Measurement of the strength of Japanese intra-family relationships based on Identical and Nonidentical Activities

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Abstract

In Japan, personal lifestyles have changed and diversified in the past decade due to the development of an information society and the shift in consciousness regarding the family. It is believed that this change has influenced family lifestyles, thereby also altering family relationships. However, there is a distinct lack of statistical data with regard to the diversification of intra-family activities in recent years.

This paper discusses intra-family relationships through the statistical analysis of Japanese Time Use Micro-data. The concepts of "Identical and Nonidentical activities" are used to identify the types of relationships and their strength in terms of shared time and space among family members. These concepts can be defined as follows:

1. Identical activity: Within a specific time slot and a family unit, when two or more family members are carrying out the same activities in same place
2. Nonidentical activity: Within a specific time slot and a family unit, when two or more family members are carrying out different activities in same place

The explanatory variables for Identical and Nonidentical activities are time factors, activity factors, household factors such as residential space, and personal factors such as the tendency to travel. The main tool which is used in the analysis of these variables is the automatic search program for the optimal variable set based on AIC, which is called CATDAP.

The main findings are as follows: (a) the likelihood of families sharing meals is less in the metropolitan areas, (b) the identical leisure activities that a family engages in are related to their tendency to travel, and (c) there is an identifiable cooperative style between mothers and fathers for sharing activities with their children.

Keywords: Intra-family relationships; Japanese Time Use Micro-data; exploratory data analysis; CATDAP

1. Introduction

In Japan, personal lifestyles have changed and diversified in the past decade due to the development of an information society and a shift in consciousness regarding the family. It is believed that this change has influenced family lifestyles, thereby also altering family relationships. Husbands and wives used to share a great deal of time with their family members while engaged in the same activities. In recent years, however, each family member has come to spend less time engaged in activities with the rest of the family members.

The diverse lifestyles of the modern family no longer support traditional ideas. Nevertheless, the relevant facts have been hardly observed that are evidenced by statistical data in regard to the diversification of intra-family activities[1], especially since 1990s when Japanese economy had experienced the serious downturn of business cycle. This paper discusses intra-family relationships through the statistical analysis of Japanese Time Use Micro-data. In the following discussion, the author uses the "Identical and Nonidentical activities" approach to represent the

[1] In the 70's and 80's, there were two main studies of Japanese intra-family relationships, Ohmachi (1979,1980, 1981,1983,1984) and Amano (1989). Ohmachi estimated the shared time and activity during meals, watching TV, and relaxing with family members by using the Macro-data of NHK National time use survey. Amano surveyed the Tama area in Tokyo and calculated descriptive statistics about time sharing.

manner as to how and with whom the time is shared.

The aims of this paper are twofold. Firstly, Identical and Nonidentical activities are estimated not only in terms of time-sharing but also for carrying out the same or different activities with family members. Secondly, the key factors that characterize these situations can be deduced from analyzing the time factors, activity factors, and household factors such as income or the density of residential space, and the individual factors including the tendency to travel, etc. The tool for analysis is the automatic search program for the optimal variable set based on AIC, which is called CATDAP.

The rest of the paper is organized as follows. In the next section, the Identical and Nonidentical activities are defined. The analysis model and method are described in the third section, and the empirical results are given in the fourth section. The final paragraphs conclude the discussion.

2. The data

The Japanese Time Use Survey (JTUS; officially called the "Survey on Time Use and Leisure Activities," which features major surveys carried out by the Japanese Statistics Bureau) has been conducted since 1976 to record and observe the daily activities of residents of Japan over two consecutive days[2]. The survey sample consists of household members over aged 10 years, the survey identifies the basic characteristics of the household and the members, and their activities in every 15 minutes slot. Since 1996, the survey item in which a family member has been together has been added. As well as identifying the time slots allocated to various kinds of activities, the questionnaire examines when each person spent time alone (1), with family member(s) (2), with classmate(s) or colleague(s) (3), or with other person(s) (4).

By employing this survey item and the survey unit of the household, we can identify how individuals' time use includes time shared with family members while engaged in specific activities. This paper identifies two specific types of activities as follows:

1. Identical activity: Within a specific time slot and a family unit, when two or more family members are carrying out the same activities in same place
2. Nonidentical activity: Within a specific time slot and a family unit, when two or more family members are carrying out different activities in same place

These variables can be categorized by the sharing-time partner as necessary. It is preferable to use parents as subjects for the purpose of this analysis, but it becomes very complicated to

[2] Owing to the new institutional framework formulated by the enforcement of the revised Statistics Act, academic researchers have access to the microanalysis of the anonymized data sets that are collected by the Statistics Bureau, which include data from the Time Use Survey. Information from this survey has been useful in helping the establishment of deeper insights into the activities that occupy people's time compared to what was presented previously using Macro-data.

identify the patterns how the family members share time and activities because of the many one-to-many correspondences (for example, in a case when a father has a son and a daughter). For the sake of avoiding excessive complexity, the following discussion has focused on the activities of the son/daughter. In this case the relationship between a child and his/her parents is considered as a one-to-one correspondence (a son has usually one father and one mother in a household). There are some combinations into which time-sharing partners can be categorized, but for the sake of precision of estimation and easy interpretation, this paper has identified two categories as being mutually exclusive:

< Shared time partner of son/daughter >
With father: child shares time and an activity with father and without mother
With mother: child shares time and an activity with mother and without father

According to these definitions, when matching the activities and the shared time of subjects to those of his/her family members in each time slot, new information about Identical/Nonidentical activity with partners can be added to the data sets.

When matching the family members' activities, the author has assumed that every member who was marked as being "with family members" in the questionnaire shared both time and space with others. The validity of this assumption was verified in a nuclear family with one to three children of over 10 years old (Appendix A1). Therefore, this paper will discuss the activity patterns of a nuclear family consisting of parents and two children over aged 10 years, especially weekday activities of children attending elementary school.

3. The variables and the method

3.1 The variables

In this section, the variables and its indices have been used in conjunction with the analysis models. The index of households is $i = 1,2,\cdots,N$, with the total sampling households being N; a family member in the i^{th} household is $j = 0,1,2,\cdots,M_i$ where total number of the family members are represented as M_i, and $j = 0$ is set to be the analysis subject; the time slots in a day are represented as $t = 1,2,\cdots,96$ which is categorized as being 15 minutes slots.

The activity variable was consequently set as $a_{ijt} = \{1,\dots,20\}$. The variable of the characteristics of the household is $w_{i,h}(h = 1,\dots,H)$, where h is the index of the variable number and H indicates the number of variables about the household characteristics. Also, the variable of the individual characteristics is $z_{ij,f}(f = 1,\dots,F)$, where the indices f and F denote to the variable number and the total number of variables that can be identified with regard to individual characteristics.

As the analysis was conducted in household with parents and two children ($M_i = 3$), the index of family members corresponds to each of the four family members.

$j = \{0.\text{Subject (a child)}, 1.\text{his/her father}, 2.\text{his/her mother}, 3.\text{his/her brother/sister}\}$

Using vector expressions, the activities and the characteristics of households and individuals are described as follows;

$$Activities: \; A_{it} = \begin{bmatrix} a_{i0t} \; (Activities\ of\ a\ child) \\ a_{i1t} \; (Activities\ of\ his/her\ father) \\ a_{i2t} \; (Activities\ of\ his/her\ mother) \\ a_{i3t} \; (Activities\ of\ his/her\ btother/sister) \end{bmatrix}$$

$$Characteristics\ of\ a\ household: \; W_i = \begin{bmatrix} w_{i,1} \; (The\ 1^{st}\ variable) \\ \vdots \\ w_{i,H} (The\ H^{th}\ variable) \end{bmatrix}$$

$Characteristics\ of\ family\ members:$

$$\boldsymbol{Z_i} = \begin{bmatrix} Z_{i0} \; (Characteristics\ of\ a\ child) \\ Z_{i1} \; (Characteristics\ of\ his/her\ father) \\ Z_{i2} \; (Characteristics\ of\ his/her\ mother) \\ Z_{i3} \; (Characteristics\ of\ his/her\ brother/sister) \end{bmatrix},$$

$$Z_{ij} = \begin{bmatrix} z_{ij,1} (The\ 1^{st}\ variable) \\ \vdots \\ z_{ij,F} (The\ F^{th}\ variable) \end{bmatrix}$$

The shared time variable is then defined using y_{ijt} as a categorical variable.

$$y_{ijt} = \{1. Identical\ activity\ \ 2. Nonidentical\ activity.\ \ 3. Other\ people\ \ 4. Alone\}$$

When the variable y_{ijt} transforms into the dummy variable with regard of an Identical activity partner for a subject child ($j = 0$), especially a father or a mother, the new variable vector is expressed as U_{it}^{I} using right-upper suffix I for “Identical Activities.”

$$U_{it}^{I} = \begin{bmatrix} u_{it,1}^{I} \quad (With\ his/her\ father) \\ u_{it,2}^{I} \quad (With\ his/her\ mother) \end{bmatrix}$$

The shared time variable y_{ijt} and its dummy variable U_{it}^{I} are created by matching the activities of the family members with each other during each time slot. After the matching process, the activities were re-coded on a scale from 20 categories to 6 categories (Sleep, Meals, Moving, Studies, Leisure, and Other, Appendix A2) for simple interpretation’s sake. The variables and their categories are summarized in Appendix A3.

3.2 The analysis model and CATDAP

The situation of shared time relates to activities and the time slots, and other characteristics influence these variables, such as Figure 1. In order to observe the use of the shared time during an activity and to identify the factors which influence that shared time, the model for the contingency table is set as the conditional probability $P\{Y|X\}$, in which Y and X show the dependent variable and explanatory variables respectively.

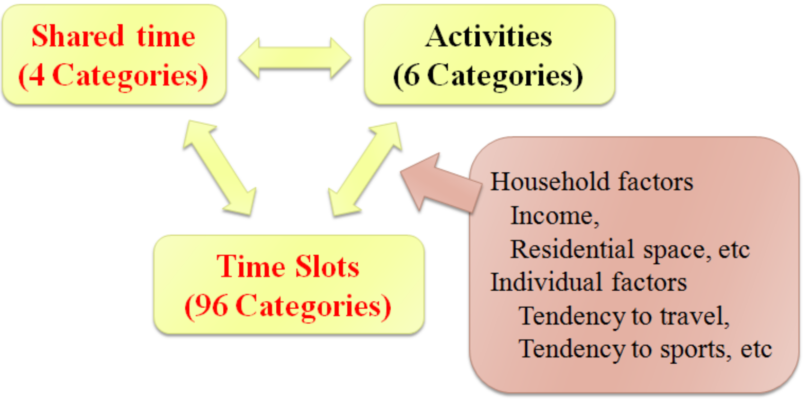

Figure 1 The relationships among each factors

Firstly, Model 1 is set to achieve a comprehensive relation among the shared time, the time slots, the activities, and the characteristics of households and individuals.

$$Model1\text{:}\ P\{y_{i0t}\mid t, A_{it}, W_i, \boldsymbol{Z_i}\}$$

Secondly, by each activity, the shared time and other factors are used for Model 2.

$$Model2\text{:}\ P\{y_{i0t}\mid t, W_i, \boldsymbol{Z_i}\}\ \ by\ each\ A_{it}$$

Lastly, the cooperative action between father and mother are measured from Model 3.

$$Model3\text{:}\ P\{u^I_{i+,1}, u^I_{i+,2}\mid W_i, \boldsymbol{Z_i}\}\ by\ each\ A_{it}$$

In the Model 3, the variable of identical activities being carried out by family members can be summed up over time (suffix +) in order to clarify the cooperative action between father and mother during a day.

These models are supported by highly multiple contingency tables. For these types of analysis, a computing program was developed in Japan called the "CATDAP" (Categorical Data Analysis Program). CATDAP is a program for the exploratory analysis of the multiple contingency tables. It calculates AIC for all combinations of explanatory variable sets and those of categories based on multinomial distribution. From this program, the researcher can select the optimal variable sets and the optimal categorizations objectively. Moreover, the bias problem caused by multicollinearity does not occur, even if one uses both the time slots and the time-related variables as explanatory variables because the theoretical probability assumes the multinomial distribution for the contingency table in this model. The outlines of the CATDAP are described in (1) the search for the optimal variable sets, and (2) the search for the optimal categories.

(1) The search for the optimal explanatory variable

The purpose of this is to select the better of two different contingency tables based on AIC for easy explanation's sake. The three explanatory variables for two contingency tables are described as Y_0, X_1, X_2, and those categories are $r_0 = 1, \dots, C_0, r_1 = 1, \dots, C_1, r_2 = 1, \dots, C_2$, respectively. Subsequently, the probability expression in the contingency table is written as $p(r_0|r_1, r_2)$, if the dependent variable is set to Y_0 and the explanatory variables are set to X_1, X_2. The estimation model using the expression $\theta(r_0|r_1, r_2)$ for the model with two explanatory variables is shown as follows;

$$Model.A\ (Y_0;X_1,X_2):\ p(r_0|r_1,r_2)=\theta(r_0|r_1,r_2) \tag{1}$$

$$where\ \sum_{r_0=1}^{C_0}\theta(r_0|r_1,r_2)=1,\qquad d.f.=(C_0-1)C_1C_2$$

If the explanatory variable X_2 does not have effective information to predict the dependent variable Y_0, the estimation model is written as Model B.

$$Model.B\ (Y_0;X_1):\ p(r_0|r_1,r_2)=\theta(r_0|r_1) \tag{2}$$

$$where\ \sum_{r_0=1}^{C_0}\theta(r_0|r_1)=1,\qquad d.f.=(C_0-1)C_1$$

The log likelihood are derived from the constrained probability model of these based on the multinomial distribution. (Appendix B1)

$$l_A[\theta(r_0|r_1,r_2)]=\sum_{r_1r_2}\left[\sum_{r_0=1}^{C_0-1}n(r_0,r_1,r_2)log\theta(r_0|r_1,r_2)\right.$$
$$\left.+\,n(C_0,r_1,r_2)\log\{1-\sum_{r_0=1}^{C_0-1}\theta(r_0|r_1,r_2)\}\right] \tag{3}$$

$$l_B[\theta(r_0|r_1)]=\sum_{r_1}\left[\sum_{r_0=1}^{C_0-1}n(r_0,r_1)log\theta(r_0|r_1)\right.$$
$$\left.+\,n(C_0,r_1)\log\{1-\sum_{r_0=1}^{C_0-1}\theta(r_0|r_1)\}\right] \tag{4}$$

where $n(r_0,r_1,r_2)$ and $n(r_0,r_1)$ indicate the cell frequency of each r_0,r_1,r_2 category.

The maximum likelihood estimators are derived from the log likelihood, and AIC to search for optimal explanatory variable sets is defined by equations (5) and (6). We can select the model which has the lesser value of AIC as indicating the presence of the optimal explanatory variable sets.

$$AIC_A=(-2)\sum_{r_0,r_1,r_2}n(r_0,r_1,r_2)log\frac{n\cdot n(r_0,r_1,r_2)}{n(r_0)n(r_1,r_2)}+2(C_0-1)(C_1C_2-1) \tag{5}$$

$$AIC_B=(-2)\sum_{r_0,r_1}n(r_0,r_1)log\frac{n\cdot n(r_0,r_1)}{n(r_0)n(r_1)}+2(C_0-1)(C_1-1) \tag{6}$$

In the case of k explanatory variables, the models for comparison are considered in all combination of the variables.

Block k (with k variables)	$Model\ (Y_0;X_1,\dots,X_k)$:	$p(r_0|r_1,\dots,r_k)=\theta(r_0|r_1,\dots,r_k)$
Block k-1 (with k-1 variables)	$Model\ (Y_0;X_1,\dots,X_{k-1})$:	$p(r_0|r_1,\dots,r_k)=\theta(r_0|r_1,\dots,r_{k-1})$
	⋮	
	$Model\ (Y_0;X_2,\dots,X_k)$:	$p(r_0|r_1,\dots,r_k)=\theta(r_0|r_2,\dots,r_k)$
⋮	⋮	
Block 1 (with 1 variable)	$Model\ (Y_0;X_1)$:	$p(r_0|r_1,\dots,r_k)=\theta(r_0|r_1)$
	⋮	
	$Model\ (Y_0;X_k)$:	$p(r_0|r_1,\dots,r_k)=\theta(r_0|r_k)$
Block 0 (no variables)	$Model\ (Y_0)$:	$p(r_0|r_1,\dots,r_k)=\theta(r_0)$

In general, the set and any subsets of explanatory variables are described as X and X', and the set consists of the elements of the explanatory variables $\{X_1, \dots, X_k\}$, while the categories of these variable set and subsets are indicated as $\boldsymbol{r}$ and $\boldsymbol{r}'$ in bold type. A contingency model for the comparison and AIC[3] is given as follows;

$$Model\ (Y_0; X') : \ p(r_0|\boldsymbol{r}) = \theta(r_0|\boldsymbol{r}')$$

$$AIC(Y_0; X') = (-2)\sum_{r_0,r'} n(r_0, \boldsymbol{r}') log \frac{n(r_0, \boldsymbol{r}')}{n(\boldsymbol{r}')} + 2(C_0 - 1)(C_{X'} - 1) \quad (7)$$

where $n(r_0, \boldsymbol{r}')$: cell frequency calculated by each explanatory variable set (X'),
$n(\boldsymbol{r}')$: marginal frequency calculated by each explanatory variable set (X'),
$C_{X'}$: total number of category of each explanatory variable sets (X').

(2) The search for the optimal categorization

This section describes the search for the optimal categorization in the explanatory variable X_1 which has three categories $r_1 = 1,2,3$. If all categories have effective information to predict the cells in a contingency table, the model for the comparison of the optimal categories is equal to the model of the search for the optimal variable sets.

$$Model. C\ (Y_0; X_1) : \ p(r_0|r_1) = \theta(r_0|r_1) \quad (8)$$

$$where \sum_{r_0=1}^{C_0} \theta(r_0|r_1) = 1, \qquad d.f. = (C_0 - 1)C_1.$$

If the categories $r_1 = 2,3$ have no different information from each other, the re-categorized variable and its categories will be expressed as X_1^* and $r_1^* = 1, 2^*$, where the number with asterisk shows a new category. The re-categorized model focusing on two categories is defined as follows:

$$Model. D\ (Y_0; X_1^*) : \begin{cases} p(r_0|X_1 = 1) = \theta(r_0|1) \\ p(r_0|X_1 = 2) = p(r_0|X_1 = 3) = \theta(r_0|2^*) \end{cases} \quad (9)$$

$$where \sum_{r_0=1}^{C_0} \theta(r_0|1) = 1, \sum_{r_0=1}^{C_0} \theta(r_0|2^*) = 1, d.f. = (C_0 - 1)(C_1 - 1),$$

$$\sum_{r_1=2}^{3} n(r_0, r_1) = n(r_0, 2^*).$$

Similarly, with the use of AIC for the selection of optimal explanatory variable sets, using the maximum likelihood estimator, the AIC are derived from the selection of the optimal categories (Appendix B2).

$$AIC_C(Y_0; X_1) = (-2)\sum_{r_0,r_1} n(r_0, r_1) log \frac{n \cdot n(r_0, r_1)}{n(r_0)n(r_1)} + 2(C_0 - 1)(C_1 - 1) \quad (10)$$

$$AIC_D(Y_0; X_1^*) = (-2)\sum_{r_0,r_1^*} n^*(r_0, r_1^*) log \frac{n \cdot n^*(r_0, r_1^*)}{n(r_0)n^*(r_1^*)} + 2(C_0 - 1)(C_1^* - 1) \quad (11)$$

$where$ X_1^*: new categorized variable,

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[3] AIC used in CATDAP adjusts the ordinary AIC for the chi-square test. If the value of AIC is negative, the dependent variable relates to the explanatory variables, and if it is positive, the correlation between the dependent variable and the explanatory variables do not exist, based on the chi-square test.

$r_1^* = 1, \dots, C_1^*$: new categories (in this case, $C_1^* = 2$),

$$n^*(r_0, r_1^*) : \begin{cases} n^*(r_0, 1) = n(r_0, 1) \\ n^*(r_0, 2^*) = \sum_{r_1=2}^{3} n(r_0, r_1) \end{cases}$$

- cell frequency after re-categorized,

$n^*(\cdot, r_1^*)$: marginal frequency after re-categorized.

In order to deal with all combinations of categories, all subsets with every combination of categories can be expressed as $C_l^*; l = 1, \dots S$. The search model and its AIC equation for the best re-categorization from the combination of categories are similar to the search model for the optimal explanatory variable sets.

$$Model. (C_1^*, \dots, C_S^*) : \ p(r_0|r) = \theta(r_0|l) \tag{12}$$

where $r_0 = 1, \dots, C_0, \quad r = \{C_1^*, \dots, C_S^*\}, \quad l = 1, \dots, s,$

$$\sum_{r_0=1}^{C_0} \theta(r_0|l) = 1.$$

$$AIC(C_1^*, \dots, C_S^*) = (-2) \sum_{r_0}^{C_0} \sum_{l=1}^{s} n^*(r_0, l) log \frac{n \cdot n^*(r_0, l)}{n(r_0) n^*(l)} + 2(C_0 - 1)(s - 1) \tag{13}$$

$$where \quad n^*(r_0, l) = \sum_{r \in C_l^*} n(r_0, r), \qquad n^*(l) = \sum_{r \in C_l^*} \sum_{r_0}^{C_0} n(r_0, r)$$

CATDAP explore the effective information of the contingency table. If the number of explanatory variables increases, although the explainable feature increases, the instability of the estimated value also increases because the number of observations is fixed. Hence, CATDAP is considered to balance these two phases. In highly multiple contingency tables, the zero cells are emerged quiet often. The program applies the value e^{-1} for the zero cells in order to penalize the zero cell because of the lack of information.

4. Empirical results

4.1 Summary of the outcomes from Models 1 and 2

The optimal explanatory variable sets categorized by AIC ranking from the 1st to the 5th place are summarized in Appendix C1. In Model 1, as regards the comprehensive relationship of the shared time and all the other variables, the time slots and the activities are included in all the top five categories. From this outcome, the amount of shared time is substantially influenced and bound by the time slots and the activities, and the household and individual characteristics contribute lesser to the shared time than the time slots and the activities. Despite this, the district was selected for the study of factors of the shared time using AIC. This is consistent with the view of the time use research which has dealt with the district as an important factor from the beginning of the research in Europe.

Moreover, the optimal categorization about time (Appendix C2) gives us some implication that a careful re-categorization of time slots is required because the time slots need to be pooled differently by activities, if time information is to be utilized effectively.

The optimal explanatory variable sets of the shared time for each activity (Model 2) were selected as follows;

Meals: Time, District

Moving: Time

Studies: Time, Density of residential space, Education of father

Leisure: Time, Income, Working hours of father and mother, Tendency of sports

Others: Time, District, Working hours of father

In the next section, the results from Meals, Studies, and Leisure are reported in detail.

4.2 The outcome from Model 2

(1) Factors of the shared time during meals

The result of the shared time by the optimal time slots and the district are summarized in Table 1. In Nonidentical activity in the metropolitan areas, 38% in the morning and 19% in the evening indicate the percentage of children taking meals alone beside family members (Table 1). The family lifestyle is clearly different between the metropolitan areas and the other areas.

(2) Factors of the shared time during studies

The education of the father and the density of residential space were selected as key factors in shared time during children's studies. In a family living in the middle or low density areas, the situations of a child during studies are divided by his/her father's education (Table 2). If the father graduated from college, the child is likely to study with other people, which means that he/she will go to a cramming school or take lessons from a tutor. If the father did not graduate from a college, etc., and there are family member(s) around the child, so the parent might take care of his/her child's study. People who have lower educational achievements do not tend to have their children taking such lessons because they might not think it is necessary or they cannot afford them. This trend seems to perpetuate the economic differences throughout generations by the father's education being followed by their children.

(3) Factors of the shared time during leisure

The amount of shared time spent in leisure depends on the income, the working hours of the father and mother, and the tendency of a child to participate in sports[4]. Leisure with their family members decreases by about 10% if the father works long hours (Table 3). Also, those on a high income tend not to have identical leisure activities (Table 4). One of the reasons for this could be the restriction of goods. For example, a family without a high income has only one TV set in their living room so they naturally gather in one place and tend to carry out same leisure activity.

[4] In the outcome of the tendency to sports, the children's fondness for sports promotes the chance that they spent time with other person, and if children are not likely to engage in sports, they share time and activities with their family.

Table 1 Shared time during meals by district based on the optimal categorized time slots (unit: %)

District / Shared time	Metropolitan areas Id.	Nonid.	Others	Alone	(Obs.)	Other areas Id.	Nonid.	Others	Alone	(Obs.)
6:00-8:45	57.6	37.8	2.8	1.8	(217)	73.8	22.0	1.4	2.8	(286)
8:45-12:15	0.0	33.3	66.7	0.0	(3)	0.0	0.0	14.3	85.7	(7)
12:15-15:15	0.6	0.3	99.1	0.0	(323)	2.7	0.5	96.4	0.5	(439)
15:15-17:15	0.0	50.0	40.0	10.0	(10)	0.0	25.0	50.0	25.0	(16)
17:15-21:15	74.6	19.1	4.6	1.7	(350)	85.0	13.3	0.2	1.4	(487)
21:15-24:00	31.6	31.6	0.0	36.8	(19)	23.1	38.5	0.0	38.5	(13)
Total	42.7	17.6	37.8	1.9	(922)	51.3	11.1	35.0	2.6	(1248)

Note: Identical activity and Nonidentical activity are abbreviated for Id. and Nonid. respectively. The number is the participation rate in each time slots. In parentheses, number of the samples in each pooled time slots is indicated, and so on.

Table 2 Shared time during studies on the density of residential space (middle or low) by the education of the father based on the optimal categorized time slots (unit: %)

Father's education / Shared time	Junior high school / high school Id.	Nonid.	Others	Alone	(Obs.)	College, etc. Id.	Nonid.	Others	Alone	(Obs.)
16:45-17:30	0.0	20.0	68.8	11.2	(125)	0.8	27.9	47.5	23.8	(122)
17:30-19:15	8.1	27.5	41.9	22.5	(160)	13.7	24.5	45.6	16.2	(204)
19:15-20:15	7.7	61.5	3.8	26.9	(52)	5.6	30.6	43.1	20.8	(72)
20:15-21:15	6.5	52.2	0.0	41.3	(92)	23.3	19.3	16.7	40.7	(150)
21:15-24:00	8.8	27.5	0.0	63.7	(80)	11.2	32.8	0.9	55.2	(116)
Total	5.3	34.7	36.1	23.8	(429)	12.4	24.6	37.8	25.2	(548)

Table 3 Shared time during leisure by the working hours of the father based on the optimal categorized time slots (unit: %)

Father's working hours / Shared time	Middle (Under 48 hours) Id.	Nonid.	Others	Alone	(Obs.)	Long (Over 48 hours) Id.	Nonid.	Others	Alone	(Obs.)
00:00-08:00	28.8	36.4	28.8	6.1	(129)	5.3	56.4	33.0	5.3	(31)
08:30-15:30	3.7	4.5	80.7	11.1	(1234)	3.1	3.6	85.0	8.3	(367)
15:30-17:30	17.9	25.0	30.1	27.1	(950)	10.5	35.5	40.2	13.8	(303)
17:30-19:00	30.3	39.0	14.6	16.1	(814)	19.3	47.1	21.6	12.0	(236)
19:00-24:00	59.5	28.3	3.0	9.2	(1814)	47.0	40.4	6.6	6.1	(495)
Total	31.9	23.7	30.2	14.2	(4941)	22.5	31.4	36.8	9.3	(1432)

Table 4 Shared time during leisure by income based on the optimal categorized time slots (unit: %)

Income / Shared time	Low and Middle Id.	Nonid.	Others	Alone	(Obs.)	High Id.	Nonid.	Others	Alone	(Obs.)
00:00-08:00	17.8	48.1	29.5	4.7	(129)	3.2	48.4	38.7	9.7	(31)
08:30-15:30	3.1	3.9	86.9	6.2	(1234)	4.4	4.4	70.0	21.3	(367)
15:30-17:30	16.0	28.7	36.8	18.4	(950)	5.6	38.9	33.7	21.8	(303)
17:30-19:00	25.1	43.1	18.2	13.6	(814)	22.0	44.1	19.1	14.8	(236)
19:00-24:00	55.1	33.3	4.5	7.1	(1814)	44.6	39.6	6.3	9.5	(495)
Total	28.7	27.1	34.2	10.0	(4941)	21.4	31.4	31.2	16.0	(1432)

4.3 The outcome from Model 3

This section examines the cooperation between father and mother regarding shared time with their children during meals and leisure (Appendix C3). The row and column of Table 5 show the patterns of the identical activity partner (each father or mother).

(a): Children have some identical activity time with mother and with father respectively[5].
(b): Children have some identical activity time with their mother not their father during the day.
(c): Children have no identical activity time with their parents during the day.
(d): Children have some identical activity time with their father not their mother during the day.

Table 5 Cooperative action between father and mother (unit: %)

with father / with mother	No	Yes
No	(a) Cooperative style	(d) Father-sided style
Yes	(b) Mother-sided style	(c) Individual style

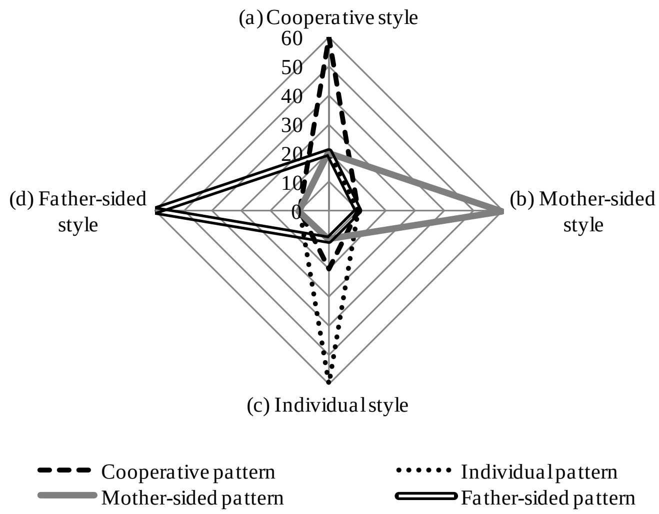


Figure 2 Cooperative action between father and mother (unit: %)

Figure 2 corresponds to the value of Table 5. The vertical line indicates the intensity of the cooperative style, so the upward line (a) shows the cooperative style between father and mother and the downward line (c) shows the individual style which means the separate action between parents and child. The horizontal line shows the intensity of the one-sided style, and the right-handed side and the left-handed side correspond to the mother-sided style of sharing time and activities (b) and the father-sided style of sharing time and activities (d), respectively.

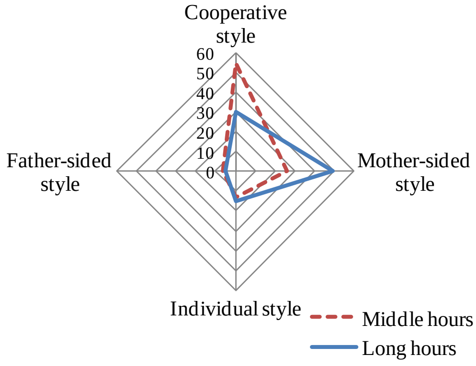
[5] (a) does not include the situation that children have some identical activity time with mother and father together. Hence, "Cooperative action" represents a kind of manner that a parent carries on a same activity with his/her children when his/her spouse cannot or do not share time with their children.

(1) The cooperative action between father and mother during meals

Based on AIC, the working hours of father and mother, the education of the mother, and the amount of meal times spent with other people are selected as factors for the cooperative action between father and mother during meals with their children. In all factors, there are mother-sided style (the (d) values of less than around 10% in Tables 6,7,8), and this expresses a typical relationship between a Japanese husband and wife.

The 50% of fathers who work long hours leave the shared time at meals to their wives. However, the value of the mother-sided style is only 26% if the father works middle hours (Table 6). According to the mother’s working hours (Table 7), though the mother-sided style is shown, the 11% of mothers who work middle hours tend to be supported by their husbands and their value is higher than the value of mothers in other working categories. The education of the mother affects the mother-sided style, so that the 46% of mothers who have had higher education share times during meals without their husbands (Table 8).

Table 6
Cooperative action during meals
by the working hours of the father (unit: %)



with father / with mother	Working hours of father: Middle hours		Long hours	
	No	Yes	No	Yes
No	12.9	6.1	14.8	5.3
Yes	26.4	54.6	49.7	30.2
Total obs.		(326)		(378)

(2) The cooperative action between father and mother during leisure

The working hours of the father, the education of the mother, and the tendency towards travel and hobbies[6] influenced the cooperative action during leisure with their children. With meals, the long working hours of the father results in an increase of the level of no identical activity with his child/children or the mother-sided style (Table 9).

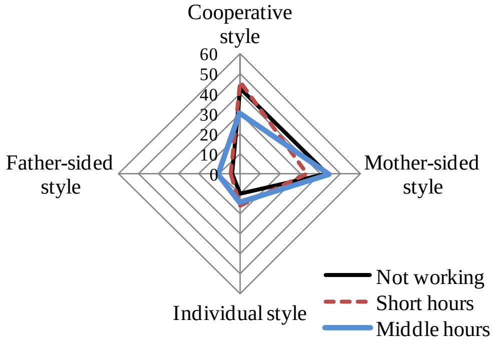
Families that often go on holiday (Table 10) spend time in the cooperative style with the father and mother (32%) or with the mother-sided style (33%). The values of the other family show distinguishing features with regard to the father-sided style (14%) or the situation of nobody sharing leisure (38%). The fondness for holidays represents the manner in which the family spends their leisure time during weekdays, and if the family travels often, the intra-family relationships tend to become either mother-sided or the cooperative style, or both.

(3) The cooperative action and time between father and mother during leisure

The working hours and the density of residential space are selected for the cooperative

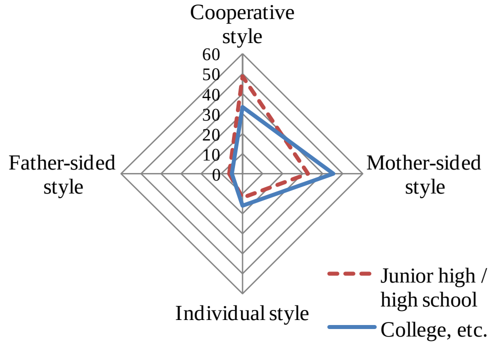
[6] In the outcome of tendency to hobbies, the children who often engage in hobbies tend to be in the situation of the father-sided style or the individual style compared with the other children.

Table 7
Cooperative action during meals
by the working hours of the mother (unit: %)



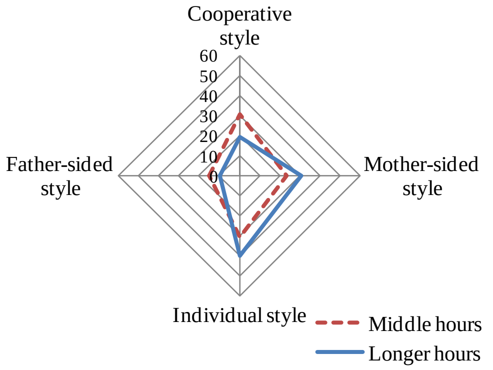
	Working hours of mother					
	Not working		Short hours		Middle hours	
with father / with mother	No	Yes	No	Yes	No	Yes
No	10.1	3.4	15.7	4.5	14.1	10.6
Yes	43.8	42.7	33.7	46.1	44.7	30.6
Total obs.		(178)		(356)		(170)

Table 8
Cooperative action during meals
by the education of the mother (unit: %)



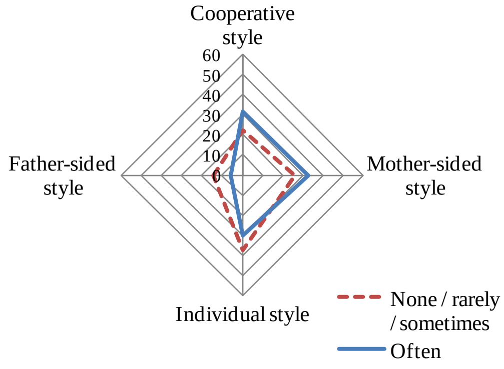
	Education of mother			
	Junior high/ high school		College, etc.	
with father / with mother	No	Yes	No	Yes
No	12.1	6.3	16.0	4.9
Yes	33.2	48.4	45.7	33.3
Total obs.		(380)		(324)

Table 9
Cooperative action during leisure
by the working hours of the father (unit: %)



	Working hours of father			
	Middle hours		Long hours	
with father / with mother	No	Yes	No	Yes
No	30.7	14.7	40.2	9.5
Yes	23.9	30.7	31.2	19.0
Total obs.		(326)		(378)

Table 10
Cooperative action during leisure
by the tendency to travel (unit: %)



	Tendency to travel			
	None / rarely /sometimes		Often	
with father / with mother	No	Yes	No	Yes
No	37.6	14.1	30.3	5.6
Yes	26.2	22.1	32.6	31.5
Total obs.		(526)		(178)

action during leisure, and this includes not only whether they have identical activity, but also the hours spent on identical leisure activities. As regards ordinary recognition, a father working long hours spends a shorter time taking part in identical activity during leisure time with his child/children (Table 11). However, the different patterns are observed by the density of residential space controlled by the father’s working hours. The cooperative actions of the family living in a middle and low density by the father’s working hours (the right-handed side of Tables 12,13) represent the basic cooperative actions which are observed by the father’s working hours only (Table 11). In a high density of residential space, the father working middle hours spends a longer time engaging in the identical leisure activities with his children, and the father working long hours tends to take a cooperative style with his wife for sharing time with their children.

Table 11 Cooperative action and hours during leisure by the father’s working hours (unit: %)

	Working hours of father					
	Middle hours			Long hours		
with father / with mother	None	Under 60 min.	Over 60 min.	None	Under 60 min.	Over 60 min.
None	30.7	7.4	7.4	40.2	9.5	0.0
Under 60 min.	21.5	9.2	4.9	27.5	8.5	2.6
Over 60 min.	2.5	6.7	9.8	3.7	2.1	5.8
Total obs.			(326)			(378)

Table 12 Cooperative action and hours during leisure on the father’s working hours (middle) by the density of residential space (unit: %)

	Density of residential space					
	High			Middle and Low		
with father / with mother	None	Under 60 min.	Over 60 min.	None	Under 60 min.	Over 60 min.
None	42.9	28.6	21.4	29.5	5.4	6.0
Under 60 min.	0.0	0.0	7.1	23.5	10.1	4.7
Over 60 min.	0.0	0.0	0.0	2.7	7.4	10.7
Total obs.			(28)			(298)

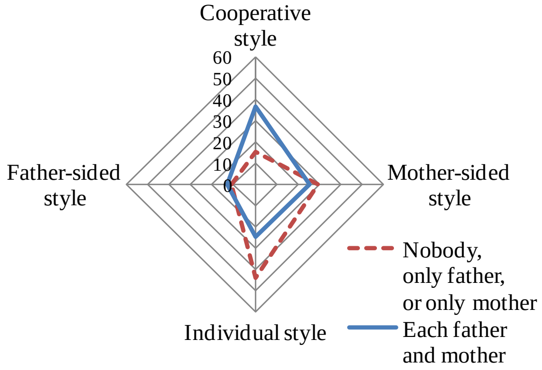
Table 13 Cooperative action and hours during leisure on the father’s working hours (long) by the density of residential space (unit: %)

	Density of residential space					
	High			Middle and Low		
with father / with mother	None	Under 60 min.	Over 60 min.	None	Under 60 min.	Over 60 min.
None	33.3	0.0	0.0	40.8	10.3	0.0
Under 60 min.	13.3	33.3	6.7	28.7	6.3	2.3
Over 60 min.	6.7	6.7	0.0	3.4	1.7	6.3
Total obs.			(30)			(348)

(4) The relation of the cooperative action during leisure and meals

It is considered that the cooperative style during leisure could be a substitute for cooperative action during meals. For example, people who cannot take a meal with their family may try to spend time with the family by carrying out the same leisure activities. After this, the cooperative action during meals is used as the explanatory variable for the model of cooperative action during leisure. The selected variables are the cooperative action during meals, the working hours and the education of the father, and the tendency to engage in hobbies. The remarkable outcome (Table 14) is that the 37% family with the cooperative style during meals tends to cooperate with the father and mother during leisure too. If children do not take meals with either parents, 44% of children also do not share time with their parents during leisure. From this outcome, two types of families can be observed; one is closer and the other is more separated.

Table 14
Cooperative action during leisure
by cooperative action during meals (unit: %)



	With whom took meals			
	Nobody, only father or only mother		Each father and mother	
with father / with mother	No	Yes	No	Yes
No	43.7	11.2	24.7	13.0
Yes	29.6	15.5	25.3	37.0
Total obs.		(412)		(292)

5. Conclusion

The degree of Identical and Nonidentical activities can be estimated from the original Micro-data in order to clarify the complicated and diversified intra-family relationships. JTUS does not give these types of information directly. Therefore, these variables are estimated by matching the activity of people being together based on the assumption that, in each time slots, all family members who marked “with family” for the person they were with shared time and gathered in the same space. The outcomes from these estimated values show both the ordinary Japanese intra-family relationships and the new findings related to it.

Although the intra-family relationship between the mother and her children tends to be more intimate as compared with that between the father and his children, it is true that eating and enjoying leisure activity together used to be a more prominent feature of the Japanese family lifestyle. It has been said, however, that the traditional lifestyle has changed and diversified substantially due to the long working hours of fathers and the increase of numbers of mothers in paid work. This analysis, based on AIC, has evidenced these recent trends which have been widely accepted in Japan.

The model analysis also evidenced new findings. Firstly, the data shows the decrease in the chances of sharing meals with family members in metropolitan areas. Secondly, the fondness for holidays relates the manner in which the cooperative action between father and mother during leisure. Thirdly, the cooperative action between father and mother during leisure correlates those of during meals. These new findings tell us that, in addition to the long working hours, factors such as the advancement of urbanization and the tendency to daily and holiday activities significantly affect the intensity of the intra-family relationship.

Acknowledgments

The analysis is based on the anonymized Micro-data, “Survey on Time Use and Leisure Activities (Version of Time Use, 2001 survey),” which was provided by the Statistics Bureau of the Ministry of Internal Affairs and Communications. The present author appreciates the Statistics Bureau, the National Statistics Center, and the Research Centre for Information and Statistics of Social Science, the Institute of Economic Research, and Hitotsubashi University for providing the data. The statistical value of this paper does not relate to the statistics made and published by the Statistics Bureau. The author is also indebted to Prof. Yoshiuki SAKAMOTO of the Institute of Statistical Mathematics for providing CATCAP for categorical analysis.

Appendix A1　JTUS data and the matching possibility

From the beginning of the JTUS, it has been conducted using questionnaire A based on the pre-coding system. Since the 2001 survey of JTUS, however, this also has added the questionnaire B based on the after-coding system. Questionnaire B also surveys the detailed categories of family members when sharing times (Table A1.1).

Table A1.1　Person(s) being together of Questionnaires A and B

<table>
<tr><th>Questionnaire B</th><th>Questionnaire A</th></tr>
<tr><td>Alone</td><td>Alone</td></tr>
<tr><td>Father
Mother
Son(s)/daughter(s)
Spouse
Other family member(s)</td><td>Family member(s)</td></tr>
<tr><td rowspan="2">Other person(s)</td><td>Classmate(s) /Colleague(s)</td></tr>
<tr><td>Other person(s)</td></tr>
<tr><td>3895 households /9826 persons</td><td>71657 households /186424 persons</td></tr>
</table>

Note: Statistics Bureau Japan(2003a,b)

Usually, it is preferable to use the variable from questionnaire B, but the survey sample is smaller than questionnaire A, so that the error problem of estimators cannot be ignored when the particular small subpopulation is analyzed. This paper employs the approach of using data from questionnaire A, which can be estimated with more validity.

When identifying the Identical and Nonidentical variables with questionnaire A of JTUS, the precision in matching families depends on the family structure about the type of household, the existence of a child under 10 years old, and the number of children in the household. Generally, in case of the more than two generations, it is more difficult to identify the partner, so that this paper restricts the family type to the nuclear family with father, mother, and children. In this restriction, the matching probability is arranged as Table A1.2 by the age of the youngest child and the number of children.

To maintain the precision of estimation, the matching of household is restricted to a nuclear family in which all family members are over 10 years old, and which consist with one to three children (the part of gray zone in Table A1.2). The precision of the matching in this method had been verified with questionnaire B (Kurihara & Sakata(2010b)).

Table A1.2 Matching possibility of time-sharing family members
(Parents and child/children of Nuclear family)

Number of child/children			Subject: Household header or his/her spouse			Subject: Child		
Total	Under 10 years old	Over 10 years old	Spouse	Child	Spouse & child	Father	Mother	Parents
1	0	1	◎（B◎）	◎（B◎）	◎（B◎）	◎（B◎）	◎（B◎）	◎（B◎）
2	0	2	○（B◎）	○（B◎）	○（B◎）	○（B◎）	○（B◎）	○（B◎）
3	0	3	○（B◎）	○（B◎）	○（B◎）	○（B◎）	○（B◎）	○（B◎）
1	1	0	◎（B◎）	×（B△）	×（B△）	×（B×）	×（B×）	×（B×）
2	1	1	○・△（B◎）	○・△(B△)	○・△(B△)	○・△（B◎）	○・△（B◎）	○・△（B◎）
	2	0	×（B◎）	×（B△）	×（B△）	×（B×）	×（B×）	×（B×）
3	1	2	○・△（B◎）	○・△(B△)	○・△(B△)	○・△（B◎）	○・△（B◎）	○・△（B◎）
	2	1	○・△（B◎）	○・△(B△)	○・△(B△)	○・△（B◎）	○・△（B◎）	○・△（B◎）
	3	0	×（B◎）	×（B△）	×（B△）	×（B×）	×（B×）	×（B×）

Note: ◎ It is possible to match in high precision.
○ It is difficult to identify the time-sharing partner because the family members might share their time in different two groups.
△ It is difficult to identify the time-sharing partner because of the existence of child/children under 10 years' old which is not surveyed.
× It fails to match.
(B…) Matching possibility in case of using questionnaire B.

Appendix A2 Table of the original code and recode categories

Original code	Recode	Original code	Recode
1 Sleep	1 Sleep	11 Moving	3 Moving
2 Personal care	6 Others	12 Watching TV, listening to the radio, reading newspapers or magazines	5 Leisure
3 Meals	2 Meals	13 Rest and relaxation	5 Leisure
4 Commuting to and from school or work	3 Moving	14 Studies and research	4 Studies
5 Work	6 Others	15 Hobbies and amusement	5 Leisure
6 Schoolwork	4 Studies	16 Sports	5 Leisure
7 Housework	6 Others	17 Volunteer and social activities	6 Others
8 Caring or nursing	6 Others	18 Social life	6 Others
9 Child care	6 Others	19 Medical examination or treatment	6 Others
10 Shopping	6 Others	20 Other activities	6 Others

Appendix A3　Table of the explanatory variables set

Variables	Categories
Time slots	96 categories divided by each 15 minutes
Activities	1.Sleep 2.Meals 3.Movieng 4.Studies 5.Leisure 6.Others
[Characteristics of household]	
District	1.Metropollitan areas,　2.Other areas
Income	1.High(Over 8 million yen),　2.Middle(4 to 8 million yen), 3.Low(Under 4 million yen)
Density of residential space	1.High,　2.Middle,　3.Low
[Characteristics of Father]	
Education	1.Junior high school 2.High school 3.College, etc.
Working hours (Paid work)	1.Middle (Under 48 hours) 2.Long (Over 48 hours)
[Characteristics of Mother]	
Education	1.Junior high school 2.High school 3.College & etc.
Working hours (Paid work)	1.Not working 2.Short (Under 34 hours) 3.Middle (Over 34 hours)
[Characteristics of Mother]	
Sex	1.Male 2.Female
Tendency to the Internet	1.None 2.Rarely 3.Sometimes 4.Often
Tendency to travel	1.None 2.Rarely 3.Sometimes 4.Often
Tendency to sports	1.None 2.Rarely 3.Sometimes 4.Often
Tendency to hobbies	1.None 2.Rarely 3.Sometimes 4.Often
Tendency to amusements	1.None 2.Rarely 3.Sometimes 4.Often

Note 1: Density of residential space represents to the relation of the residence rooms and the number of family members. If the number of residence rooms is equal to the number of family members plus one, the density of residential space indicates "Middle," if more rooms the category is "Low," and if less rooms the category is "High."

Note 2: The variables of tendency are made from the survey items that surveyed about the frequency of sports, hobbies, amusements, travels, in a year.

Appendix B1　Deriving equation (6)

Based on the multinomial distribution, the probability distribution of $n(r_0,r_1)$ with regard to variables Y_0 and X_1 is written as (b1), and the log likelihood for $p(r_0,r_1)$ is given by (b2) except the irrelevant terms to $p(r_0,r_1)$.

$$P(n(r_0,r_1)|\, p(r_0,r_1)) \quad = \frac{n!}{\prod_{r_0}^{C_0}\prod_{r_1}^{C_1} n(r_0,r_1)\,!}\prod_{r_0}^{C_0}\prod_{r_1}^{C_1} p(r_0,r_1)^{n(r_0,r_1)} \tag{b1}$$

$$l\big(p(r_0,r_1)\big) = \sum_{r_0}^{C_0}\sum_{r_1}^{C_1} n(r_0,r_1)\, log p(r_0,r_1) \tag{b2}$$

By using the definition of the conditional probability $p(r_0,r_1) = p(r_0|r_1)p(r_1)$, equation (b2) is transformed to equation (b3).

$$l\big(p(r_0,r_1)\big) = \sum_{r_0}^{C_0}\sum_{r_1}^{C_1} n(r_0,r_1)\, log p(r_0|r_1) + \sum_{r_0}^{C_0}\sum_{r_1}^{C_1} n(r_0,r_1)\, log p(r_1) \tag{b3}$$

The log likelihood for estimation of model B is defined as equation (b4) employing only the relevant term to the conditional probability $p(r_0|r_1)$.

$$l\big(\theta(r_0|r_1)\big) = \sum_{r_0}^{C_0}\sum_{r_1}^{C_1} n(r_0,r_1)\, log\theta(r_0|r_1) \tag{b4}$$

To obtain the equation (b5) which corresponds to equation (4), the equation of constraint on model B is substituted into equation (b4).

$$\sum_{r_0=1}^{C_0} \theta(r_0|r_1) = 1$$

$$\Leftrightarrow \quad \theta(C_0|r_1) = 1 - \sum_{r_0=1}^{C_0-1} \theta(r_0|r_1)$$

$$l(\theta(r_0|r_1)) = \sum_{r_1}^{C_1} \left[\sum_{r_0}^{C_0-1} n(r_0, r_1) log\theta(r_0|r_1) + n(C_0, r_1) log \left(1 - \sum_{r_0=1}^{C_0-1} \theta(r_0|r_1) \right) \right] \quad \text{(b5)}$$

In order to derive the maximum likelihood estimator, equation (b5) is differentiated with parameter $\theta(r_0|r_1)$ and sets to be zero.

$$\frac{\partial l}{\partial \theta} = \frac{n(r_0, r_1)}{\theta(r_0|r_1)} - \frac{n(C_0, r_1)}{1 - \sum_{r_0=1}^{C_0-1} \theta(r_0|r_1)} = \frac{n(r_0, r_1)}{\theta(r_0|r_1)} - \frac{n(C_0, r_1)}{\theta(C_0|r_1)} = 0$$

$$\Leftrightarrow \quad \frac{\theta(r_0|r_1)}{n(r_0, r_1)} = \mathrm{K},$$

where $\mathrm{K} = \frac{\theta(C_0|r_1)}{n(C_0, r_1)}$.

The constant term K that is satisfied by the equation of constraint for model B is given by (b6).

$$\sum_{r_0}^{C_0} \theta(r_0|r_1) = \mathrm{K} \sum_{r_0}^{C_0} n(r_0, r_1) = 1$$

$$\therefore \ \mathrm{K} = \frac{1}{\sum_{r_0}^{C_0} n(r_0, r_1)} \quad \text{(b6)}$$

Then, the maximum likelihood estimator is derived as follows:

$$\hat{\theta}(r_0|r_1) = \frac{n(r_0, r_1)}{\sum_{r_0}^{C_0} n(r_0, r_1)} \quad \text{(b7)}$$

Substituting the maximum likelihood estimator (b7) into the equation (b5) and using the degree of freedom on model B, AIC for the selection of the explanatory variable set is shown as equation (6), where the term (b8) for the adjustment for chi-square test is added to the general definition of AIC.

$$(-2) \sum_{r_0}^{C_0} n(r_0) log \frac{n}{n(r_0)} - 2(C_0 - 1) \quad \text{(b8)}$$

Appendix B2 Deriving equation (11)

In the same way as deriving the equation for the selection of the explanatory variable set, the likelihood of the categorization with regard to model D is written as follows:

$$l(\theta(r_0|r_1^*)) = \sum_{r_0}^{C_0} \left[n(r_0, 1) log\theta(r_0|1) + \sum_{r_1}^{2,3} n(r_0, r_1) log\theta(r_0|2^*) \right]$$

$$= \sum_{r_0}^{C_0-1} \left[n(r_0, 1) log\theta(r_0|1) + \sum_{r_1}^{2,3} n(r_0, r_1) log\theta(r_0|2^*) \right] + n(C_0, 1) log\theta \left(1 - \sum_{r_0=1}^{C_0-1} \theta(r_0|1) \right)$$

$$+\sum\nolimits_{r_1}^{2,3} n(C_0, r_1) log\theta \left(1 - \sum\nolimits_{r_0=1}^{C_0-1} \theta(r_0|2^*)\right) \qquad \text{(b9)}$$

Similarly, with the equation (b9), the maximum likelihood estimator for each new categories of the explanatory variable is derived as equation (b10) and (b11) by using the equation of constraint on the model D.

$$\frac{\partial l}{\partial \theta(r_0|1)} = \frac{n(r_0, 1)}{\theta(r_0|1)} - \frac{n(C_0, 1)}{1 - \sum_{r_0=1}^{C_0-1} \theta(r_0|1)} = 0$$

$$\therefore \ \hat{\theta}(r_0|1) = \frac{n(r_0, 1)}{\sum_{r_0}^{C_0} n(r_0, 1)} \qquad \text{(b10)}$$

$$\frac{\partial l}{\partial \theta(r_0|2^*)} = \frac{\sum_{r_1}^{2,3} n(r_0, r_1)}{\theta(r_0|2^*)} - \frac{n(C_0, 2^*)}{1 - \sum_{r_0=1}^{C_0-1} \theta(r_0|2^*)} = 0$$

$$\therefore \ \hat{\theta}(r_0|2^*) = \frac{\sum_{r_1}^{2,3} n(r_0, r_1)}{\sum_{r_0}^{C_0} \sum_{r_1}^{2,3} n(r_0, r_1)} \qquad \text{(b11)}$$

Substituting the maximum likelihood estimator (b10) and (b11) into the equation (b9) and using degree of freedom on model D, AIC for the selection of the pooled categories is defined as equation (11), where the term (b8) is also added to the general definition of AIC in order to adjust it for chi-square test.

Appendix C1 Summary of the outcome of Models 1 and 2 from CATDAP

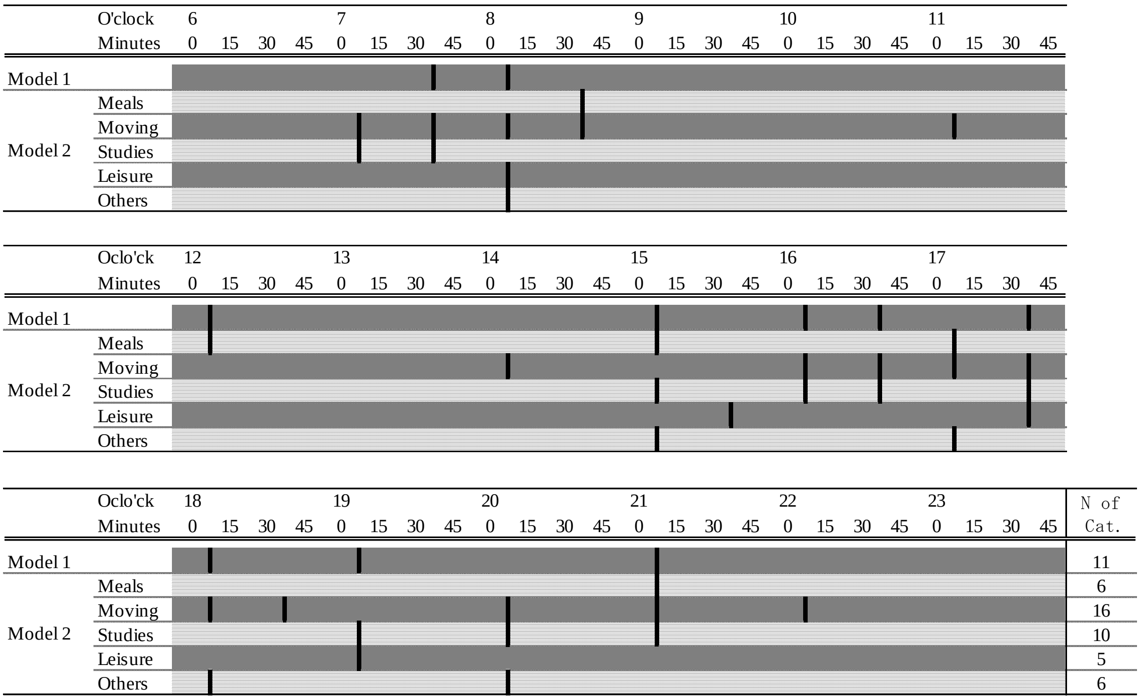
Explanatory variable	O.C.	Model 1					Model 2									
							Meals					Moving				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Time slots	96	11	o	o	o	o	6	o	o	o	o	16	o	o	o	o
Activities	6	6	o	o	o	o	-	-	-	-	-	-	-	-	-	-
[Characteristics of household]																
District	2	2					2									
Income	3				o			o							o	
Density of residential space	3															
[Characteristics of Father]																
Education	3															
Working hours	2		o													
[Characteristics of Mother]																
Education	3															
Working hours	3			o												
[Characteristics of children]																
Sex	2															
Tendency to the Internet	4													o		
Tendency to travel	4										o					o
Tendency to sports	4															
Tendency to hobbies	4															
Tendency to amusements	4									o			o			
Number of variables		3	3	3	3	2	2	2	1	2	2	1	2	2	2	2
Number of total categories		132	132	198	198	66	12	12	6	12	12	16	48	48	48	64
AIC		-37140	-37098	-37020	-37005	-36974	-2507	-2496	-2489	-2485	-2482	-393	-337	-329	-324	-258
Difference of AIC		0	42	120	135	166	0	11	18	22	25	0	57	64	69	135

Note : "O.C." in the column shows the number of each original category in each explanatory variable. Numbers one to five in the column means the ranking of AIC calculated by CATDAP, and the selected explanatory variable sets are colored by gray. The numbers in the gray zone crossed by explanatory variables indicate the number of optimal categorization. In the colorless zone, there are circle marks which show the selected explanatory variables by AIC.

Appendix C1 Summary of the outcome of Models 1 and 2 from CATDAP (continued)

Explanatory variable	O.C.	Model 2 (Continued)														
		Studies					Leisure					Others				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Time slots	96	10	o	o	o	o	5	o	o	o	o	6	o	o	o	o
Activities	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[Characteristics of household]																
District	2											2			o	o
Income	3						2		o							
Density of residential space	3	2	o			o										
[Characteristics of Father]																
Education	3	2			o											
Working hours	2						2	o			o	2	o	o		o
[Characteristics of Mother]																
Education	3															
Working hours	3						3	o	o	o						
[Characteristics of children]																
Sex	2															
Tendency to the Internet	4												o		o	o
Tendency to travel	4															
Tendency to sports	4						4	o	o	o	o					
Tendency to hobbies	4			o		o										
Tendency to amusements	4															
Number of variables		3	2	2	2	3	5	4	4	3	3	3	3	2	3	4
Number of total categories		40	20	40	20	80	240	120	120	60	40	24	36	12	36	72
AIC		-4455	-4409	-4404	-4402	-4398	-5117	-4904	-4693	-4441	-4316	-1557	-1509	-1507	-1499	-1492
Difference of AIC		0	46	51	54	57	0	212	424	676	801	0	48	50	58	64

Appendix C2 The optimal categorization of Models 1 and 2



Appendix C3 Summary of the outcome of Model 3 from CATDAP: The cooperative action between father and mother during meals or leisure

Explanatory variables	O.C.	Model 3																			
		Cooperative action during meals					Cooperative action during leisure (2 categories)					Cooperative action and hours during leisure (3 categories)					Cooperative action during leisure (in relation to that of meals)				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
[Characteristics of household]																					
District	2																				
Income	3																				
Density of residential space	3												o	2		o					
[Characteristics of Father]																					
Education	3		o						o	o		o	o				2	o			
Working time	2	2	o	o	o	o	2		o	o	o	o	o	2	o	o	2		o		
[Characteristics of Mother]																					
Education	3	2	o	o		o	2	o	o		o										o
Working time	3	3	o	o	o	o															
[Characteristics of children]																					
Sex	2																				
Tendency to the Internet	4																				
Tendency to travel	4						2	o							o			o	o	o	o
Tendency to sports	4																				
Tendency to hobbies	4						3	o	o	o	o						3	o	o	o	o
Tendency to amusements	4							o													
[Shered time of children]																					
Alone	2																				
Other people	2	2			o							o				o					
Meals with father or mother	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	o	o	o	o
Number of variables		4	4	3	3	4	4	4	4	3	3	3	3	2	2	3	4	4	4	3	4
Number of total categories		24	36	12	12	24	24	24	36	18	12	8	8	4	8	8	24	24	24	12	36
AIC		-124	-118	-115	-109	-105	-108	-97	-79	-72	-67	-77	-75	-74	-65	-62	-118	-103	-103	-94	-93
Difference of AIC		0	6	9	15	19	0	11	29	36	41	0	2	3	12	15	0	15	15	24	25

Note 1: "O.C." in the row shows the number of each original category in each explanatory variable. Numbers one to five in the row means the ranking of AIC, and the selected explanatory variable sets are colored by gray with the exception on Model 3 for cooperative action and hours during leisure. In this model, the differential of AIC is only three and the number of variables is only two, so the author concludes that the third model is more efficient than the first model. The numbers in the gray zone crossed by explanatory variables indicate the number of optimal categorizations. In the colorless zone, there are circle marks which mean the selected explanatory variables by AIC.

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