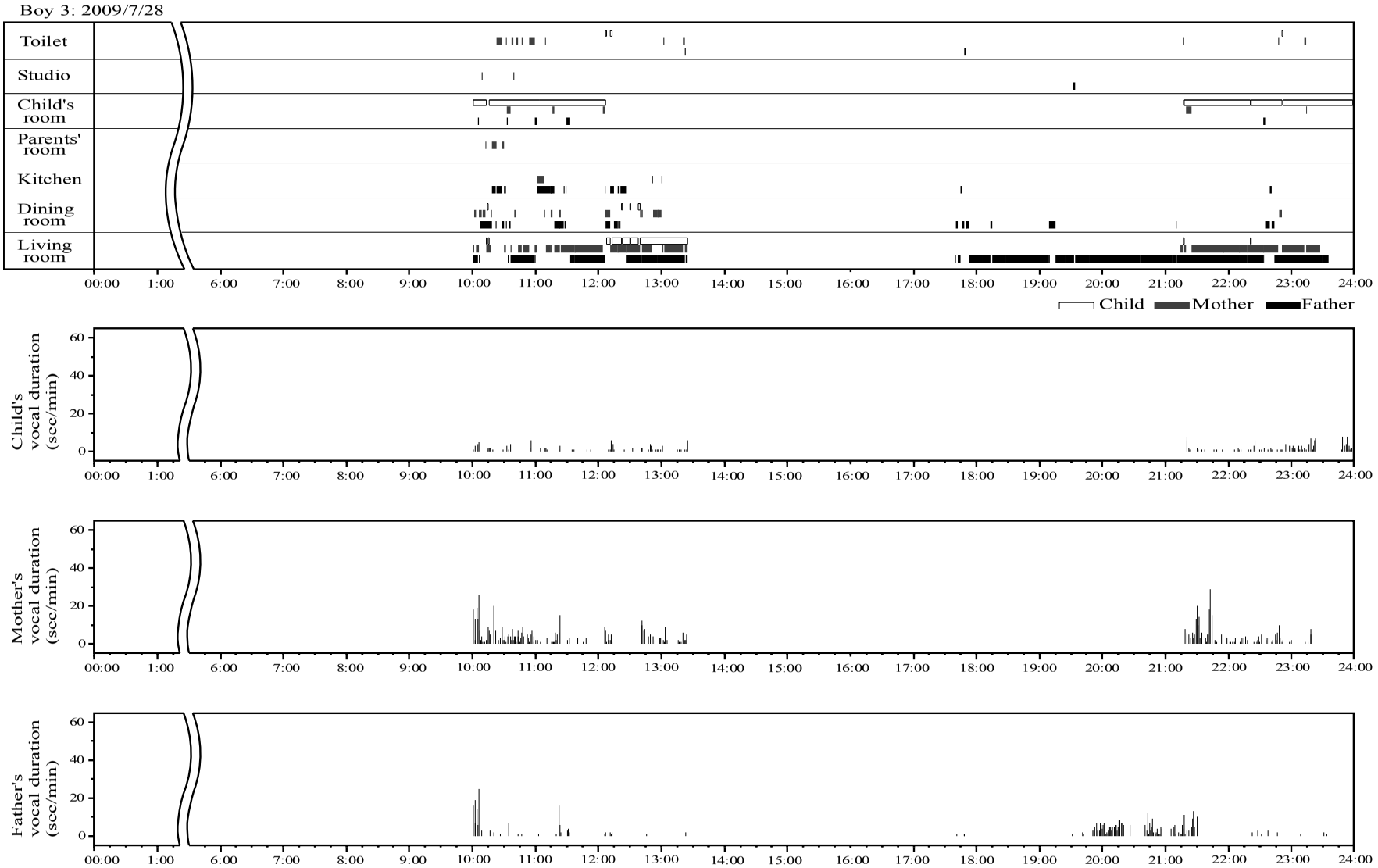

Boy 1: 2009/7/6
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

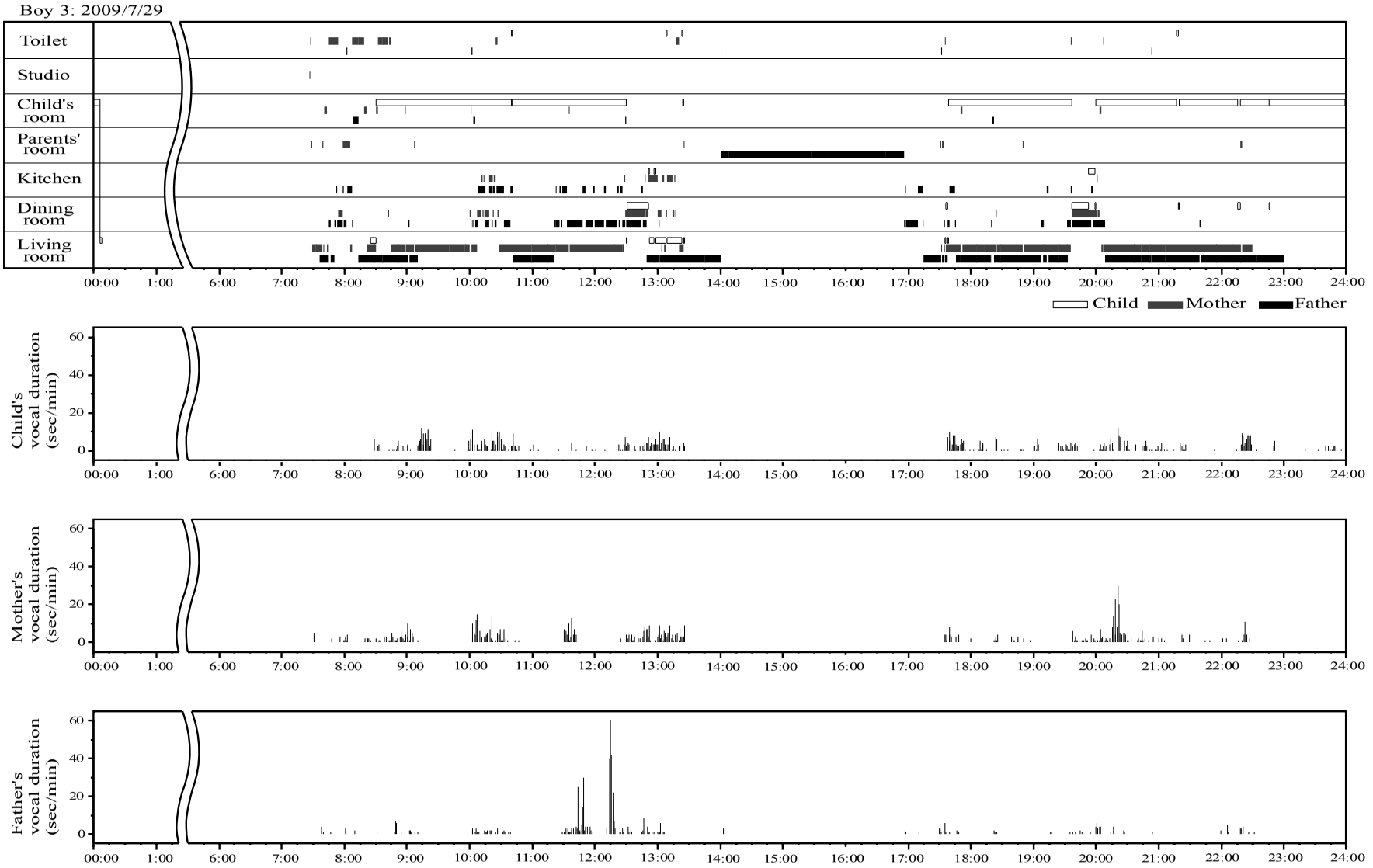

Boy 1: 2009/7/7
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

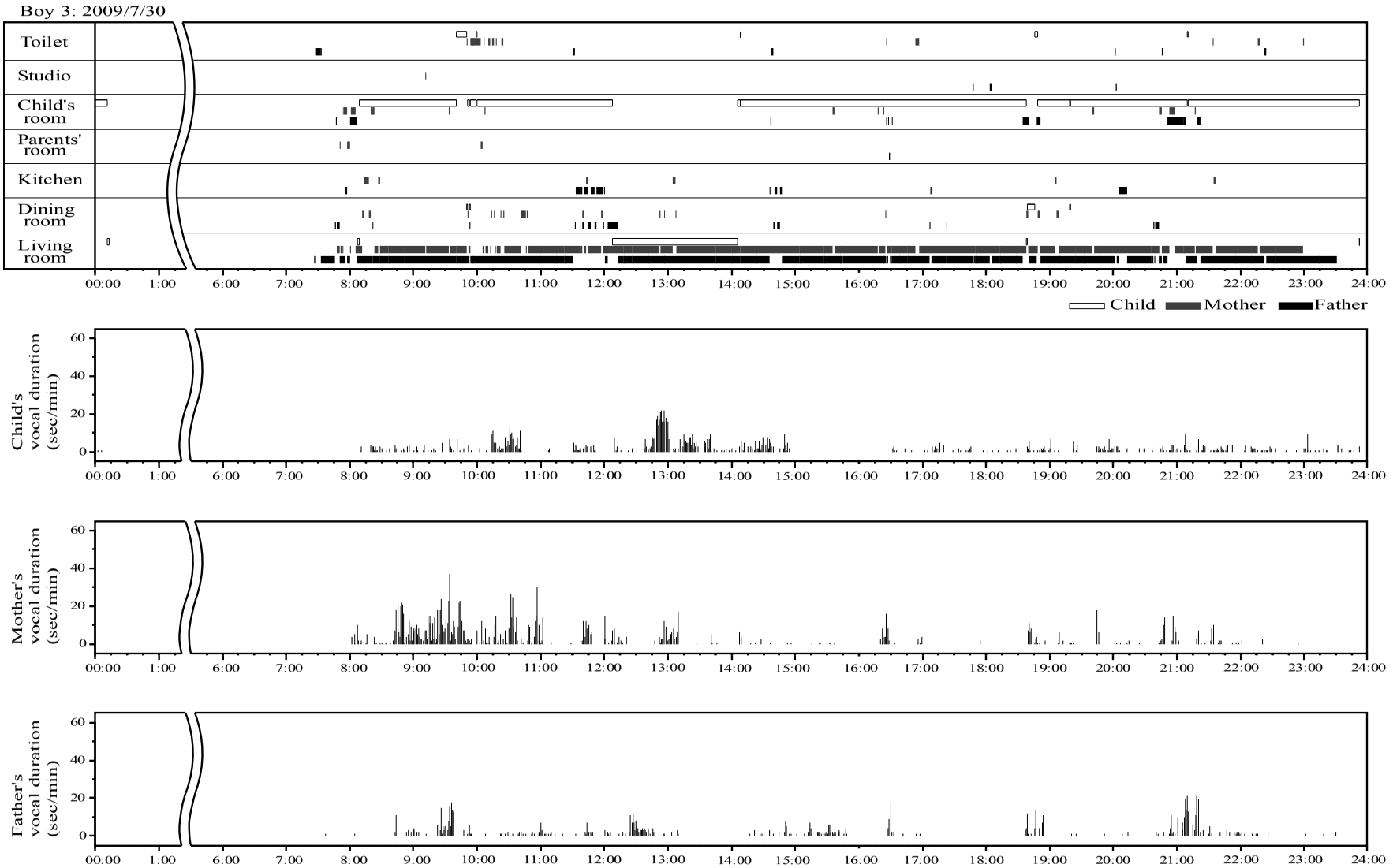

Boy 1: 2009/7/8
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

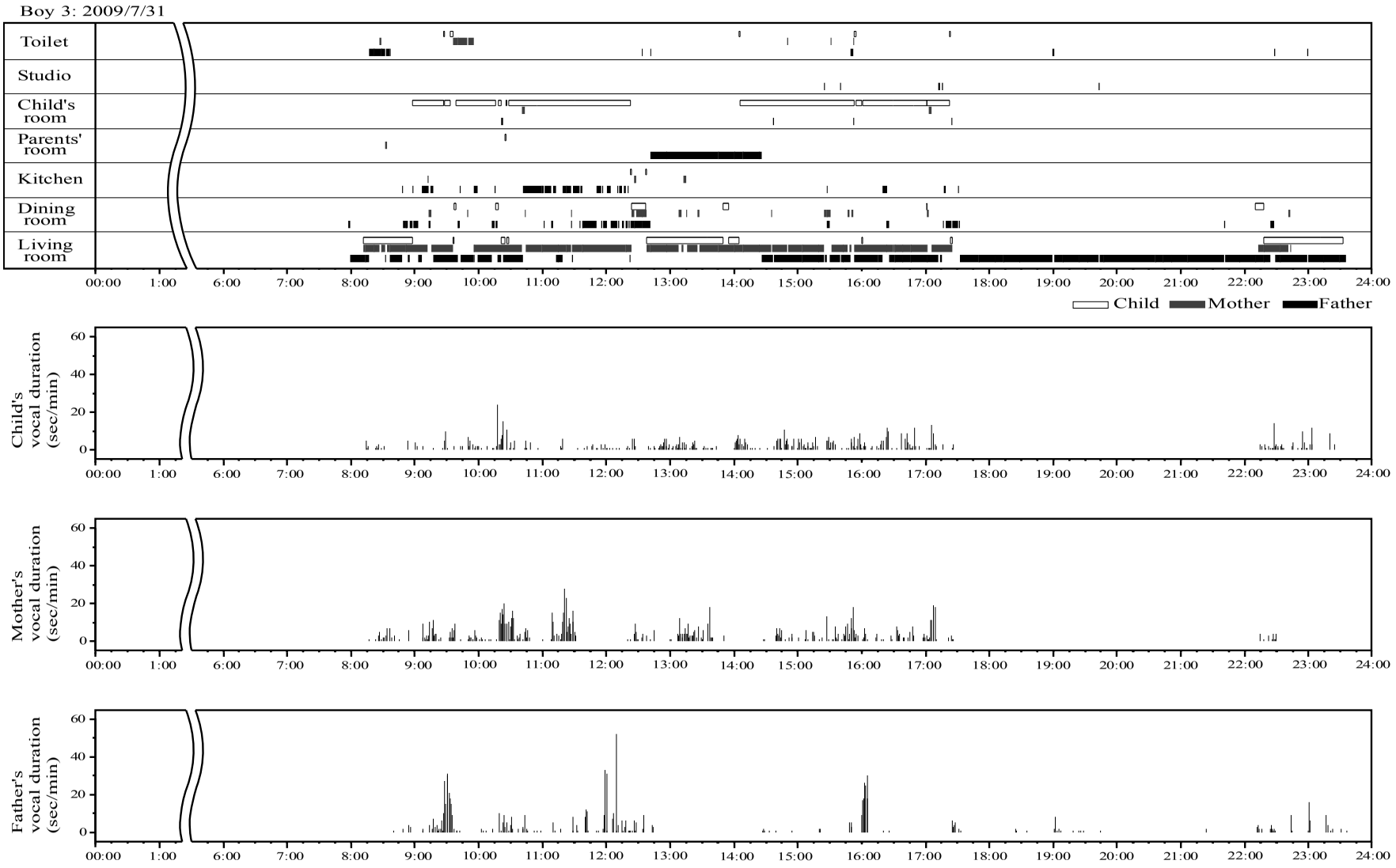

Boy 2: 2009/7/15
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

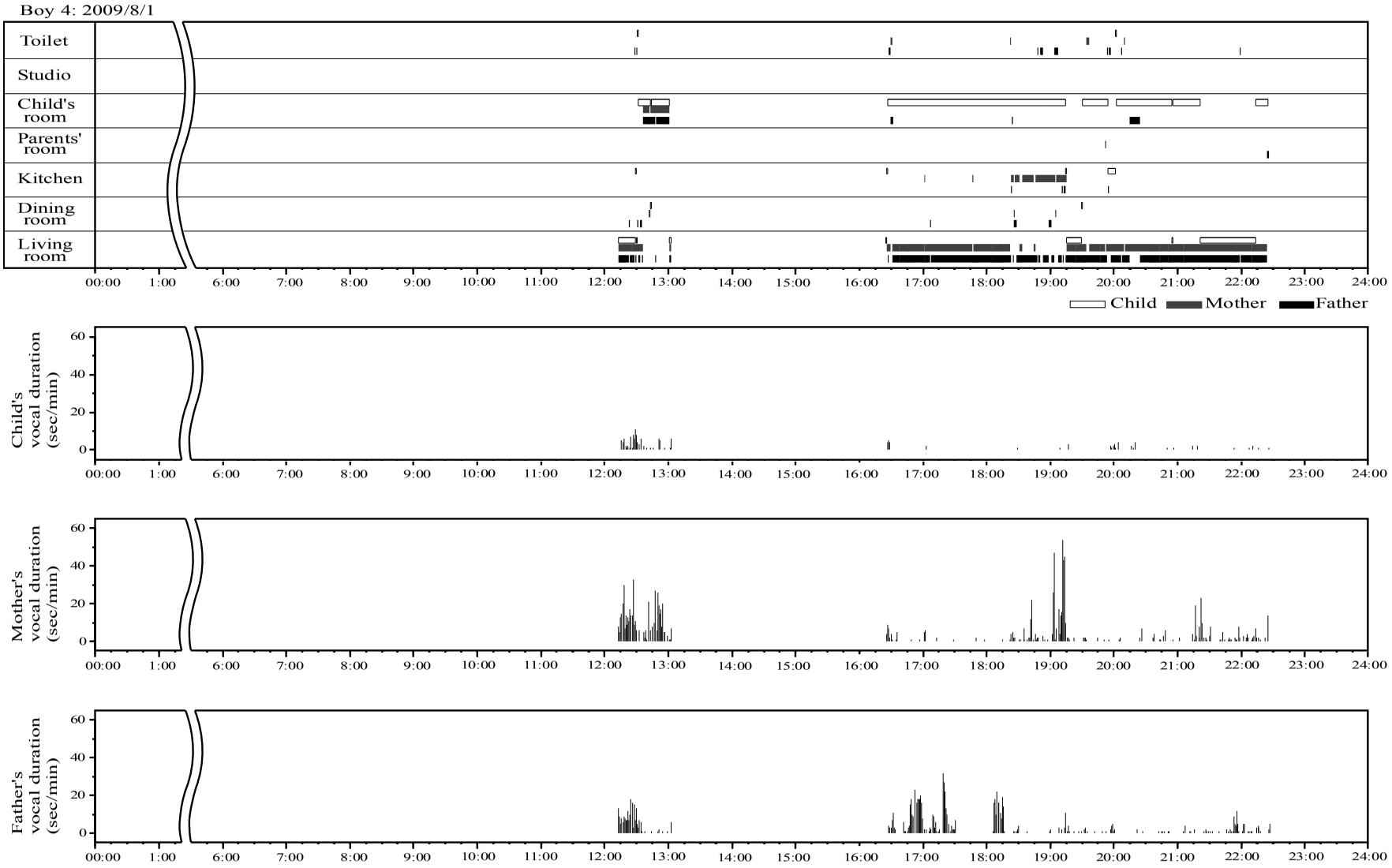

Boy 2: 2009/7/16
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

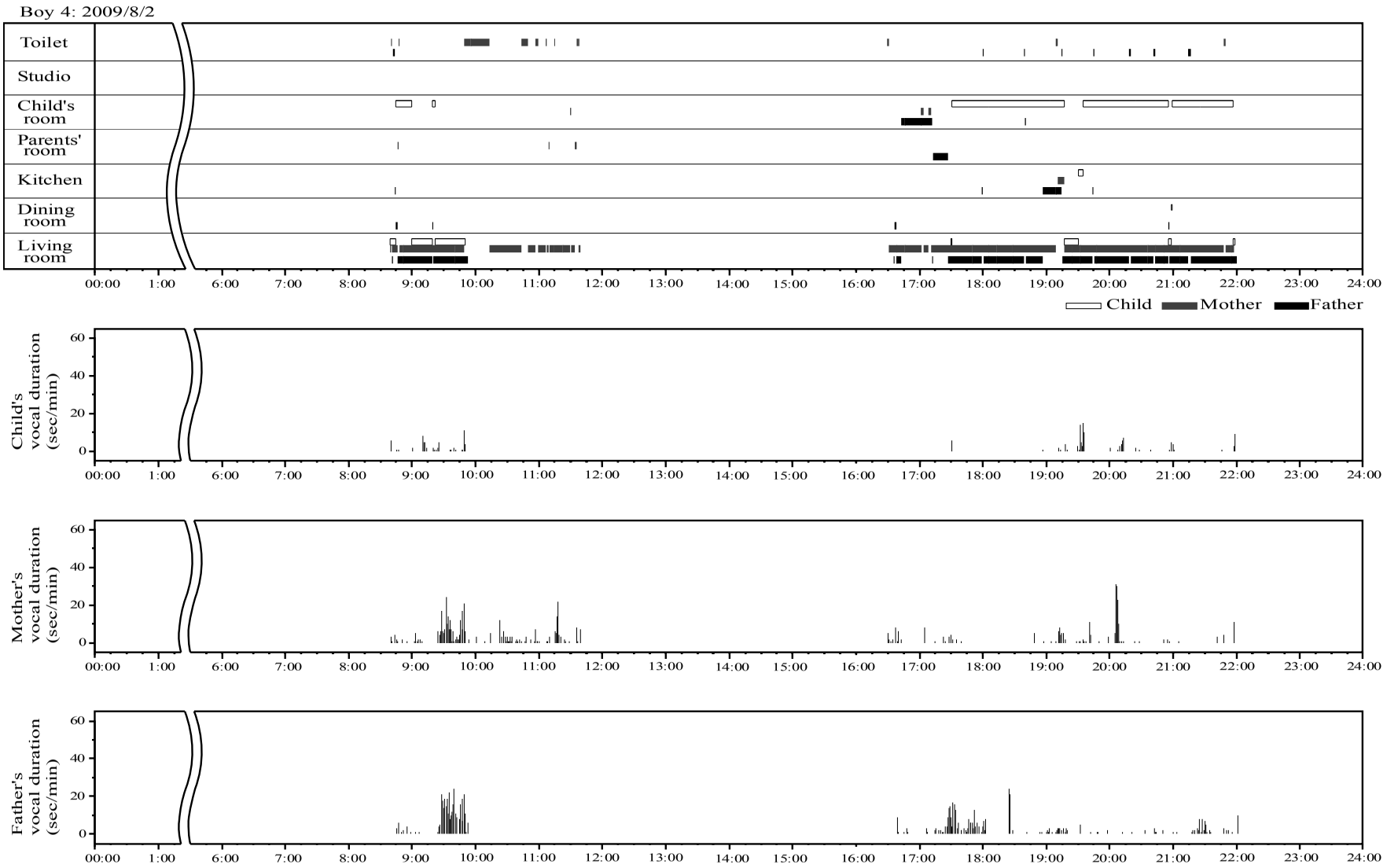

Boy 3: 2009/7/28
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

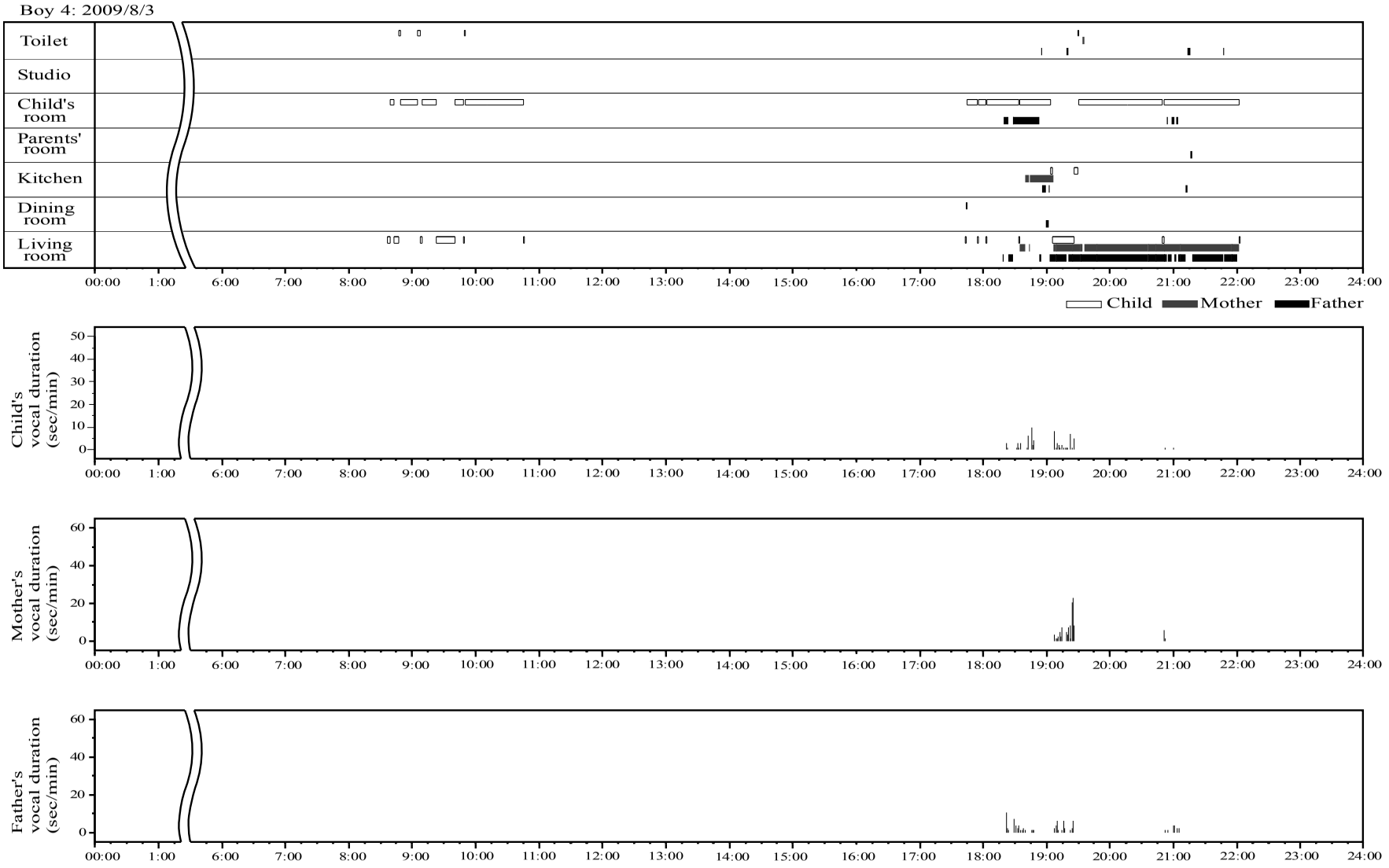

Boy 3: 2009/7/29
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

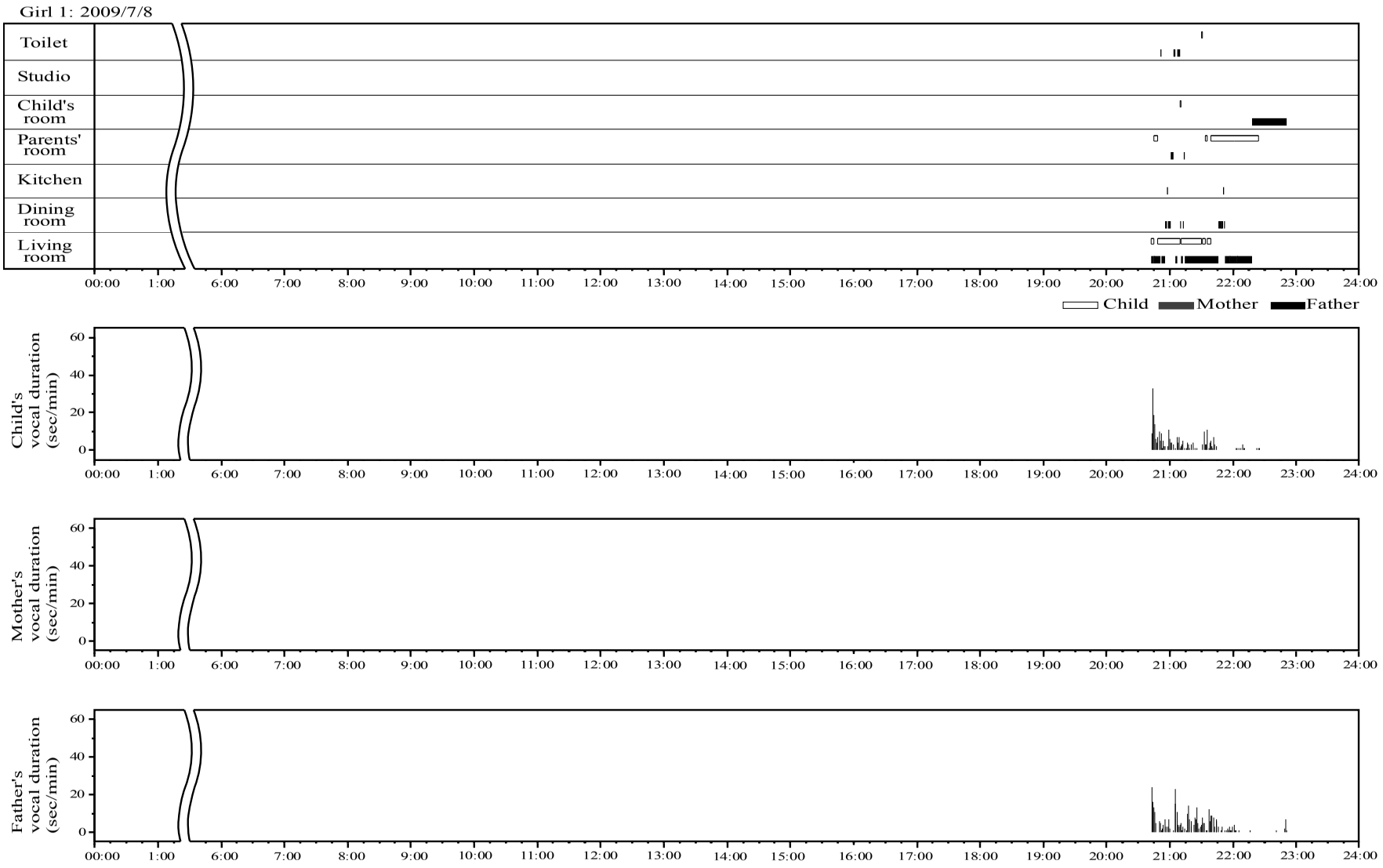

Boy 3: 2009/7/30
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

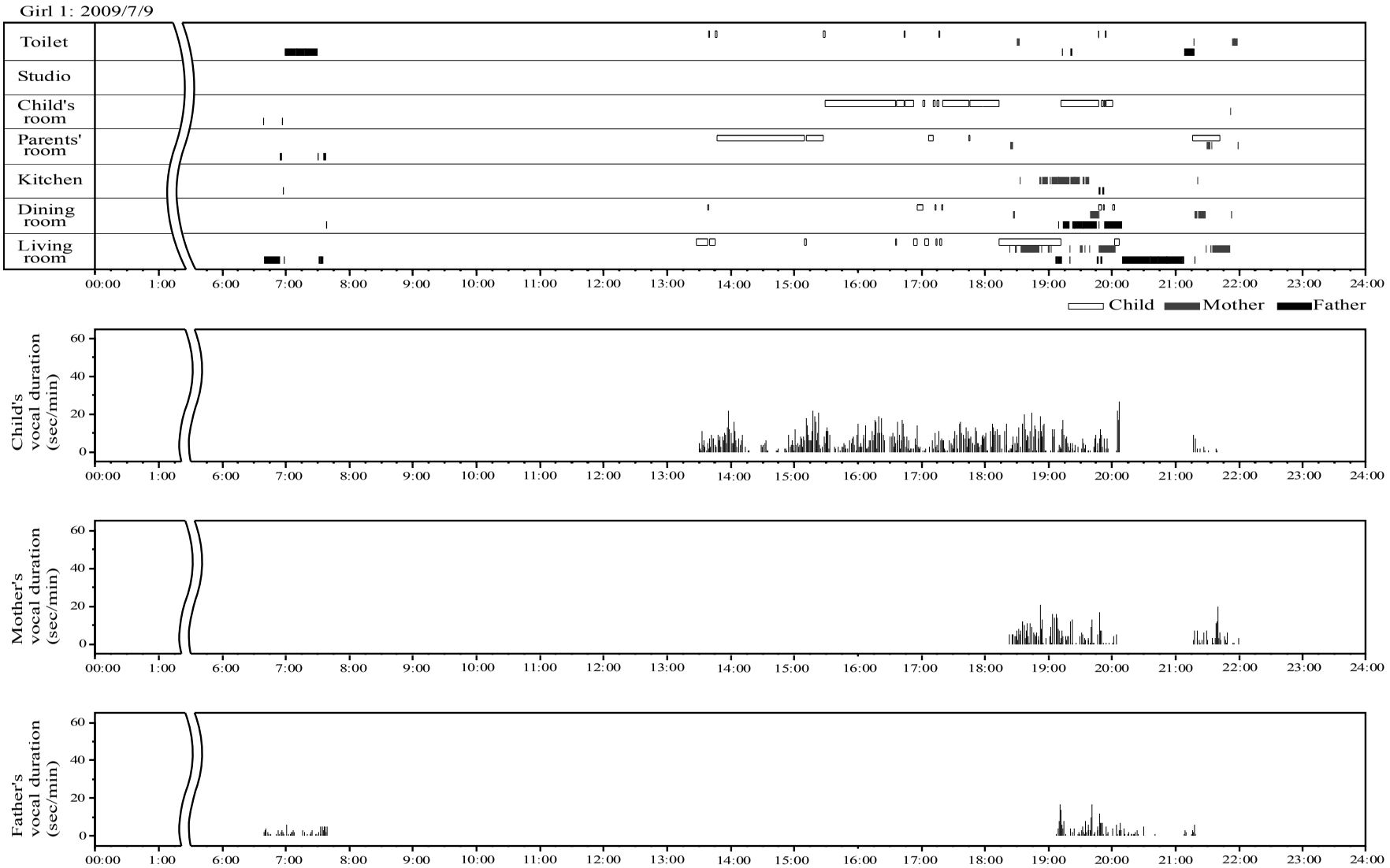

Boy 3: 2009/7/31
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

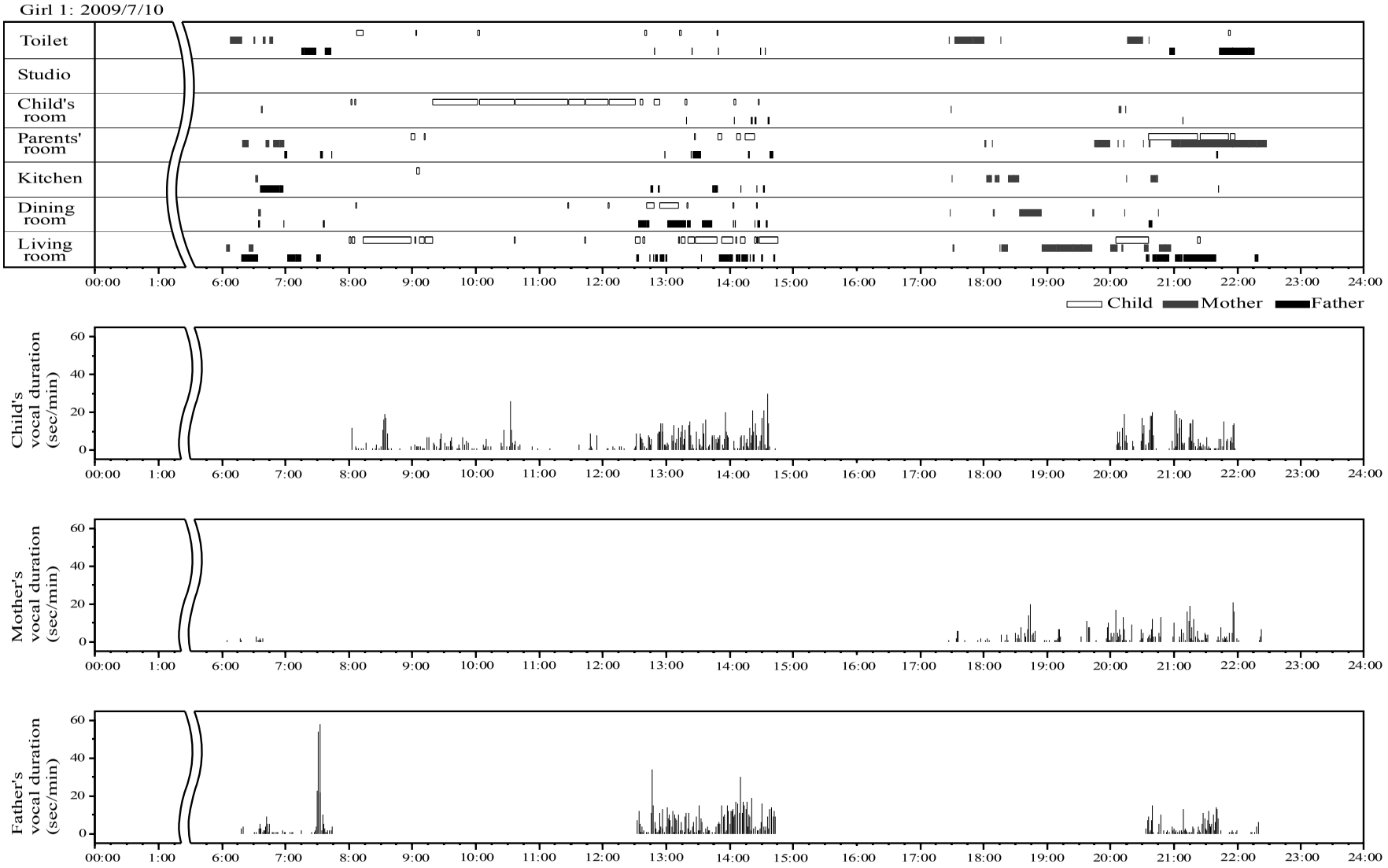

Boy 4: 2009/8/1
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

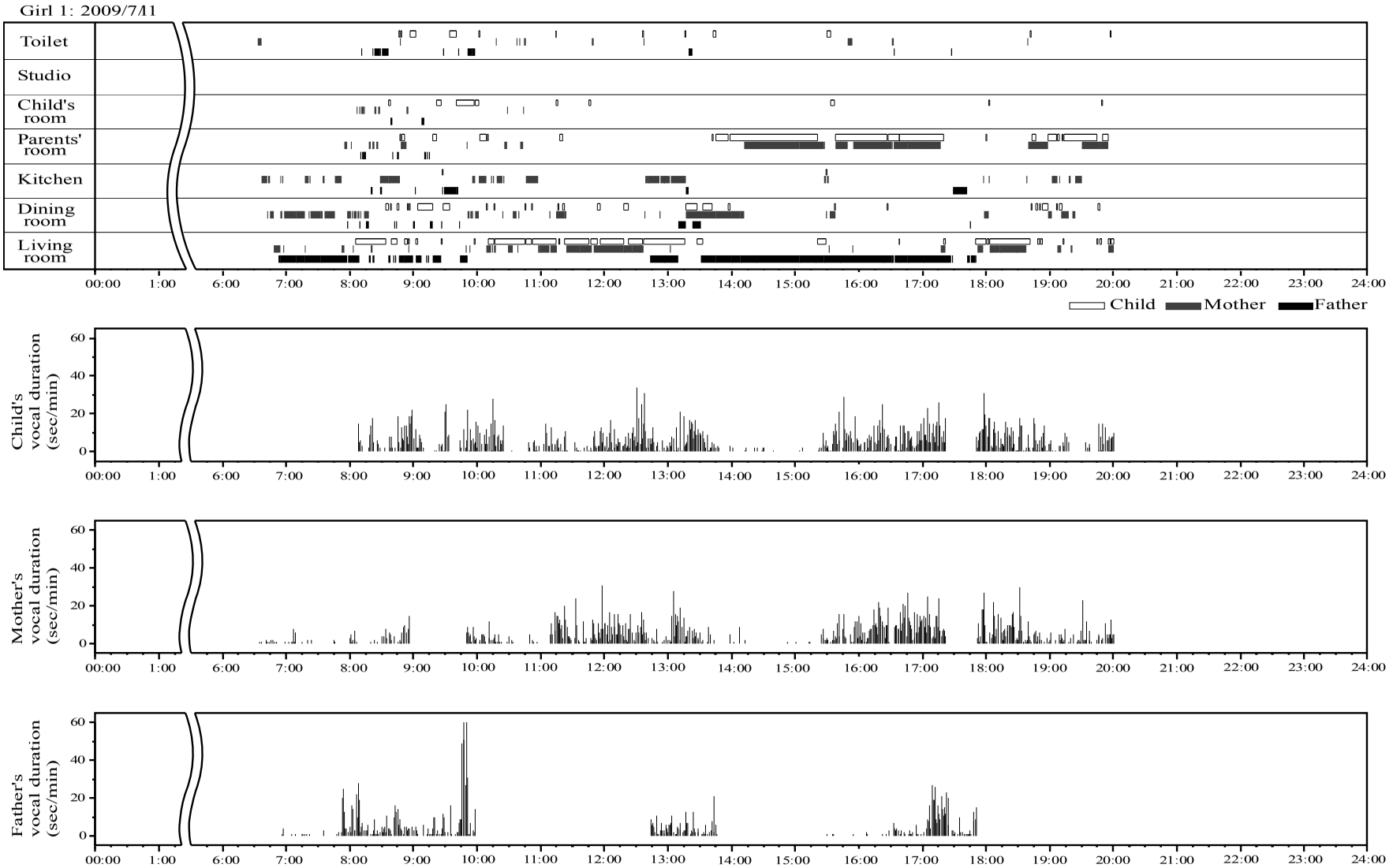

Boy 4: 2009/8/2
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

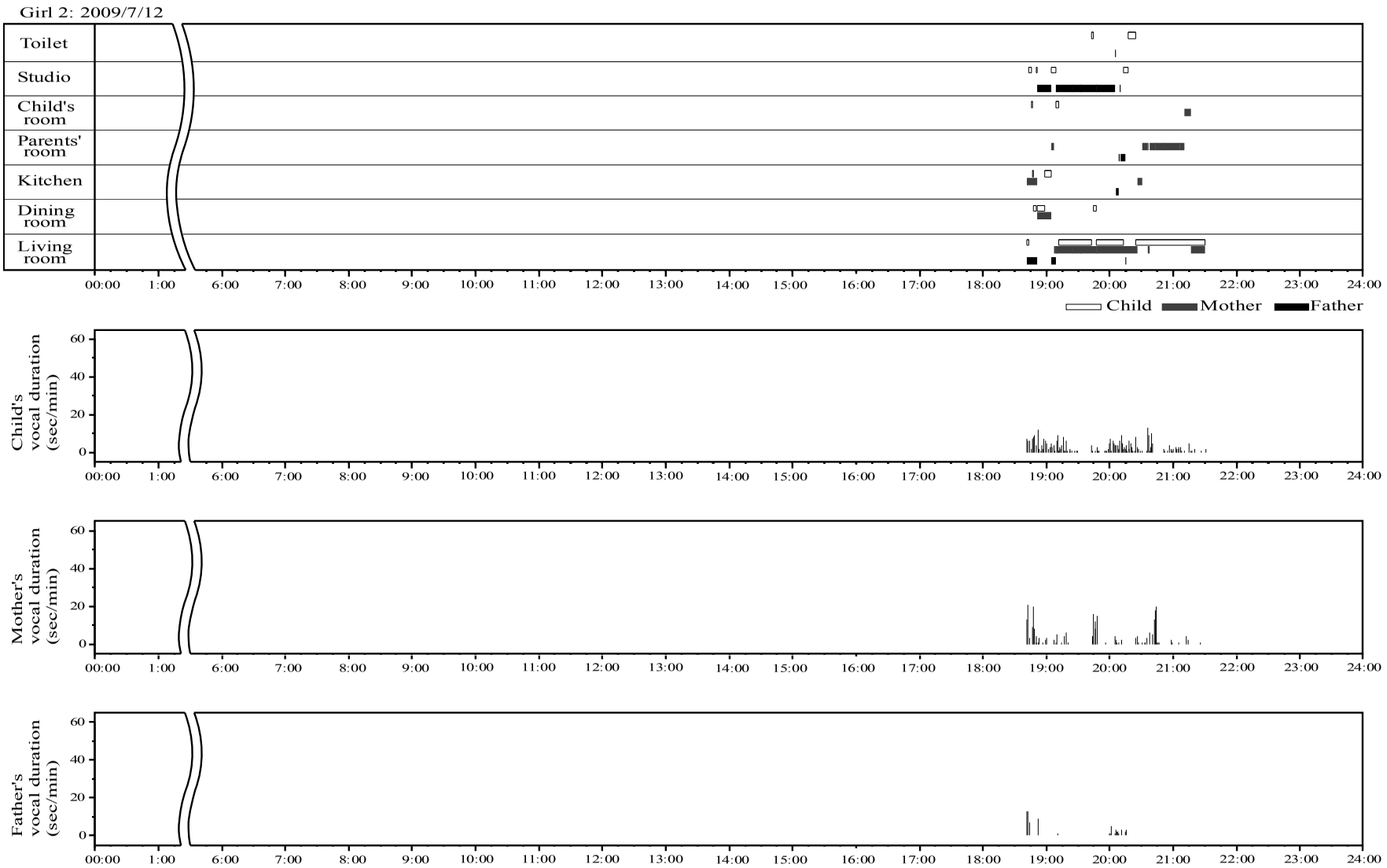

Boy 4: 2009/8/3
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)

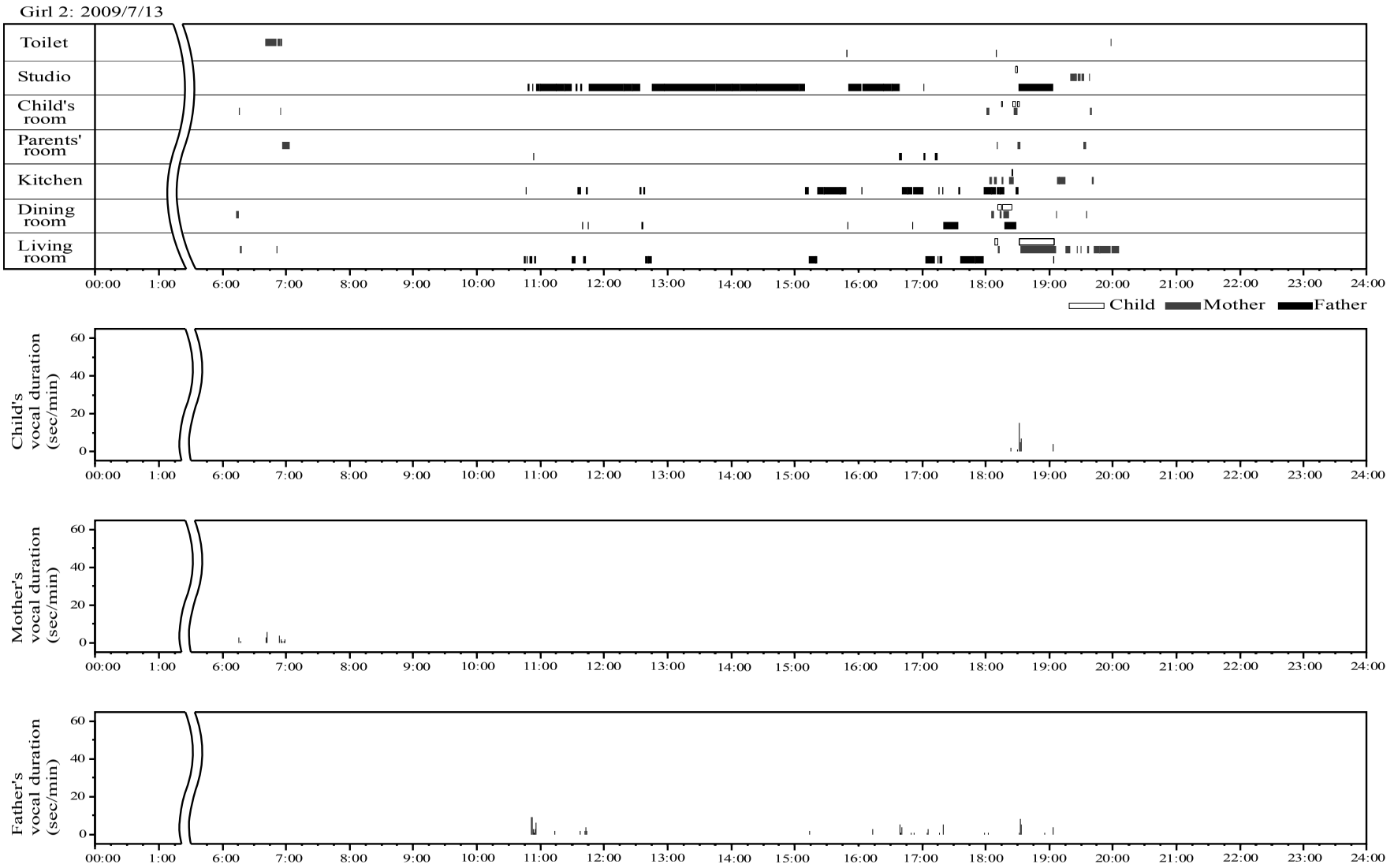

Girl 1: 2009/7/8
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

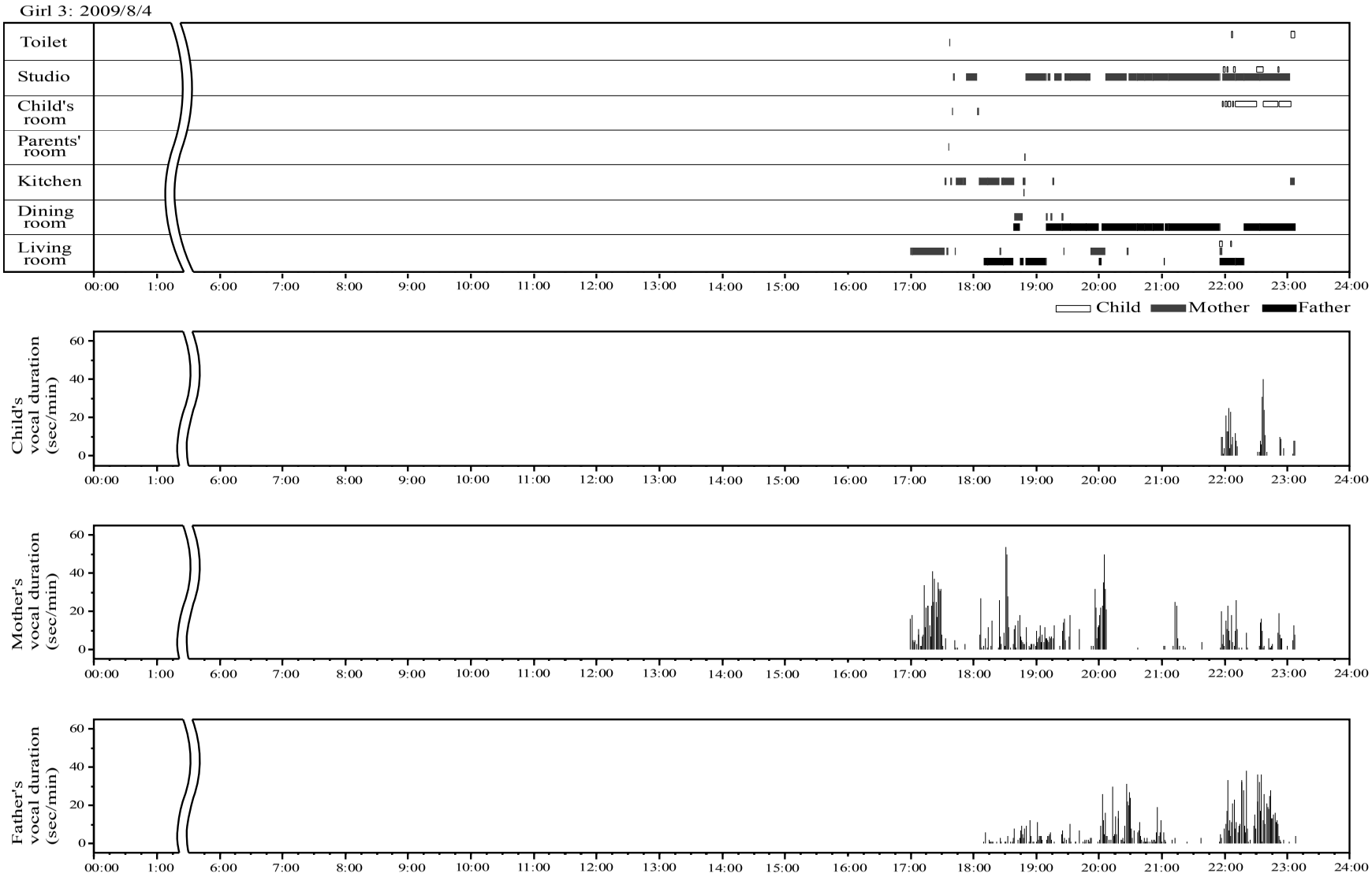

Girl 1: 2009/7/9
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

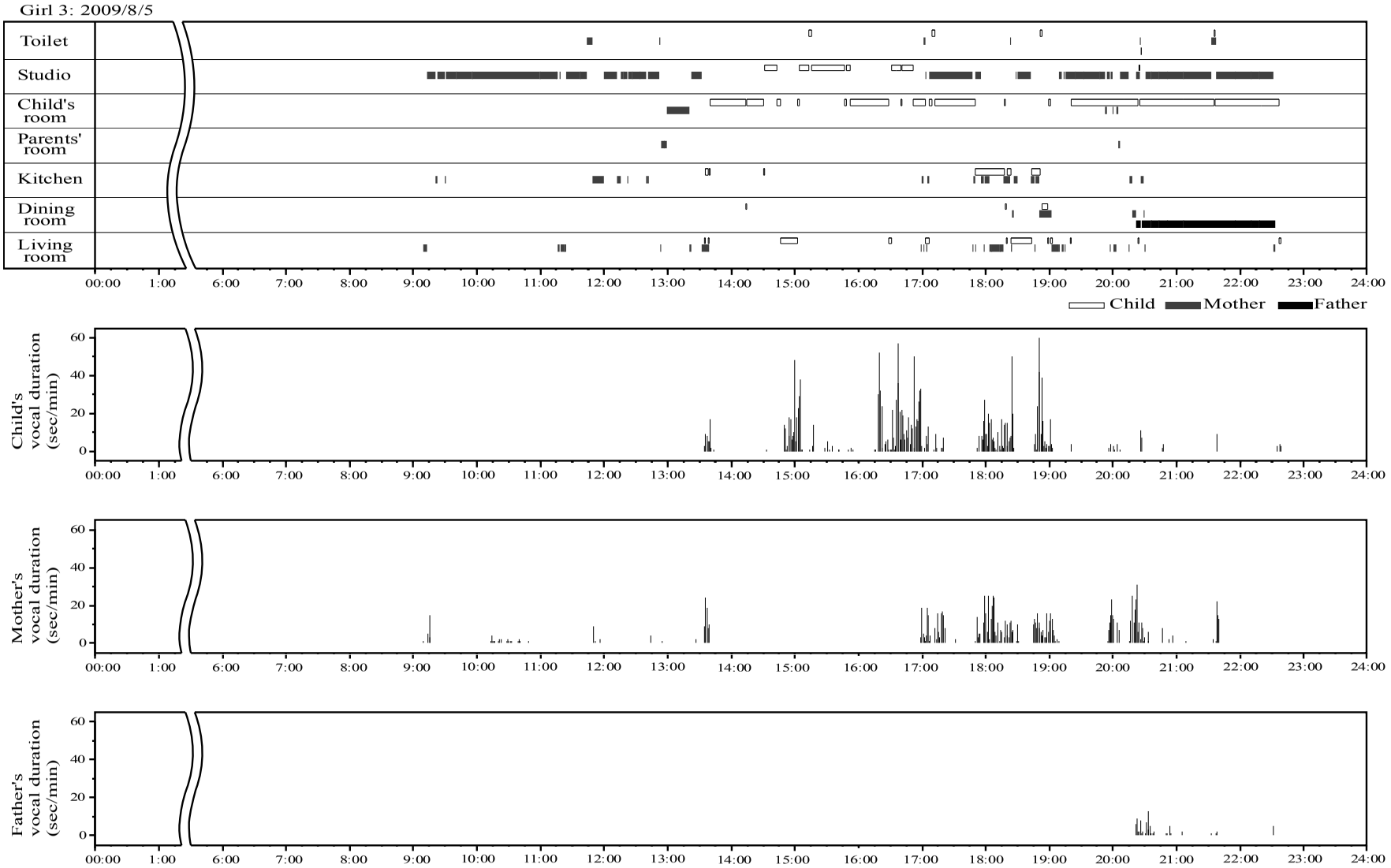

Girl 1: 2009/7/10
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

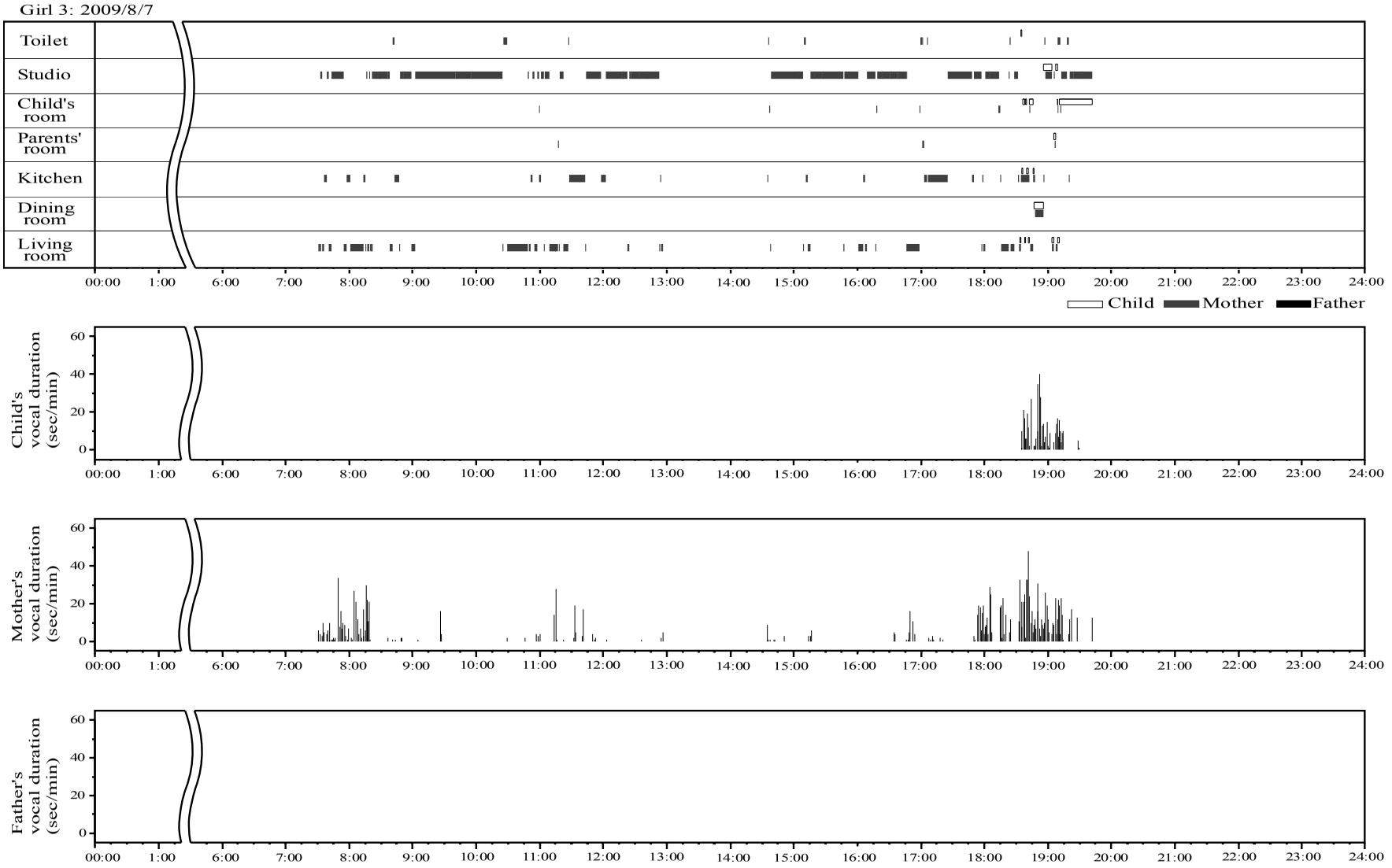

Girl 1: 2009/7/11
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60


Girl 2: 2009/7/12
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60


Girl 2: 2009/7/13
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60


Girl 3: 2009/8/4
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60


Girl 3: 2009/8/5
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60


Girl 3: 2009/8/7
Toilet
Studio
Child's room
Parents' room
Kitchen
Dining room
Living room
00:00 1:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00
Child
Mother
Father
Child's vocal duration (sec/min)
Mother's vocal duration (sec/min)
Father's vocal duration (sec/min)
0
20
40
60

Acknowledgements

I would like to express my deep appreciation to all the people who have helped me to complete this dissertation.

My deepest appreciation goes to my supervisors, Professor Dr. Eng. Hokoi Shuichi, for his instructive suggestions and continuous encouragement for my research. Sincere appreciation and gratitude are also extended to Professor Dr. Eng. Monnai Teruyuki and Professor Dr. Eng. Takada Mitsuo for reviewing this dissertation and providing instructive advices. I would like to sincerely appreciate Associate Professor Dr. Eng. Yoshida Tetsu, for his valuable suggestions and sharing of his time, expertise and experience.

My heartfelt thanks belong to Dr. Eng. Matsushita Daisuke, an associate professor of Department of Architecture, Okayama University of Science, who invested a lot of energy on my research. His precious advices were fundamental for the completion of this research. I am particularly grateful to Professor Dr. Eng. Munemoto Junzo, who taught me how to start a research and always encourage me to move ahead.

I would like to sincerely appreciate Professor Guan Zhaoye in Tsinghua University, for his insightful comments and warm encouragement throughout the years. He has been and will forever be the mentor and example for me in my future career and life. Special thanks go to Dr. Eng. Han Mengzhen, an associate professor of Tsinghua University. He taught me how to write academic papers, confidenced in me when I doubted myself and brought out good ideas for my research.

I would like to express my sincere thanks to the following people, who were once the colleagues of Munemoto laboratory: Associate Professor Dr. Eng. Tang Peng, Professor Dr. Eng. Li Zao, and Dr. Eng. Huang Weixin, a lecturer of Tsinghua University. They were always there to meet and talk about my ideas about the research or questions in the daily life as a doctor candidate. I am indebted to Mr. Zhang Xinnan, Mrs. Xu Weimin and Mr. Zhang Ying, for their valuable help during the investigation, including looking for families who would agree to cooperate in my survey and installing devices. I am particularly grateful to Mr. Sun Miqin and plenty of friends of mine, who provided great support to this research.

Last, but not least, I thank my parents, Mr. Qu Xiansheng, and Mrs. Xu Dong, for their unconditional support, sacrifices and encouragement to pursue my interests, and valuable help during my investigation. I always owe a huge debt of love to them. I would also like to thank my cousin, Dr. Eng. Li Yifan, whose technical support was very important to this research.