1.1 Introduction

In this report, the implementation process of the experiment is outlined. The experiment presents a virtual smart home and lets the respondents explore multiple smart technologies. Then, the respondents are asked to imagine how they apply smart technologies in their daily life. After virtually living in the smart home, they are asked to change the spatial characteristics of the smart home according to their preferences and configure their final preferred layout.

1.2 Implementation of the experiment

The experiment consists of five steps, which can be executed in this virtual smart home by users from the real-world: Step 1) the initial questionnaire, Step 2) a virtual tour through the smart home, Step 3) daily living arrangement, Step 4) spatial layout arrangement, Step 5) the final questionnaire. The structure of the experiment and these five steps are represented in Figure 1.1.

Step 1) the experiment starts with an initial questionnaire with multiple sections, in which we ask some questions about the respondents' characteristics (e.g., Socio-demographics and the technology acceptance level) and their current lifestyle patterns. Table 1.1 reports the variables included in the survey.

For exploring current lifestyle patterns of respondents the following variables are included in the questionnaire:

- Timing pattern, the level of having time pressure and a busy lifestyle.
- Tele activity pattern, the level of doing tele activities (teleshopping, telecommunicating, and other types of tele activities) in the current lifestyle,
- Work at home, the level that the respondent currently work at home,
- Privacy pattern, the level that the respondent generally prefers to have personal and spatial privacy for doing his/her activities in the current lifestyle,
- Current space use pattern, the pattern that the respondent currently uses the spaces of his/her house, such as, kitchen and living room; (e.g. whether the respondent currently does multiple activity types in the kitchen or tends to use the kitchen only for kitchen related activities.)
- Current flexibility pattern, the flexibility pattern that the respondent currently experience in his/her house; (e.g. whether the respondent currently has a house with flexible boundaries and spaces).

These variables are expected to influence the behavior of respondents in the smart home and their design decisions in the next steps of the experiment. By including these variables in the questionnaire we can measure their effects on respondents living preferences and spatial preferences in smart homes, which will be exclusively discussed in the following chapters.

While the information about the personal characteristic of respondents can be easily received from categorical questions, getting information about how people live and how their lifestyle is cannot be asked so straightforward. Hence, we applied Likert scale questions. A statement describing a specific living pattern is given and then the respondent can rate to what extent the statement is valid in his/her case. For instance, for knowing to what extent the respondent has a busy lifestyle, we give the below three statements:

- I usually have a tight schedule to manage all my "inside-home activities" (e.g. cooking, taking care of family, social life activities, personal activities) during a day.
- I usually have a lack of time to do all my "outside-home activities" (e.g. Shopping, picking up child from school, visiting family or friend)
- I usually have a lack of time to spend with my family or to do my favorite activities.

The respondent can rate the extent that each statement applies to him/her in 7 levels from “not at all” to “extremely”.

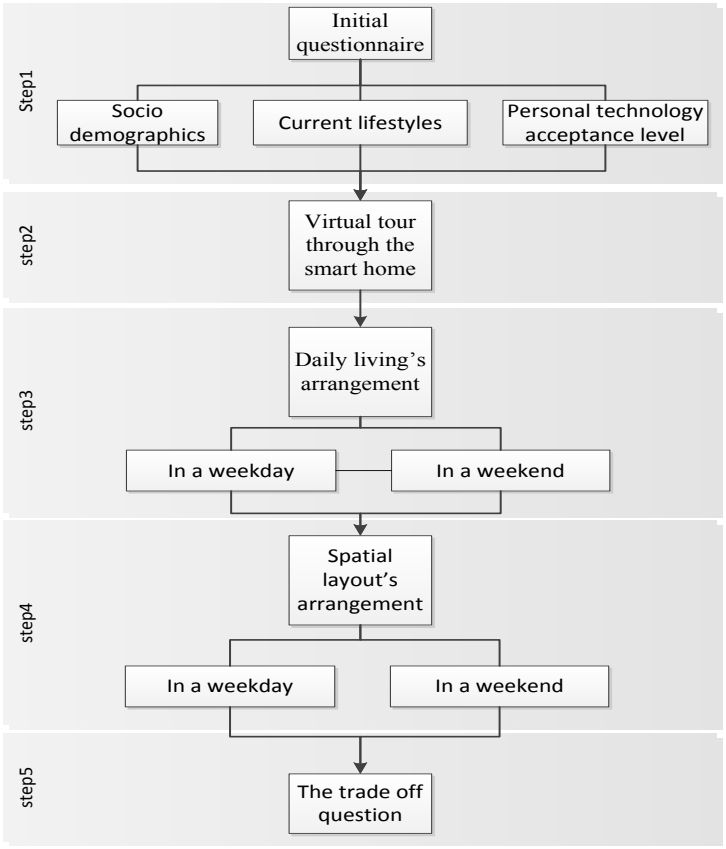


Figure Error! No text of specified style in document.**.1 The structure of the experiment**

Table 1.1 Variable categories of users' characteristics (their socio-demographics and current lifestyle)

	Categories	**Variables**	**Initial Levels**
Personal characteristics	Socio-demographic	Age	0 to 17 18 to 34 35 to 54 55 to 64 Over 65
		Gender	Male Female
		Nationality	The Netherlands Iran Germany Belgium France Italy Spain Poland Greece China Indonesia India Other
		Education	Less than high school

			High school graduated College/university graduated Post graduated
		Working status	Single incomes Dual incomes Not working
		Household	Living alone Living with my partner Living with my Family (with children) Living with my parent Other
		Housing Type	Apartment Row house Semi-detached house Detached house
		Number of bedrooms	No separate bedroom One bedroom Two bedroom Three bedroom More than three bedroom
	Technology acceptance		7 Likert scales
Current lifestyle	Timing pattern	Time pressure at home Time pressure out of home Lack of free time General preferred level of time-saving	7 Likert scales
	Tele activity	Tele- shopping Telecommunication Other types of tele activity General preferred level of tele activity	7 Likert scales
	Work at home	Work at home outside of working hours Work at home within working hours General preferred level of working at home	7 Likert scales
	Privacy pattern	Personal privacy Spatial privacy General preferred level of privacy	7 Likert scales
	Current space use	Current use of kitchen Current use of living room General preferred level of multi-functionality in spaces	7 Likert scales
	Current flexibility	Flexible boundaries in current house Flexible spaces in current house General preferred level of flexibility	7 Likert scales

Step 2) in this step, respondents take a virtual tour through the smart home environment and watch several movies about the smart technologies. Specifically, seven movies are prepared by collecting pieces of promo movies from different companies producing smart technologies. Then the movies are inserted in a different location of the 3D simulated sample of a smart home. Through the movies, respondents can explore different spaces in a smart home and the embedded smart technologies. Accordingly, respondents become familiar with the general concept of smart homes, the involved technologies, and their functionalities before starting the other tasks. Figure 1.2 illustrates a screenshot of this step of the experiment. But more information is provided in Appendix 3.

Figure Error! No text of specified style in document.**.2 Screen shot of the experiment representing the virtual tour**

In particular, two of the movies introduce the smart kitchen table and represent how it provides interactive, flexible and safe cooking by wireless power, and creates different mood conditions for different activities. The movies also show how different activity types, such as food preparation, studying, sharing tasks, gathering together, dining, washing, tele activities (e.g. browsing on the internet, getting medical information, watching media, teleshopping, telecommunication), and working can take place around a smart kitchen table. One of the movies introduces the smart private zone and represents how it provides physical comfort, different privacy levels, mood adaptation and flexible activity zones in a house. One of the other movies introduces smart surfaces and represents how users can control devices, control home conditions, transfer and display data on different screens, and personalize devices using the smart surfaces. Another movie introduces smart boundaries and represents how a smart glass can respond to the outside environment and adjust natural light accordingly, how it can respond to the inside human activities and adjust privacy settings by regulating visual presence, and how it can provide personalized interactions and programmable reactions. The two other movies introduce the smart wall and represent how it provides different possible interactions (e.g. through smart phones, smart furniture, body gesture, or haptic interactions), projecting different sceneries on the wall, and supporting health monitoring and fall recognition. The movies also show how different activities, such as entertainment, watching media, tele-educating, telecommunication, teleshopping, and teleworking can be supported by a smart wall.

Step 3) the involved tasks in this step are called the “daily living arrangement”. Figure 1.3 represents the interface of this step.

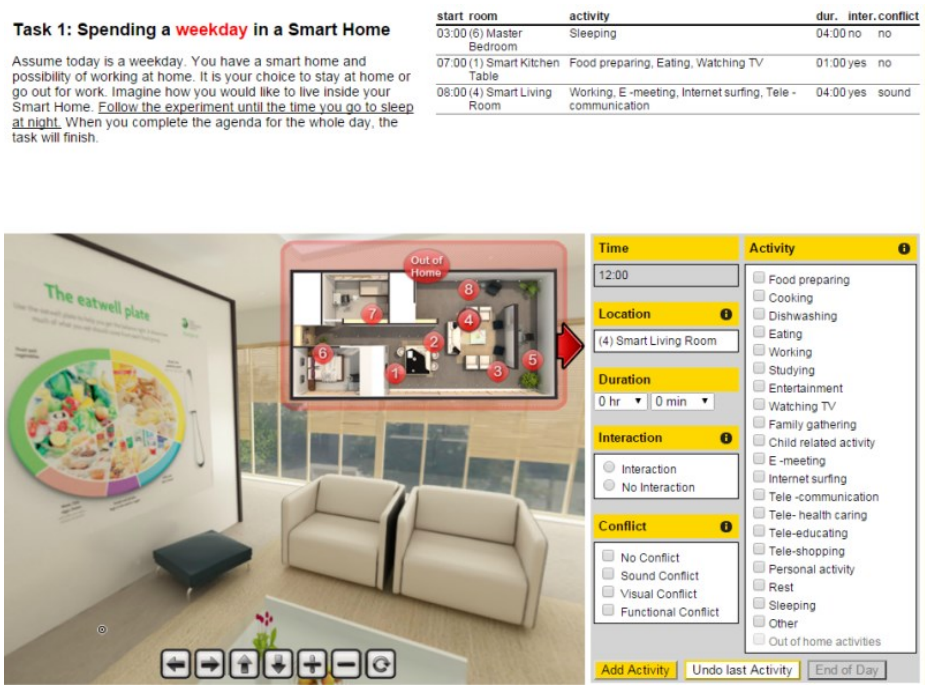


Figure Error! No text of specified style in document.**.3 Screen shot of the experiment representing the task of daily living arrangement**

Respondents are asked to imagine if they have a smart home, how they will live inside it. They can report their daily livings using a schedule. Specifically, they can specify the activities that they want to do around each technology, the time, and the duration of activities and whether or not they have any conflict or interaction during those activities.

At the end of the task, a complete daily schedule is gained for each respondent indicating how he/she would use the smart technologies in his/her daily life. Accordingly, we can elicit the living preferences of that respondent. Figure 1.4 is a graphical representation of such a kind of daily schedule for a respondent. Using this schedule, we can evaluate the types of activities occurring in each zone and the total time spending in each zone. For instance, the presented respondent in Figure 1.4 did multiple activity types, such as secondary activities, working, tele activities and kitchen related activities in the two spots of the smart kitchen 1 and the smart kitchen 2, which are jointly considered as the kitchen zone. But this respondent only did working in the semi-private zone. The total time spending in each zone can also be specified by adding up the durations that the sample spent in the zones. For instance, the presented respondent spent time in the kitchen in separate time slots. The total time spending in this zone can be calculated by adding up all the durations that the respondent spent in it. Moreover, a comparative analysis can be done for different space uses. As an example, the presented respondent tended to use the private zone less than the public or the kitchen zone; because the respondent did fewer activity types and spent less time in the private zone. Accordingly, a lot of information about the living patterns of users in the smart home can be gained from the daily schedule of respondents.

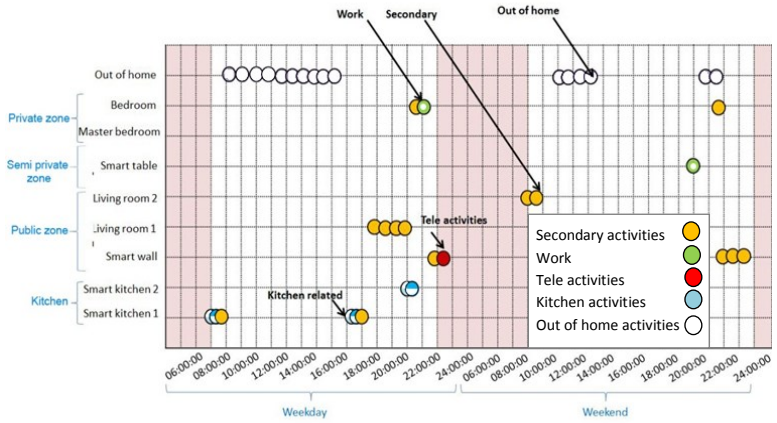


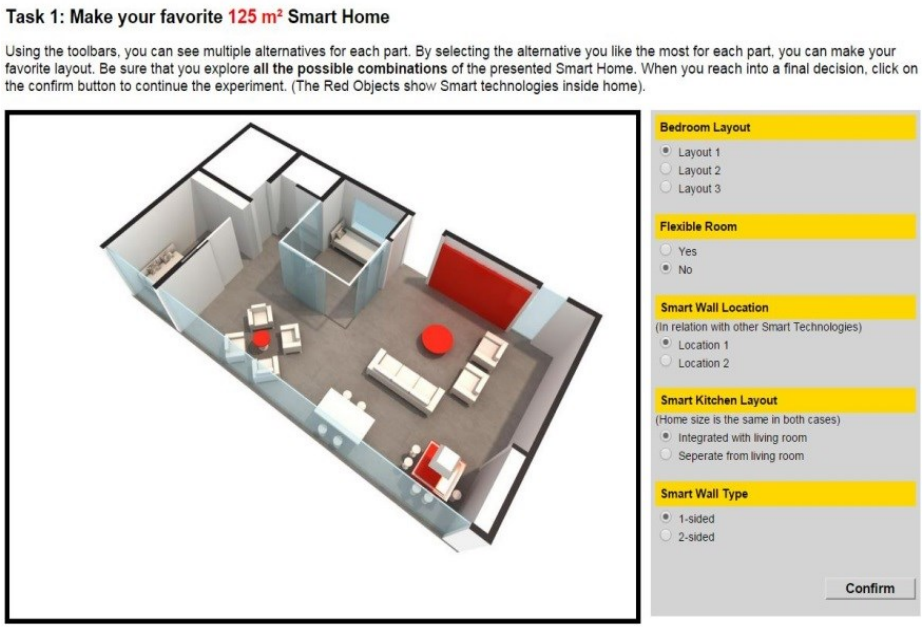
Figure Error! No text of specified style in document.**.4 Graphical representation of the daily schedule of a respondent**

Step 4) the involved tasks in this step are called the "spatial layout's arrangement". In this step, respondents are able to make their preferred home layout by arranging multiple spatial alternatives in a virtual smart home (Figure 1.5).Outputs are mainly used for the spatial preference modeling.
The experiment consists of two design tasks for two different sizes of smart homes (125m^2 and 80 m^2). Two different sizes are included in the experiment because spatial preferences of people could be dissimilar regarding the limitation of size; meaning that a spatial layout, which is suitable for a small smart home, could be undesirable in a large smart home. By limiting the size, applying an optimal spatial layout becomes more important. Every room in a large smart home can easily be upgraded while a lot of functional conflicts, privacy disturbances, or spatial problems may happen by the upgrading of a small smart home. Hence, analyzing different sizes seems crucial in a smart home design. Figure 4.4 shows the design tasks in the both sizes.

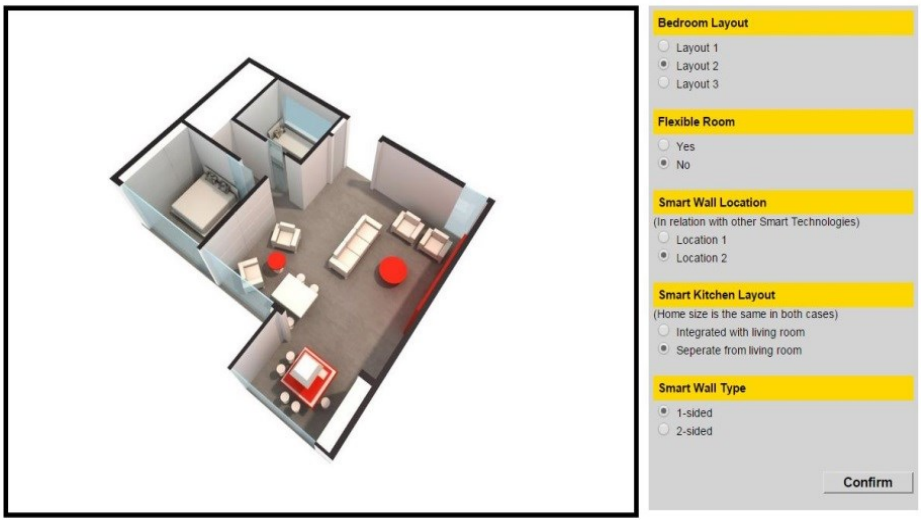
In each task, respondents explore multiple design alternatives for different zones of the smart home. A respondent can explore all the possible combinations until reaching a final decision and selecting the most preferred layout. The spatial preferences can be elicited from the selected layout. The design alternatives are:

- Public-private layout with different alternatives for the bedroom layout and the level of flexibility.
- Smart kitchen layout with different alternatives for the level of kitchen integration,
- Smart living room layout with different alternatives for the smart wall's location and the smart wall's type.

Step 5) a complementary questionnaire is included in the final step of the experiment for measuring the respondents' final satisfaction and evaluating their tradeoff decision for having a smart home or a bigger home.



a.



b.

Figure 1.5 Screen shot of the experiment representing the task of spatial layout's arrangement: a. Task 1: make the favorite smart home in the size of 125m^2, a. Task 2: make the favorite smart home in the size of 80m^2

1.3. Outputs of the "daily living arrangement" Task

After completing the task, the filled activity schedule is saved into the database. Figure 1.7 shows the output data of the daily living task. As it is obvious, each row of the data is dedicated to a time slot and reports the location, duration, activities, interaction and conflict feelings of the respondent in that time slot. Each respondent is recognized by an ID and each ID is repeated in the output data as many times as the respondent request to "add an activity". Therefore, multiple rows of the output data belong to each respondent. According to the level of detail that the respondent reports his/her daily schedule and the time of sleeping at night (finishing the task), the numbers of rows are different for each respondent. There is not any limitation for the numbers of rows for each respondent. The only controlling feature for the detailing level of the answers is the time slots. The duration of activities can be selected from a drop-down list for the hour and the minute, which is set to every 5 min. Figure 1.6 shows the drop down list of the duration. Hence, respondents can report their activities with a controlled detailing level, not too much detailing or too much generalization.

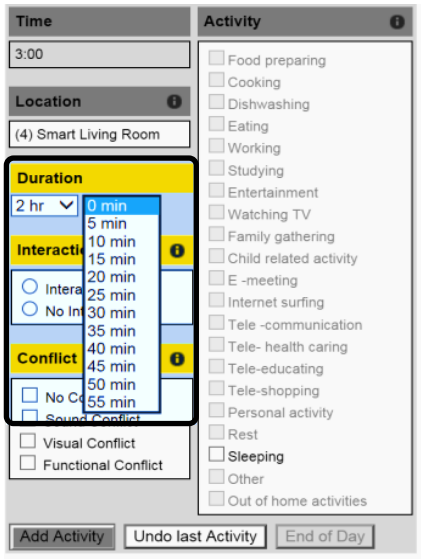


Figure Error! No text of specified style in document.**.6 A screen shot of the activity schedule representing the time slots in the duration part**

As Figure 1.7 shows, the selected activities in each time slot and location are reported as 1, while the unselected activities are reported as 0 in the database. This raw output data give us information on how the respondents live in a smart home. Post processing on data is needed to deduce the basic living patterns of each respondent. Figure 1.7 illustrates a screenshot of the output after applying the calculations and determining the living patterns, namely, the space use pattern, the time spending pattern, the working pattern, the pattern of doing tele activity, and the pattern of multitasking for each of the respondents. This screened data is ready for further analysis and can be applied for the modeling.

id	answerai r_id	kind	positi on	time	Location	durati on	interact ion	Noconfl ict	Soundco nflict	Visualc onflict	Function alconflict	Foodpr eparing	Cookin g	Dishwa shing	Eat...	Worki ng	Studying	Enterta inment	Watchi ngTV	Famil gathe ng
5	103416	0	0	180	bedroom	240	0	1	0	0	0	0	0	0	0	0	0	0	0	
6	103416	0	1	420	SmartTable	480	1	1	0	0	0	0	0	0	0	1	0	0	0	
7	103416	0	2	900	SmartTable	60	1	1	0	0	0	0	0	0	1	0	0	0	0	
8	103416	0	3	960	Living	120	1	0	1	1	0	0	0	0	0	0	0	1	0	
9	103416	0	4	1080	Living	180	0	0	1	1	0	0	0	0	0	0	0	0	1	
10	103416	0	5	1260	Living	60	0	0	1	1	0	0	0	0	0	0	0	0	0	
11	103416	0	6	1320	Living	300	0	1	0	0	0	0	0	0	0	0	0	0	0	
110	103463	0	0	180	bedroom	300	0	1	0	0	0	0	0	0	0	0	0	0	0	
111	103463	0	1	480	kitchen	60	1	1	0	0	0	1	1	0	1	0	0	0	0	
112	103463	0	2	540	OutOfHome	540	0	1	0	0	0	0	0	0	0	0	0	0	0	
113	103463	0	3	1080	kitchen	60	0	1	0	0	0	1	1	0	0	0	0	0	0	
114	103463	0	4	1140	Living	120	1	1	0	0	0	0	0	0	0	0	0	1	1	
115	103463	0	5	1260	Living	60	1	0	1	1	0	0	0	0	0	0	0	0	0	
116	103463	0	6	1320	Living	60	1	1	0	0	0	0	0	0	0	0	0	1	0	
117	103463	0	7	1380	Living	540	0	1	0	0	0	0	0	0	0	0	0	0	0	
165	103518	0	0	180	bedroom	300	0	1	0	0	0	0	0	0	0	0	0	0	0	
166	103518	0	1	480	kitchen	20	0	1	0	0	0	0	0	0	1	0	0	0	1	
167	103518	0	2	500	Living	240	1	1	0	0	0	0	0	0	0	1	0	0	0	
168	103518	0	3	740	kitchen	60	1	1	0	0	0	0	0	0	1	0	0	1	1	
169	103518	0	4	800	Living	300	1	1	0	0	0	0	0	0	0	1	0	0	0	
170	103518	0	5	1100	kitchen	60	1	1	0	0	0	1	1	1	0	0	0	0	1	
171	103518	0	6	1160	Living	60	1	1	0	0	0	0	0	0	1	0	0	0	1	
172	103518	0	7	1220	Living	180	1	1	0	0	0	0	0	0	0	0	0	1	1	
173	103518	0	8	1400	bedroom	450	1	1	0	0	0	0	0	0	0	0	0	0	0	
271	103727	0	0	180	bedroom	300	0	1	0	0	0	0	0	0	0	0	0	0	0	
272	103727	0	1	480	kitchen	30	1	1	0	0	0	0	0	0	1	0	0	0	0	
273	103727	0	2	510	bedroom	15	0	1	0	0	0	0	0	0	0	0	0	0	0	

ID2	kind	MostTimespendingzoneMerg	ActivityTypeKitchen	ActivityTypePrivate	ActivityTypePublic	ActivityTypeSemiPrivate	LocationWork	LocationTele	WorkIntegration	TeleIntegration	MostMultitaskingzone	WorkTimeRecode	WorkTime	KitchenTimeCluster	KitchenTime
103416	0	Public	1	1	1	1	SmartTable	Living	1	1	None/private	3	480	1	0
103463	0	Public	1	1	1	0	None	Living	1	1	public	1	0	1	120
103518	0	Public	2	1	2	0	Living	Living	2	2	kitchen	4	540	1	140
103727	0	Public	2	1	3	0	Living	Living	3	3	public	2	240	1	150
103745	0	Public	2	1	2	0	None	Living	1	2	public	1	0	2	180
103857	0	Public	2	2	3	0	Living	Living	3	3	kitchen	3	450	3	330
104268	0	Kitchen	3	2	1	0	None	kitchen	1	3	kitchen	1	0	2	180
104289	0	Kitchen	3	3	2	2	bedroom	SmartTable	3	3	kitchen	2	90	2	240
104290	0	Public	2	2	1	0	None	Living	1	1	kitchen	1	0	1	45
104292	0	Public	3	2	3	1	SmartTable	Living	3	3	kitchen	3	360	2	240
104353	0	Kitchen	3	2	2	0	None	kitchen	1	3	kitchen	1	0	2	180
104367	0	Public	2	2	1	0	None	kitchen	1	2	kitchen	1	0	1	150
104370	0	Public	1	1	1	1	Living	SmartTable	1	1	None/private	3	330	2	255
104389	0	SmartTable	3	1	2	1	kitchen	Living	3	2	kitchen	2	120	2	165
104408	0	Kitchen	3	2	2	1	None	bedroom	1	3	kitchen	1	0	2	210
104428	0	Kitchen	3	1	2	1	SmartTable	kitchen	1	3	kitchen	2	60	1	150
104436	0	SmartTable	3	1	2	1	None	Living	1	3	public	1	0	1	90
104439	0	Public	1	1	1	1	None	Living	1	1	None/private	1	0	1	100
104442	0	Public	2	1	2	0	None	Living	1	3	kitchen	1	0	1	65
104447	0	SmartTable	2	2	1	2	SmartTable	None/	2	1	kitchen	3	480	2	240
104451	0	Public	2	1	2	0	None	Living	1	2	kitchen	1	0	1	120
104455	0	Public	3	1	1	0	Living	kitchen	1	2	kitchen	2	120	3	540
104460	0	Private	3	3	2	0	bedroom	bedroom	3	3	kitchen	3	420	2	300
104469	0	Kitchen	3	2	1	1	None	kitchen	1	3	kitchen	1	0	3	480
104472	0	Public	1	2	1	0	Living	Living	1	1	None/private	3	360	2	210
104485	0	Public	1	2	1	0	None	None	1	1	None/private	1	0	1	120
104499	0	Public	2	2	2	0	Living	Living	2	2	kitchen	3	360	2	240

Figure Error! No text of specified style in document.**.7 Screenshots of the output data, a) a data in which multiple rows are specified by one ID (respondent), b) screened data in which the living patterns of each respondent are determined. Each row is dedicated to one ID.**

1.4. Conducting the experiment

we conducted the experiment through an internet-based survey to obtain a sufficiently large and diverse sample size. In an internet-based experiment, no specific location is required for conducting the experiment and people can easily access the experiment from their own computers. In addition, there is a higher chance to have more participants with diverse characteristics. Accordingly, the experiment was conducted with 320 respondents. The final sample size was reduced to 254 respondents due to several withdrawing's, which are caused by technical problems, faults in responses and incomplete tasks.