Analysis Thermo-Hygric of Occupied Social Welfare Housing in a Warm Sub-Humid Weather

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ABSTRACT: Social welfare housing (SWH) in Mexico is known for being the one with the highest production in the country. Due to its form of production, becomes the only option available to the underprivileged classes. Unfortunately, this typology is the one with most sacrifice comfort conditions. In this research, it was analyzed the thermo-hygric conditions of eight social welfare housing with the addition that they were inhabited during monitoring. The study was carried out during a week in two critical seasons for Colima, dry warm in March with temperatures between 14.5 ° C and 33.5 ° C and averaged RH of 50%, and warm wet in October with temperatures between 18.7 ° C and 33.0 ° C and averaged RH of 65%. The results showed that although SWH show rates of high discomfort perception, reality is another. All homes were found to improved thermal and hygric comfort respect to outdoor conditions. Regarding the alterations produced by the inhabitants, for the thermal variable was found that 50% of cases, is the inhabitant who, based on its activities, produces improvements in comfort. While for the hygric variable, only one case in a season was identified that the resident was responsible for this improvement.
Keywords: Adaptative ability, habitability, social welfare housing.

INTRODUCTION

In urban Mexico, the refuge with higher proliferation has been the social welfare housing (SWH). This is because the financial accessible cost and the homogenization of the construction processes that makes its production easier. Unfortunately this type of mass housing carries on with it certain problems about the comfort that the inhabitant must face, due to the fact that this kind of house is built equal for any weather, orientation or population, without carrying out an intense study to solve the problem.

A very important part that adds up to the SWH issue is the inhabitant of the house, as the house is built trying to meet their needs. On the other hand is the directly influenced area by the climate and environmental conditions created outside the house making the inhabitant to response this behavior.

Thus, this research identified the activities of the resident in housing as a result of the climatic conditions that the same property generates and then, what activities modify as a feedback to the climatic conditions of the home.

BACKGROUND

Szokolay in 1990 [1] noted that comfort is an effective-cognitive-affective-discriminatory mechanism. It turns out then that comfort is physiological and psychological, both at the very same time. When the physiological barrier is overcome, i.e. thermal-physiological mechanisms of the body are overwhelmed by weather levels out of the body; it becomes a nuisance to the same so start searching the psychological mechanisms of recovery comfort by performing certain behaviors.

Also, Alicia Delgado [2] mentions that within the *"adaptive trend, when any environmental change occurs that causes some discomfort, people seek to take steps to restore comfort conditions";* i.e., if thermo-physiological mechanisms are obsolete by the adverse conditions in the environment, the human being begins the psychological mechanisms consciously and voluntarily, such as activities related to change its location, physical activity that develops, their clothing, food or even modifying their space by alteration of temporal elements such as windows, doors, curtains, electromechanical devices as fans or air conditioners systems, etc.. as a result, he modifies its way of living space due to the need to regain comfort.

Human behavior is merely the mental process that the human being makes to produce responses based on certain stimulus received [3], and in this specific research, stimuli produced or generated by the space resulting answers given by the inhabitant towards himself or the same space dwells in.

Charles Holahan [4] mentions that "*the scenarios that surround and support our daily lives are a big influence in the way of thinking, feeling and behaving".* Then, the spaces we inhabit constantly send stimulus, positive or negative, toward people who inhabit them.

In similar researches such as Indraganti [5, 6, 7 and 8] made in Hyderabad, India showed the relationship between the adaptive capacity of the inhabitant and the knowledge of their environment to improve natural conditions by opening and closing windows, balconies and door or using fans and air conditioners at times where temperatures reached more than 35° C.

RESEARCH METHODS

The city of Colima is located in the southwest of Mexico near the Pacific coast. Its location is 10°12'50" north latitude and 103°43'21" west longitude and is approximately 433 meters above sea level. It has a warm sub-humid climate with summer rains. Temperatures range between 15.0°C and 34.0°C throughout the year and relative humidity ranges from 30.04% and 87.91% (See Table 1).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average T	22.95	23.25	23.90	24.90	26.35	27.30	26.60	26.30	25.90	25.85	25.10	23.75	
T max	30.90	31.50	32.40	33.40	34.00	33.60	32.40	32.10	31.40	32.00	32.20	31.50	°C
T min	15.00	15.00	15.40	16.40	18.70	21.00	20.80	20.50	20.40	19.70	18.00	16.00	
RH	55.89	53.15	51.21	49.70	51.45	58.58	65.50	63.55	68.75	64.50	57.10	52.15	
RH max	77.13	73.88	71.57	69.36	70.09	76.79	84.50	82.02	87.91	84.21	76.75	71.50	%
RH min	34.66	23.42	30.85	30.04	32.81	40.47	46.50	45.08	49.59	44.79	37.45	32.80	

Table 1: Temperatures and relative humidities average annual maximum and minimum for the city of Colima, Colima. Source: developed from climatological normals 1980-2000, National water commission.

According to Roberto Hernández [9], "*in a non-experimental study any situation is built, but existing conditions are observed, not intentionally caused by the researcher*". Because the subjects in each case are studied in its natural context, and the investigator did not make any modification or stimulation of independent variants, so they could interact with the inhabitant, the type of trials being conducted in this research were non-experimental. Referring the same author and according to the periods of analysis of the study subjects, studies were longitudinal and transectional.

The study group was defined from the building housing code [10] which defines SWH as that which has a construction area of 45 m^2 approximately and includes the following architectural areas: 1 bedroom, kitchen, living room, dining room and bathroom.

Since this parameter was identified in research carried out by Chávez [11] neighborhoods with greater seniority who met the parameter of SWH, in order to find the people who were mostly adapted to their space.

Besides the SWH parameters contained in the building housing code, others parameters were identified who were required to fulfill the selection of the division as house modifications (equal number of houses) orientation (least amount of guidance) and prototypes (the smallest number of prototypes).

The result was a prototype house of 110.50 m^2 land and 35.89 m^2 built area, with the next architectural areas: 2 bedrooms, kitchen, full dining room and bathroom. (See figure 1).

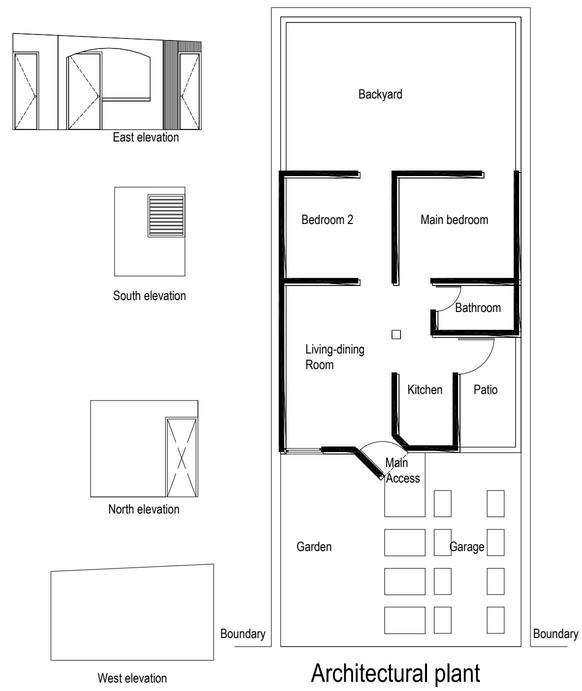

Figure 1: Architectural plant of the house prototype. Source: Authors

Climate variables

Weather variables monitored outside the houses were dry bulb temperature and relative humidity. These were monitored using a micro data logger station, Onset Computer Corporation HOBO model H21-002 with external sensors. It was placed over the roof from one of the study cases. This house was selected by being nearest to the geometric center of the analysis space.

Indoor climate conditions monitored were the same as the exterior. Onset Computer Corporation HOBO data loggers model U12-12 were used and placed at the geometric center of the area analyzed. Because the houses were inhabited while the study was conducted, It was not able to place the data logger to the center of the z axis, so this It was placed at 30 cms. hanging from the ceiling to prevent that the activities of the inhabitants were altered.

Research season

To define the period in which the research were conducted, it was decided to use the bioclimatic chart developed by Givoni [13]. On this, the dry bulb temperature and the relative humidity data were placed every hour identifying two main seasons, hot humid from June to October and the hot dry from November to May.

Psicrom software was used for the psychometric template.

In order to define how long it was going to be the monitoring period in each season one week was defined because this would allow to drive two surveys, at the beginning and the end, also to obtain working days and weekends. Besides, a cycle of various activities performed by human beings in their daily lives was completed. Therefore, the monitored periods were from Sunday 10^{th} to Saturday 16^{th}, October 2010 and from Monday 4^{th} to Sunday 10^{th}, April 2011.

Developed tools

Based on the experimental design, transectional and longitudinal [9] two types of surveys were designed: daily and weekly. The direct answer of the SWH inhabitant was one of the daily survey main features It worked like a diary of actions, behaviors, dress preferences, status of the window, temperature and RH perceptions and special conditions. Daily survey is the main source for obtaining information of the inhabitants, plus it is responsible for detecting phenomenon evolution through a period of time, which in this case was a week.

This survey was personal, i.e., a total of seven surveys to solve were awarded to each inhabitant for any case.

Moreover, weekly survey was conducted twice, once at the beginning of the week, when daily compendium surveys were given and the other at the end of the week when the data loggers and daily surveys were collected.

Weekly survey serves to find phenomenon conditions in a spot of time, confirming situation observed at the daily survey or even detecting others that would not be able to be observed. Weekly survey was applied by the researcher.

It was decided to determine the hygro-thermal conditions inside houses. The hours when the inhabitant was in comfort were discarded, and then, behavior was placed when the environment contained no comfort conditions for their activities. Hygro-thermal comfort standard for Colima city developed by Pavel Ruiz [14] was used. This is determined by the following equation:

$Tn = 0.058(Tm)2 – 3.3143(Tm) + 71.044$

Where:

Tn is the comfort temperature

Tm is the mean temperature

Range ratio was determined as follows:

$Tnmax = Tn + 5.4°C$

$Tnmin = Tn – 1.6°C$

Where:

Tnmax is the upper limit of comfort temperature range.

Tnmin is the lower limit of comfort temperature range.

Hygric comfort zone were defined by taken constants values found also by Pavel Ruiz [14], which values are for the lower limit 23% and the upper limit of 70%. Thus, the discomfort hours inside the houses were determined daily for each case and the research was focused on locating the behaviors performed by the inhabitants in these times.

To define the resident involvement degree in environmental changes within the houses, research conducted by Ricardo Moreno in Colima was used [15], which determined that the habitability of the human being in an area cause alterations to the weather conditions thereof.

It shows correlations of indoor-outdoor conditions in spaces that are not inhabited at the time of the measurements. These reveal a very high correlation ($r^2 \approx 1$), indicating that after the expiry of a period of time, the differences between indoor and outdoor conditions got stabilized.

However, in cases inhabited, this correlation got decreased. This was because the behaviors and actions taken by the inhabitants did not allow to stabilized the indoor-outdoor condition cycle.

RESULTS

In figure 2, it is observed the dry bulb temperatures recorded inside the eight houses, as well as dry bulb temperatures outside in the hot dry season. Its shows the temperature variation from the outside with a greater breadth over the week unlike indoor temperatures which has a lower thermal oscillation. Termopreferendum for this season was maintained between 22° C and 29.5° C with minimal variations every day. It also indicates that thermal comfort was reached between the early mornings until noon.

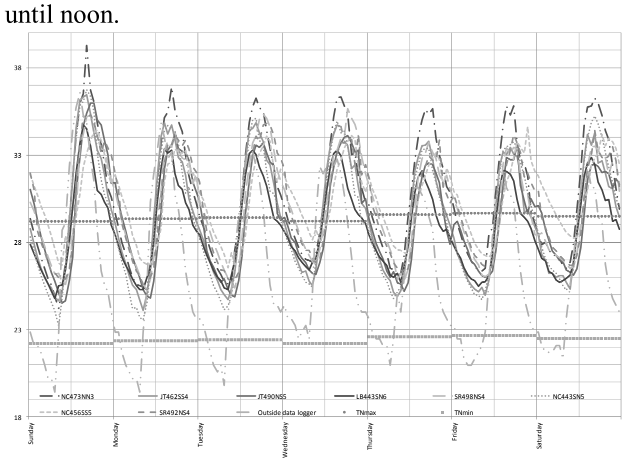

Figure 2. Thermal oscillation of inside and outside SWH in hot dry season (n=168 per home) Source: Authors.

Figure 3 shows daily oscillation of relative humidity both indoors and outdoors thereof in hot dry season. Hygric outside oscillation has greatly variances throughout the week making extreme data from 14% achieved on Sunday at noon and 88% hit on Friday at dawn. Given the breadth of hygric preferably between 23% and 70%, all the houses were kept almost entirely in comfort.

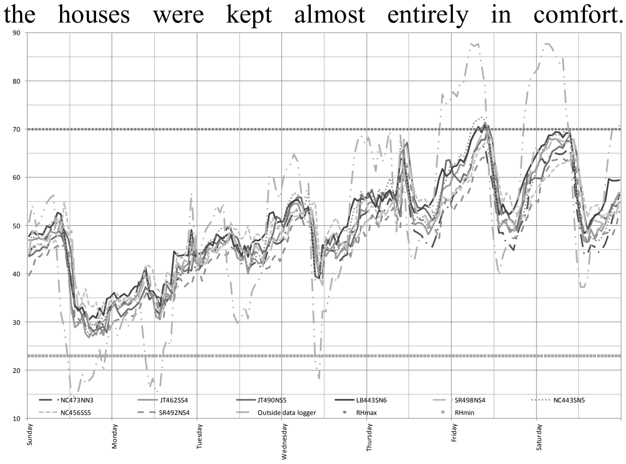

Figure 3. Hygric oscillation of inside and outside SWH in hot dry season (n=168 per home) Source: Authors.

Figure 4 shows dry bulb temperatures monitored inside-outside of the houses analyzed in hot wet season. Outside temperature oscillation continued to be greater than any of the dwellings. Thermal stability and termopreferendum can be observed in this season, maybe by the humidity registered in the environment. Also for this variable can be noted that most of the hours are outside the comfort zone determined between 22° C and 29° C almost equally in every day.

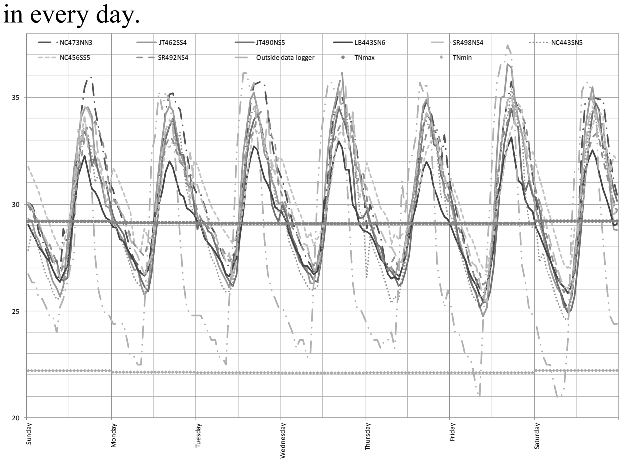

Figure 4. Thermal oscillation of inside and outside SWH in hot wet season (n=168 per home) Source: Authors.

Finally, figure 5 shows relative humidity oscillation inside and outside SWH for hot wet season. Similar the other season, outside oscillation is greater than the oscillation inside the house, but a few hours over hygric comfort can be observed this time. These hours were observed at the beginning of the week.

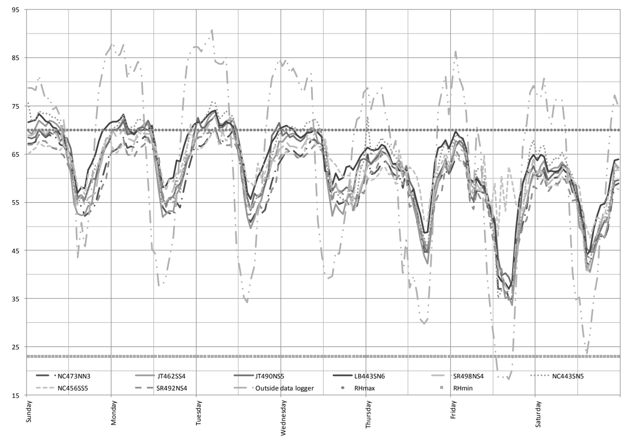

Figure 5. Hygric oscillation of inside and outside SWH in hot wet season (n=168 per home) Source: Authors.

With temperature and relative humidity hourly data for each season was determined the hours in which exist hygro-thermal comfort inside the housing and its percentage of the total number of hours per day (see table 2).

#	Case	hygric-thermal Comfort							
		Hot dry				Hot wet			
		Hours in comfort	%	Hours in discomfort	%	Hours in comfort	%	Hours in discomfort	%
1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
4	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
5	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
6	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
7	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
outsite data logger		[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 2. Comfort and discomfort hours concentrate for the hot dry and the hot wet season. Source: Authors.

Although it was expected that the housing were with a higher degree of discomfort due to in figures 2 and 4 was revealed a large number of hours over thermal comfort, when temperature and relative humidity are combined, the number of hours of comfort is increased leaving all households over 50% and improving conditions outside which reached 34% and 14% comfort hours for hot dry and hot wet season respectively.

From the hourly temperature and relative humidity data, it was made a correlation between internal and external temperatures and HR of each case, identifying those cases where r^2 was less than 0.5, which its indicates that the inhabitant was a key factor in the variations inside the house.

Further this, depending on the slope of the line, it was able to define whether the interaction was beneficial or not for the conditions inside the house, i.e. if the slope is less than 45°, the interaction is profitable to the internal conditions because there is a reduction in temperature or humidity. If the slope of the line is greater than 45°, the interaction is not profitable to the interior because there is an increase in temperature or humidity.

#	Case	Temperature							
		Hot dry				Hot wet			
		R^2	Equation	Inside vs Outside	Hours in confort	R^2	Equation	Inside vs Outside	Hours in confort
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.3779	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	0.2113	[illegible]	[illegible]	[illegible]	0.3494	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	0.2271	[illegible]	[illegible]	[illegible]	0.3637	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	0.0412	[illegible]	[illegible]	[illegible]	0.1638	[illegible]	[illegible]	[illegible]
10	[illegible]	0.1674	[illegible]	[illegible]	[illegible]	0.3131	[illegible]	[illegible]	[illegible]
#	Case	Humidity							
		Hot dry				Hot wet			
		R^2	Equation	Inside vs Outside	Hours in confort	R^2	Equation	Inside vs Outside	Hours in confort
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.3495	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 3. Inside and outside temperature and relative humidity correlations for both seasons (n=168 per case and season) Source: Authors.

Table 3 shows correlations between temperature and relative humidity indoors and outdoors for each case in both seasons. From this, It can be identified in which cases the inhabitants are modifying the inside conditions due to their activities and as it was observed in table 2, this modifications were done for the better.

It was observed than in variable temperature the inhabitant had further intervention. For hot dry season 50% and hot wet season over 75%. Meanwhile in relative humidity, it was revealed only one case in hot wet season. This also indicates the insignificant appreciation from the inhabitants of the relative humidity phenomenon.

With all these data, it was identified in the inhabitants surveys from each seasons the perception of temperature and relative humidity, activities done, use of artificial air conditioning devices and the status of doors and windows in order to observe behaviors which were affecting the climate performance within the housing, and therefore, the adaptive capacity of the inhabitants by their actions.

Figure 6 shows the study subjects perception that was observed from the environment in their home. In the middle it is observed the activities carried out by inhabitants in the area analyzed. Finally, at the right it is observed the use of environmental controls such as using fans and opening doors and windows.

Although the two seasons have different percentages, It showed some patterns that stand out and shown the adaptability of the behavior of the inhabitants. It can be observed that perception of hot temperature is greater in dry season than in wet season. For relative humidity it is observed an increase in non-wet non-dry perception and less in humid for hot dry season.

Important activities found a slight increase in rest for the dry season as well as the use of a cold bath for the inhabitants to the hot dry season.

Finally, it is observed the use of fan and opening windows and doors as a means of cooling the interior of homes, especially in the hot wet season. It is important that any case was observed in the deactivation of these sections.

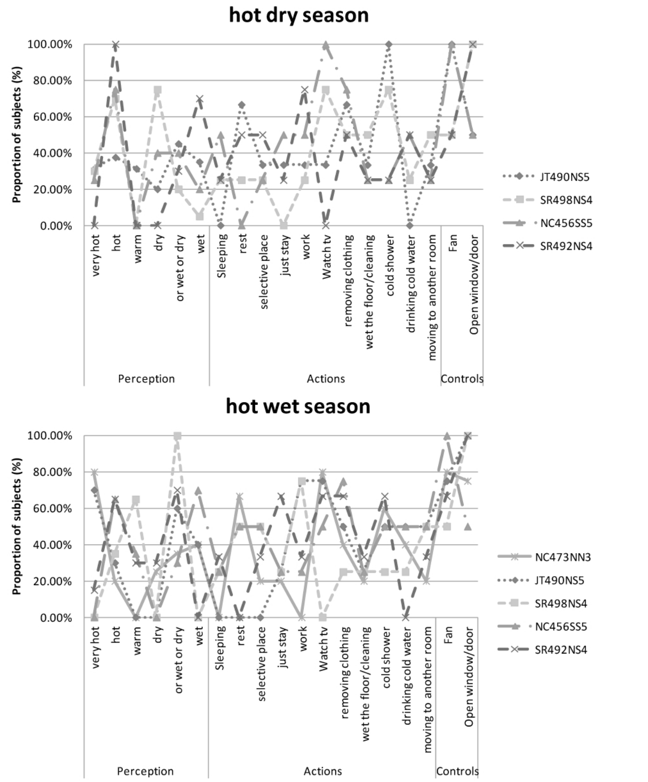

Figure 6. Proportion of participants who perceived any weather conditions, performed any activity and activated any environmental control mechanism for both seasons (hot dry n=119 and hot wet n=140) Source: Authors.

CONCLUSION

In Colima, any behavior was clearly expressed from people who live in this area with the conditions that characterize it. But It was identified some actions carried out in general as: cold bath, rest or sleep in the area and the use of air conditioning devices as were the use of fan and opening doors and windows.

It is also important to note that this type of housing as a shelter from outside, as in all cases was observed more hours of comfort within the same in contrast to the hours of discomfort located abroad.

In conclusion, although the indoor environment is intimately connected to the outside this is governed by more than 50% of cases by actions of the inhabitants, displaying the adaptative ability and the human understanding of their space.

ACKNOWLEDGMENTS

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