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## Modeling users' work activities in a smart home

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### Abstract

Almost everyone would agree that teleworking is increasingly growing; but beyond this broad statement, we know little about how people behave when they work at home and how they balance their work and life. User comfort and productivity cannot be addressed properly, without a deep understanding of users' working behavior. This gap is even deeper when it comes to the domain of smart homes as new types of housing which aim to enhance working at home. Hence, more user-centered studies are needed to comprehend the interrelationships among housing, technology, daily life and the work activities. In this paper, we use the outputs of an experiment to model users' work activities in a smart home. The experiment was conducted among 254 respondents, who were asked to explore a smart home in a virtual environment and then to arrange their daily activities including work related activities in the virtual smart home. A choice modeling approach, based on the Multinomial Logit Model (MNL), is applied to model how an individual works at a smart home given influential factors such as the individuals' socio-demographic profile and their current lifestyle. Two features of working in a smart home are covered in this paper, namely, "the integration of work activities with other daily activities" and "the location of work activities in the house". The results give better insight into the future trends of working at home and the effects of smart homes on working behavior of people. The results can be used in further developments of both smart homes and teleworking.

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*Keywords:* smart homes, work activity, daily activity, choice modeling, virtual experiment.

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## 1. Introduction

Teleworking is a type of working that differs from preceding practices with respect to its location, the opportunities and constraints under which work and other daily activities are carried out, and the nature of interpersonal contacts that are involved<sup>1</sup>. As a consequence, there is reason to believe that the major components of teleworkers' behavior are important for a full understanding of teleworking as a new and increasing phenomenon. In the meantime, teleworking has been considered as one of the basic functionalities of new smart technologies applied in smart homes. Meaning that by integrating ICT and Ambient Intelligent technologies with physical space of a house, teleworking becomes more flexible, comfortable, natural and better balanced with daily life.

In general, applying smart technologies in a home environment affects the way people live inside and outside of their home and shapes a new lifestyle with new types of activities, relations of activities, patterns of time allocations, and usages of technology<sup>2,3</sup>. Hence, work activities as one of the daily activities will also experience some changes. Accordingly, we aim to model work activities emerging from this new lifestyle in smart homes. The model is based on the assumption that different individuals and households prefer to behave differently in smart homes and to manage their work activities differently, since they have various characteristics, lifestyles and needs. We consider these individual differences as influential factors that cause individuals to behave differently in using the technologies and in performing work related activities. If designers and technology developers would be able to understand these influencing factors, they could match their designs to what users really need and prefer. Accordingly, an increase in users' comfort and productivity of teleworking can be expected.

The paper is organized as follows. First, we describe different features of working at a smart home. We discuss the possible working pattern changes as a result of applying different smart technologies in smart homes. Following, we present our developed experiment as an empirical basement for evaluating how people really work in a smart home. In the experiment, we want users to practice how they would like to live and work in a smart home if they had one. Based on the final daily schedule of users, we elicit the influential factors on the different working behavior of users in the smart home. Achieving this aim, we did some descriptive analysis on the sample data and then we used choice modeling methods, which are explained in the last part of the paper. Finally, we draw conclusions by interpreting the gained results from the model. Moreover, we discuss expected applications of the model in future developments of both smart homes and teleworking.

## 2. Working in a smart home

As mentioned above, future types of working is going to have some changes thanks to the developments of smart technologies. Some of the new smart technologies that are involved in a smart home to facilitate work related activities are “flexible partitions”, “smart boundaries with adjustable transparency”, “smart kitchen table with flexible cook top, wireless power system and wireless data network”, “smart wall with intelligent and interactive system”, “smart work table with connection to smart wall”, “smart furniture with programmable context and data network” (see Fig. 1).



Fig. 1. Overview of smart technologies; (a) Smart Work Table<sup>4</sup>; (b) Smart Kitchen Table<sup>5</sup>; (c) Smart Furniture, (d) Smart Wall<sup>6</sup>.

In this paper, we focus on two main changes that are expected to happen in future teleworking. One of the expected changes is in “the integration of work activities with other daily activities”. Throughout the past century, workspace and home were distinct both mentally and physically. Work and private life were considered as two separate spheres. But according to Leonard et al.<sup>7</sup>, this trend is going to be reversed by an increasing integration of the two domains. Increasingly more people are beginning to work from home either part-time or full-time. Changes to the nature of work, including technological advancement, the introduction of flexible working hours and teleworking increasingly interweave work activities with home life. On the other hand, as Kennedy et al.<sup>8</sup> remarked “the more time spent working at home, the greater integration and blurring of home and work boundaries will happen”. That is to say, that work-related activities on the one hand and daily activities on the other hand are going to be integrated in future. In the case of smart homes, the integration of work and life is expected to increase, since all the technologies applied in a smart home support flexible working. In a smart home, any space could accommodate any activities. Hence, people do not need a specific space to work. Any corner in a smart home can be suitable as a home office thanks to ICT and Ambient Intelligent technologies.

The other main change is expected to occur in “the location of work activities in the house”. In fact, the separation of workspace and living space is increasingly broken down and rearranged by “blurring boundaries”<sup>7</sup>. Hence, smart technologies are expected to bring profound changes to the ways people work at home, with boundary less physical spaces, more virtual workspaces, and the potential for constant wireless connection to one’s work. The workplace is no longer necessarily a discrete physical location.

To have a greater understanding of such changes, more user studies are needed. According to Hootsmans<sup>1</sup>, formerly telework research mainly focused on organizational efficiency, cost reduction and environmental and transportation concerns from the perspectives of the teleworker and organization. But when focusing on smart homes, we need to have more in depth investigation of working within the context of users’ daily living in a smart home (their time usage, space usage and the use of different technologies). Hence, we did an experiment to make an empirical basis for evaluating how people really work at a smart home.

### 3. Virtual experiment

We design an experiment, which simulates a smart home in a virtual environment. The virtual smart home consists of several smart technologies, namely, smart walls, smart kitchen table, smart private zone and smart furniture<sup>9</sup>. During the experiment, each respondent performs three tasks: Task 1) Filling a questionnaire, Task 2) Taking a virtual tour through the smart home and finally Task 3) Spending a day in the smart home and arranging activity.

Task1 contains a questionnaire with two main sections. The first section is composed of multiple questions about their socio-demographic characteristics, while the second section is more about their current lifestyle (e.g. To what extent they work at home, do Tele activities, have a busy lifestyle, need privacy for doing daily activities in their current lifestyle). This information is helpful to evaluate the effects of individual differences in their future working behavior in a smart home (Fig. 2-a).

Task 2 provides a virtual environment for representing a smart home. Respondents can take a virtual tour though the environment and watch several movies about smart technologies and their functionalities. This task helps respondents to gain a general overview toward the smart home (Fig 2-b). Since respondents do not have any prior experiences about smart homes, exploring different parts of a smart home in the beginning of the experiment is essential.

Task 3 is spending a day in the smart home and arranging activity (Fig. 2-c). In this task, we do not directly ask respondents where they would like to work, or how they would like to manage work activities. Otherwise, we ask respondents to imagine if they have a smart home, how they would like to live inside it. Such a kind of indirect questioning helps us to receive more natural answers. In a way that we can elicit respondents’ work behavior and their preferences based on their complete daily schedule.

This task consists of two scenarios: “weekday” and “weekend”. Different time scenarios tend to include spatio-temporal analysis in the evaluations. Because working behavior in weekdays and weekends are not similar to each other. Respondents are also free to choose to go out for work or to stay at home and use smart technologies to do their work activities at the smart home, partly or completely. Respondents are able to virtually explore different

spaces and technologies in the smart home using the navigation bar and arrange their activities in different zones. By clicking on each number in the map, the camera goes there and a blank schedule appears on the screen in which the respondent can report the activities he/she would like to perform in that zone (Fig. 2-c). For instance, the respondent can report the types of activities, the duration of activities, possible interactions or conflicts during the activities. At the end of the task, a complete daily schedule for each respondent is created which gives us information about the way people live in a smart home. Therefore, the output can be used for any kind of future lifestyle studies. But we only focus on work related activities in this paper.

#### 4. Conducting the experiment

The experiment was Internet-based with the sample size of 254 respondents. As the sample composition, 57 per cent were males, while 43 per cent were females. From all of the respondents, 57 per cent lived in apartments, 21.7 per cent lived in middle-scale houses, while the remainder lived in large-scale houses. 7.9 per cent of the respondents were Dutch, 67.7 per cent were Iranian and the remainder had other nationalities. Regarding to working status, 48.8 per cent were single income family, 41.7 per cent were dual income family and the remainder were unemployed or retired. This sample contains more young people with high education.

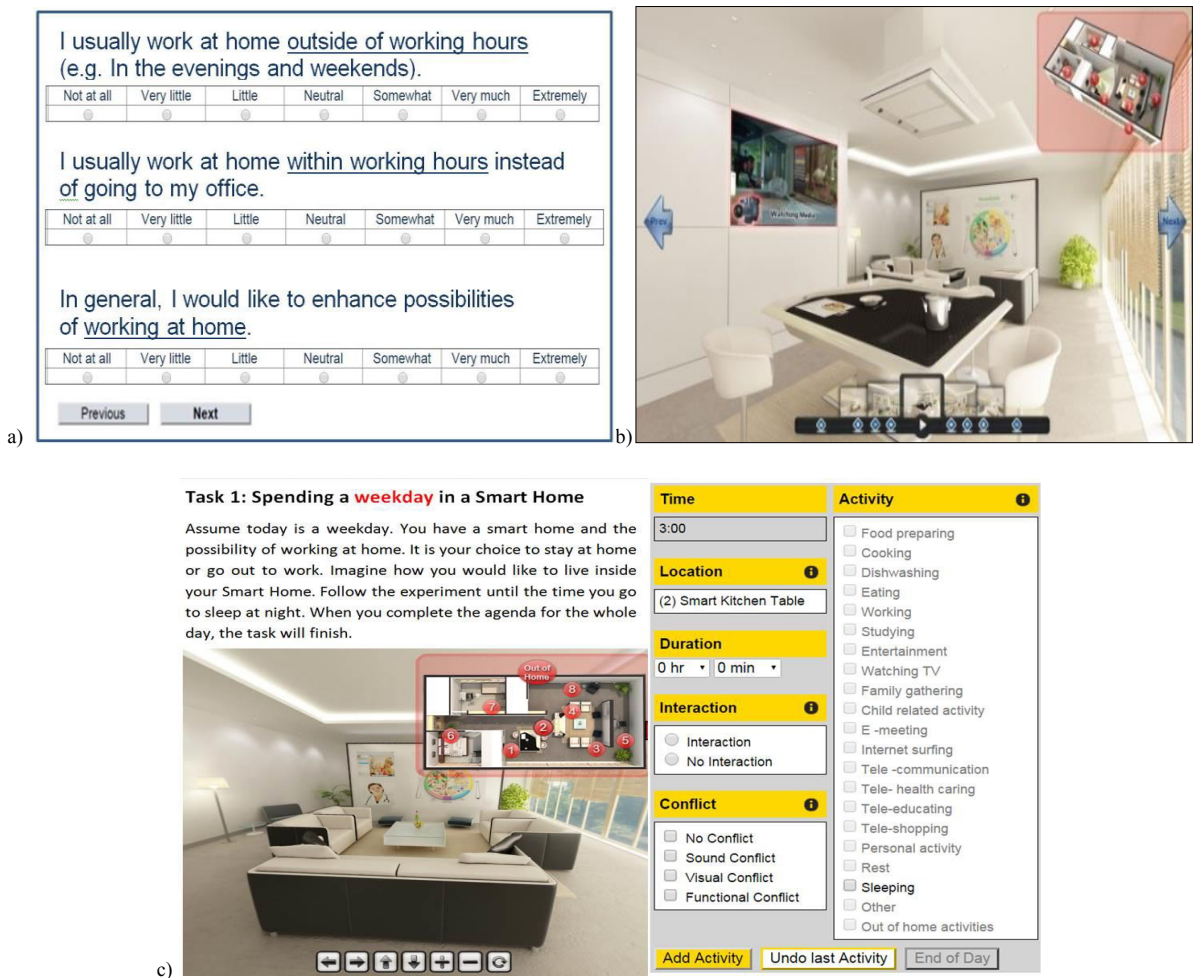


Fig. 2. (a) The questionnaire; (b) Virtual tour; (c) Daily living in a smart home.



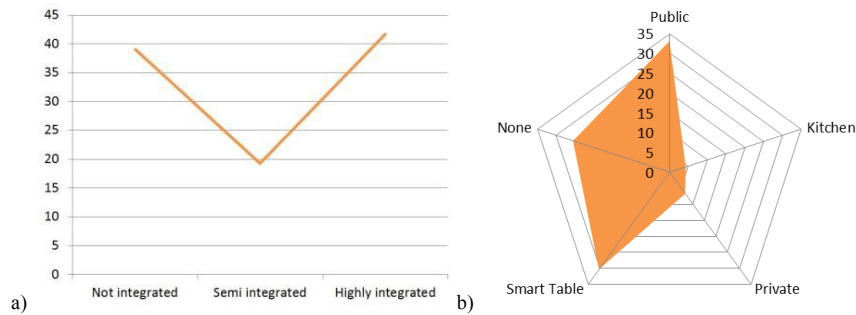


Fig. 3. The general trend of “work integration” (a) and “work location” (b) on weekdays in a smart home.

## 5. Descriptive analysis

A descriptive analysis of the observed data demonstrates the two main general trends of future working behaviour in a smart home. Fig. 3 represents the general trends of work “integration” and “location” in a smart home.

- The border of work-life is losing in a smart home and the work activities are going to be integrated with other daily livings. In general, 61percent of the respondents did other daily activities while working on weekdays (Fig. 3-a).
- Work activities in a smart home move from the private zones to the public zones and kitchen. While only 11.1 percent of the respondents did work in private zones, 67.9 percent did work in public zones (in the living room around smart wall and smart work table) and 10.5 percent did work in the kitchen (using the smart kitchen table). Meaning that most of the respondents conducted their work activities in the hub of events instead of working in isolated private zones. (Fig. 3-b)

## 6. Model specification and estimation

Choice modeling attempts to model the decision of an individual with its underlying rationale<sup>10</sup>. The typical discrete choice models capture statistical relationships between a dependent and a set of independent variables. The models statistically relate the choice made by each person to the attributes of the person and the attributes of the alternatives available to the person. The models estimate the probability that a person chooses a particular alternative. They are often used to forecast how people’s choices will change under changes in demographics and/or attributes of the alternatives<sup>11</sup>. In this study, choices are related to behavior that the individual do for working in a smart home. Particularly, we estimate a multinomial model accounting for state dependency that may influence the “integration” and “location” of work activities.

The “integration of work activities with other daily activities” includes 3 alternatives: (1) low, (2) medium and (3) high. The alternatives indicate the level of doing other types of activities while working. In the experiment, respondents were free to choose multiple activities from the activity list in one time slot. There were four types of activities that a respondent could select from the activity list which are: a) Work related activities including: working and e-meeting, b) Secondary activities including: child related activities, family gathering, entertainment, study, watching TV, personal activities or rest, c) Tele-activities including: internet surfing, telecommunication, tele-shopping, tele-educating or tele-health caring, and d) Kitchen related activities including: food preparing, cooking, washing or eating. From the final daily schedule gained at the end of the experiment, we can evaluate to what extent the respondent had multitasking while working and would like to integrate working with his/her other daily activities. Fig. 4 is a graphical representation of the daily schedule for a respondent. It shows that the respondent worked on the smart kitchen table from 13:00 to 15: 00 in the afternoon of the weekend while he/she did also some secondary activities, tele-activities and kitchen related activities; but in another time slot (from 20:00 to 21:00), he/she only did work in the semi-private zone near the smart wall.

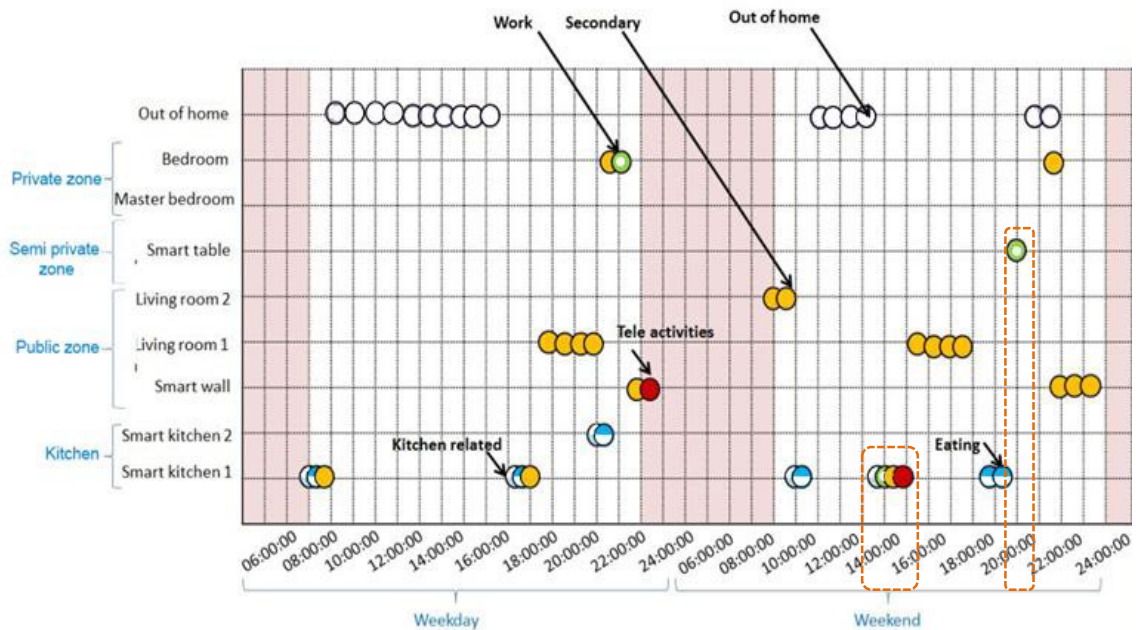


Fig. 4. Graphical representation of the daily schedule of a respondent resulted from the experiment.

The “location of work activities in the house” varies with the location of work chosen by the respondent. It includes 5 alternatives: (1) Private zone, (2) Smart kitchen table, (3) Public zone (around the smart wall) and (4) Semi Private zone near Smart Wall and (5) not working.

In a smart home, there are multiple smart technologies such as smart wall, smart surfaces, smart kitchen table and smart private zones which support work related activities in flexible and natural ways. But people do not behave similarly. They use the technologies in different ways depending on the possibilities that the technology offers them also depending on their personal differences, needs and preferences. To be able to model, we make categorizations among the possible options for work’s location in the experiment. The alternatives are depicted in Fig. 5. Each of the alternatives provides different environment and possibilities for doing work related activities:

- The Private zone (Fig. 5-a) provides high levels of privacy for users who prefer quiet, separate or isolated space with some distance from the family, for working. Although smart technologies support flexibility in working, but privacy is the priority for the group of users who choose this alternative.
- The Smart kitchen table (Fig. 5-b) supports multitasking during working. For instance, an individual can cook or supervise her/his child while working. So it can be a suitable alternative for those who would like to work “at the hub of events”.
- The Public zone (Fig. 5-c) also can be suitable alternative for those who would like to work with smart wall or other smart furniture while they are “at the hub of events”. The users who choose the place of work according to where they feel most comfortable at the moment.
- Semi Private zone near smart wall (Fig. 5-d) provide a corner in a part of the living room for work purposes. It also lets users work with smart wall and smart work table. This alternative implies a close integration of professional life with daily routines while letting users manage the level of privacy whenever it is needed (e.g. Privacy for working with concentration or having e-meeting with colleagues).

This categorization is based on the four metaphors introduced by Wikstrom et al.<sup>12</sup> as the ways people usually arrange their work activities at home.



Fig. 5. Four choice alternatives for the location of work activity in the experiment; a. Private zone, b. Smart kitchen table, c. Public zone, d. Semi-Private zone near smart wall.

In order to explore the determinants of these two features of working in a smart home, we include several independent variables related to the current lifestyle of individual in the model. Reviewing behavioral and psychological literature<sup>13,14</sup> shows that individuals have repeated behaviors and decisions based on their prior experiences and the actions they had in the Past. Meaning that the way an individual will work in a smart home can be influenced by the types of lifestyle he/she follows in current daily routines; especially because smart homes are not still in the housing market and people do not have real experiences of living and working in a smart home. It is expected that when an individual wants to spend a day in a virtual smart home, he/she try to map the new smart technologies and new working conditions in the smart home into his/her current lifestyle and then behave accordingly. The parameters of current lifestyle that we take into consideration are the level of preferred privacy, time pressure during a day, working at home and doing tele-activities, flexibility in current house and the way of using current kitchen that individuals have in their current lifestyle.

In addition to current lifestyle, the effects of socio-demographic factors are also investigated by including individual's characteristics as independent variables in the model. It is expected that people with different age, gender, working status, nationality, household type and etc. work differently in a smart home.

Hence, a multinomial logit model, which is one of the basic discrete choice models<sup>15</sup>, was estimated for "integration" and "location" of work activities in a smart home. For the alternatives of each feature, the effects of individual's current lifestyle and his/her characteristics were analyzed. The multinomial logit model commonly used in choice modeling as it is a good approximation to the economic principle of utility maximization. That is, human beings strive to maximize their total utility. In fact, the utility function,  $U$ , has the property that an alternative is chosen if its utility is greater than the utility of all other alternatives in the individual's choice set<sup>11</sup>. The utility that an individual  $n$  associates with alternative  $i$  is written as:

$$U_{ni} = V_{ni} + \varepsilon_{ni} \quad (1)$$

$$V_{ni} = \beta_0 + \beta_1 \cdot x_{i1} + \beta_2 \cdot x_{i2} + \dots \quad (2)$$

where  $\beta_0$  is the constant and  $\beta_k$  is the set of estimated parameters of variables  $x$ , and  $x_i$  is the set of independent variables<sup>16</sup>. In fact,  $\beta_0$  represents the mean utility of the 'alternative  $i$ ' option and the ' $k$  parameters' measure deviations from this mean utility.



Table 1. Estimated Parameters of Variable: Work Integration (MNL Model). Note: \*\*\*, \*\*, \* ==&gt; Significance at 1%, 5%, 10% level.

Main Category	Independent Variables	Low	Medium
Scenario	Constant	-0.04	-1.44***
	Weekday	-0.55***	0.00
	Weekend	0.55	0.00
Current lifestyle	Flexibility of individual's current home (Low)	0.58*	0.45
	Flexibility of individual's current home (Medium)	0.63*	0.23
	Flexibility of individual's current home (High)	-1.21	-0.68
	Working at home in current lifestyle (Low)	0.51***	0.44**
	Working at home in current lifestyle (Medium)	0.06	-0.15
	Working at home in current lifestyle (High)	-0.57	-0.29
Socio demographic	Nationality(Netherlands)	0.58**	-0.09
	Nationality(Iranian)	-0.30*	0.28
	Nationality(Others)	-0.28	-0.19
	Working Status (single income family)	0.24	0.23
	Working Status (duel income family)	0.35**	0.19
	Working Status (not working)	-0.59	-0.42

## 7. Model Results

The multinomial logit model for the “integration of work activities with other daily activities” was estimated using LIMDEP (Econometric Software). The Table 1 shows the Estimated Parameters of Variables  $x$  (influential factors) for the 3 alternatives of work integration, namely, low, medium and high. The alternative of “high work integration” is considered as the reference alternative and the two other alternatives are compared to it.

- In general, the constant parameter of low and medium work integration is lower than the reference alternative, which is high work integration. Meaning that the probability of integrating work activities with other daily activities generally is the highest one. This result is an indication of the fact that the smart home can really help users have a better balance of work and life; since they can manage both working and other daily activities parallel thanks to smart technologies. All remaining parameters represent deviations from these constant values.
- Among all of the individual characteristics explained in section4, nationality and working status have significant effects on Work Integration. Such that Dutch respondents appear to have a higher preference for not integrating work related activities with other daily activities than Iranian respondents. In other words, Iranians prefer working integrated with daily life more than the Dutch. Regarding to working status, being in a dual income family increase the probability of not integrating work related activities with other daily activities. The reason may rely on the fact that working 2 persons in a smart home may bring them some conflicts. Hence, they prefer to only concentrate on their work activities and not doing any other activities in between to reduce the possible conflicts.
- In addition, “the flexibility of individual’s current home” is an influential factor. Such that not experiencing the flexibility in current home increase the probability of not integrating work related activities with other daily activities. In contrast, respondents who currently live in a house with high flexibility appear to have the highest preference to have integrated working with daily life compared to the two other groups of respondents (people who have houses with low or medium levels of flexibility). This result is due to the logic that has discussed in the previous section. People generally tend to do repeated behaviors based on their prior experiences. Hence, they try to map the new condition into their current lifestyle and then behave accordingly. Another influential factor in work integration is “the extent that the people work at home in their current lifestyle”. The lower they currently work at home (part time/ full time), the lower they integrate work activities with other daily activities while working in a smart home.

Table 2. Estimated Parameters of Variable: Work location (MNL Model). Note: \*\*\*, \*\*, \* ==&gt; Significance at 1%, 5%, 10% level.

Main Category	Independent Variables	Public	Kitchen	Private	Semi private
	Constant	-0.44**	-2.04***	-1.84***	-1.03***
Scenario	Weekday	0.75***	0.39*	0.72***	0.92***
	Weekend	-0.75	-0.39	-0.72	-0.92
Current lifestyle	Working at home in current lifestyle (Low)	-0.29*	-0.71*	-0.07	-0.49**
	Working at home in current lifestyle (Medium)	0.02	0.23	-0.56*	-0.15
	Working at home in current lifestyle (High)	0.27	0.48	0.63	0.64
	Use kitchen for different types of activities (Low)	-0.02	-0.18	-0.44	0.49**
	Use kitchen for different types of activities (Medium)	-0.09	0.84**	0.29	-0.85*
	Use kitchen for different types of activities (High)	0.11	-0.66	0.15	0.36
Socio demographic	Working Status (single income family)	-0.01	0.04	0.07	-0.04
	Working Status (dual income family)	-0.16	-0.14	-0.55*	-0.15
	Working Status (not working)	0.17	0.1	0.48	0.19

In the same way, the multinomial logit model for the “location of work activities in the house” was estimated. The Table 2 shows the Estimated Parameters of Variables  $x$  (influential factors) for the 5 alternatives of work location, namely, private zone, smart kitchen table, public zone, semi private zone and not working. The alternative of “not working” is considered as reference alternative and the four other alternatives of work location are compared to it. According to Table 2, the effective factors are working status, the extent that the individual works at home and use kitchen for different types of activities in his/her current lifestyle.

According to the Table2, people generally tend not to work on weekends since all the constant parameters of four other alternatives of work location have the negative signs compared to the reference alternative of not working. The remaining parameters represent deviations from these constant values.

- Working status is the only individual characteristic that has significant effects on the selection of work location in a smart home. Such that being in a dual income family highly decreases the probability of working in the private zone of a smart home. In the previous part, the work integration model showed that dual income families do not like to have high work integration since they need more concentration; but it does not mean that they prefer isolated and completely separated space to work. According to the Table 2, if dual income families would like to work in the smart home, they prefer public areas rather than private areas.
- Among the parameters of current lifestyle, which were discussed in the section 6, the extent that people currently work at home applies significant effects on the selection of work location. People who rarely work at home in their current lifestyle prefer public areas of the smart home (e.g. Living room, kitchen or semi private zone) less than the private zone as a work location. But if people sometimes work at home, their trend is reversed. In this case, they prefer public areas more than the private zone. According to the Table 2, the lowest coefficient value of selecting the private zone as a work location relates to the people who sometimes work at home.
- Regarding to the parameters of current lifestyle, the extent that people use their current kitchen as a multifunctional space also applies significant effects on the selection of work location. Based on the Table 2, people who intermediately do different types of activities in their current kitchen will continue this behavior in the smart home. Meaning that they tend to use the smart kitchen table for doing other non kitchen related activities such as work activities. Therefore, they are more likely to choose the kitchen as their work location. On the other hand, the probability of choosing the semi private zone is the lowest among this group of people. But

this trend is reversed among people who currently do not use or rarely use the kitchen for working. The probability of choosing the semi private zone as a work location is increased and the probability of choosing the smart kitchen table is decreased among this group of people. Since the semi private zone and the smart kitchen have relatively similar functionalities for supporting work activities, choosing one of them as a work location decreases the probability of choosing the other one.

Since working behavior of people on weekdays is different than weekends, we include scenario as an influential factor in both of the models; it increases the accuracy in modeling. For estimating the effects of scenarios, we used panel data as the input data for the MNL model. Making panel data is an efficient way when the data contain a repeated task by the same respondents. As explained in section 3, respondents did the task of activity arrangement twice, one time on a weekday and the other time on a weekend. The outputs of the Table 1 and Table 2 report the effects of scenario on working behaviors. For instance, the Table 1 shows that the probability of low work integration is decreased on weekdays. Meaning that people tend to integrate work activities with their daily life during the weekdays. According to the Table 2, working on weekdays increases the probability of all the work locations in the smart home, especially the probability of selecting the semi private zone.

## 8. Conclusion

As the technology of smart homes expands, developers have a greater need to comprehend the interrelationships among housing, technology, users (composition, demands, behavioral patterns and values) and the upcoming daily life and working conditions. We believe that applying smart technologies in a house will change the way people live and work inside the house. The findings of our experiment reveal that the border of work and life is losing in a smart home and work activities are going to be integrated with other daily livings. In addition, work activities in a smart home move from the private zones of houses to the public zones and the kitchen. Hence, working in a smart home will be more flexible, integrated with daily life, not isolated and not restricted to a specific location. But these changes vary among different target groups since they have different characteristics, needs and lifestyle. In the present study, we developed two multinomial logit models (MNL) for users' working behavior in a smart home. The models account for both features of "work integration" and "work location". "Work integration" includes 3 alternatives: (1) low, (2) medium and (3) high and "work location" includes 5 alternatives: (1) private zone, (2) smart kitchen table, (3) public zone (around the smart wall) and (4) semi Private zone near the smart wall and the alternative of (5) not working. The effects of scenarios (weekday and weekend) on the work behavior of users were explored. The panel data include information about one day living in a virtual smart home made by 256 respondents with different socio-demographic characteristics (nationality, age, gender, education, working status and current housing type).

Results demonstrated that the proposed model formulations are valuable to analyze the new patterns of working behavior in a smart home given the individual differences and the parameters of current lifestyle associated with individuals. The models are able to estimate where an individual would like to work around smart technologies and to what extent the individual would like to integrate his/her working with other daily activities. Therefore, the findings not only contribute to the literature on future teleworking, but also contribute to the existing literature on smart home developments. An insight into how people use the smart technology for doing their work related activities and managing other daily activities is relevant to both future housing design and office design.

It should be noted that working behavior in a smart home is very likely to be affected by other variables such as types of working, spatial designs of the house, characteristics of the technologies and etc. These variables were not considered in this study because it would add in complexity to the models. Future research should include these and other variables that might influence future behaviors of working at home.

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