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Subjective Assessment of Thermal Outdoor Comfort in Downtown Guelma During Summer Heatwave

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Abstract
The assessment of the outdoor thermal comfort should consider the interrelationships between the thermal conditions outdoors, the psychological responses of users and physiological phenomena. The aim of our study is to subjectively assess thermal outdoor comfort in downtown Guelma during summer heatwave. The scientific methodology is based on the acquisition of quantitative and qualitative data, to do so we have conducted a survey questionnaire in parallel with a field microclimatic measurement during the heat wave period. As a result, we assessed the thermal sensation of the three parameters, air temperature, relative humidity and air speed for six sessions from 09:00 to 21:00. As well as, the thermal acceptability, the thermal comfort levels and the thermal preferences for each session. The findings indicate that the subjective assessment of the outdoor thermal comfort makes it possible to conclude on the effect caused by the urban thermal environment in space and time.
Keywords: Outdoor thermal comfort; Subjective assessment; summer heatwave; survey questionnaire; downtown Guelma.

1. Introduction

A comfortable outdoor space provides a pleasant climate comfort experience for people and effectively improves the quality of urban life. However, people experience different thermal sensations when performing different outdoor activities; in streets, squares, playgrounds and urban parks. According to ASHREA 55, thermal comfort is "that state of mind that expresses satisfaction with the thermal environment". On this basis, the thermal comfort is synonymous with the availability of pleasant thermal conditions in outdoor spaces. However, outdoor thermal comfort is fully considered as a guarantor of the use of outdoor spaces (Elnabawi & Hamza, 2019; Hammadi., 2017). The assessment of the outdoor thermal comfort should consider interrelationships between the thermal conditions of the environment, the psychological responses of users and physiological phenomena (Sayad & Alkama, 2021a). The human thermal sensation can be evaluated objectively or subjectively, the subjective evaluation consists in exploring the thermal sensation of the local populations by means of questionnaires or interviews.(Andris Auliciems and Steven Szokolay, 1995; Sayad & Alkama, 2021b, Amen,2021).

The Subjective assessment of outdoor thermal comfort is based on the acquisition of data relating to the physiological phenomena carried out by the users, hence, it is necessary to explore the thermal sensation of the local population. This data is generally collected by means of questionnaires or interviews, describing the satisfaction of the latter vis-à-vis the external thermal conditions. For example, the research of (Neto, 2016) who considered that the feeling of thermal comfort is influenced by environmental and personal factors while thermal comfort must be measured by the number of people complaining of thermal discomfort. The author proposed a procedure to assess thermal comfort, including the creation of a ratio scale and a set of statistical procedures to process the data collected from this scale. This method was used to assess the influence of fans on the feeling of thermal comfort of the occupants of a small office, it proved to be useful and then it was applied to outdoor environments. As a result, the method has shown great ease in including humans in the control loop of comfort systems. Also, a research by (Cheung & Jim, 2019) who implemented an outdoor thermal comfort survey questionnaire to determine the range of acceptable transient temperatures. Which is only valid when the answer of more than 80% of the respondents is acceptable. The study therefore proposed a new evaluation of outdoor thermal acceptability: thermal acceptability in 1 hour. Respondents were asked to indicate whether the urban thermal environment is acceptable at the time of the interview and to stay at the interview site for one hour. This predictive assessment was tested against the transitional assessment in Hong Kong by a survey questionnaire for a whole year, with 830 respondents. Results at 80% over 1-hour summer from 22.6° to 25.4°C air temperature.

2. Material and Methods

As the aim of our study is to subjectively assess thermal outdoor comfort in downtown Guelma during summer heatwave, we simultaneously conducted a survey questionnaire with a field microclimate measurement of three microclimate parameters to acquire both, quantitative and qualitative data.

2.1. Assessment Methodology

The investigation was carried out following an urban pathway composed of 41 different points which requires two hours to cover it (120 minutes), whose collection of data specific to this pathway involves a complicated process which consists in measuring three microclimatic parameters of a given place and at the same time to question its users, in a period of time which does not exceed three minutes at most. The figure below explains the data collection process for an investigation session.

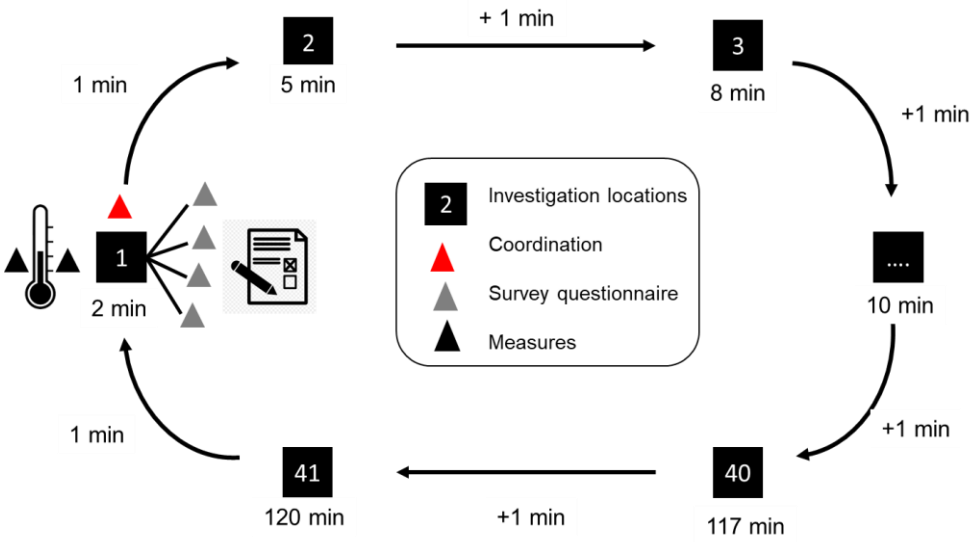

Figure 1. Data collection process (in-situ measurements and questionnaire) for an investigation session.

2.2. On-Site Measurement

The field measurement was carried out following the urban pathway located in downtown Guelma made up of 41 points using a calibrated multifunction hand-held device (Testo 480 – AG 501 1ST, 0563 4800) (Sayad, Alkama, Rebhi, Kidar, et al., 2021). As a result, we obtained a daily record made up of six sessions from 9:00 a.m. to 9:00 p.m. of the three parameters:

- **Air temperature:** the air temperature is a main element of the atmosphere, it refers to the sensation of hot and cold outdoors. In our research it is used as a subjective independent indicator to measure thermal sensation during summer overheating, but also an objective indicator of climatic comfort used to quantify heat stress.
- **Relative humidity:** relative humidity represents the amount of water present in the atmosphere, it is a good indicator to demonstrate the effects of air humidification (Sayad, Alkama, Rebhi, Menni, et al., 2021). Its measurement then allowed us to study the effects of natural elements; water and vegetation in outdoor spaces, it is also an important element for quantifying the degree of outdoor thermal comfort.
- **Wind speed:** air speed represents the flow or movement of air particles, it is conditioned by the urban configuration and it is an important parameter for evaluating outdoor climatic comfort.

2.3. Survey Questionnaire

The survey questionnaire was conducted simultaneously with the field measurement, following the same measurement points for. The questionnaire is organized into two sections and set out in tables to encourage respondents to provide accurate, unbiased and complete information.

The first section; "Thermal sensation assessment", the assessment is based on three synthetic criteria, degree of thermal comfort, thermal acceptability and thermal preferences. Each of these addresses detailed criteria through a closed question with an assessment level (choice of answer) and an open question aims to develop the citizen's opinion in terms of thermal preference.

The second section "Assessment of the microclimatic parameters influencing thermal sensation" asks direct questions about the microclimatic parameters responsible for all thermal sensations, including the sensation of stress. For the three measured parameters, temperature, humidity and wind speed, the question “How do you rate such a parameter in this place? “was asked with a scale of five answers.

The management and accessibility to the collected data were greatly facilitated using the IBM SPSS Statistics 23 software "Statistical package for the social sciences". The process began with coding and a twice-hourly manual

entry of the questionnaires, then a step of cleaning up the data was carried out, of which 581 is the total number of valid questionnaires, then the preparation of the tabulation, namely frequency, cross-reference or descriptive and finally the export of the data usable in tables or graphs.

3. Results and Discussion

3.1. General Weather of The Study Period

According to the weather forecast of Guelma city (Ventusky - Weather Forecast Maps, n.d.), the highest value of temperature was 41°C, the minimum relative humidity was ± 20%, with an average wind speed of 3.5 m / s. In-situ measurements in downtown Guelma showed more meteorological detail, giving an accurate description of the weather during the study period. The highest temperature reached 42.9°C at 3:00 p.m. at point 41 with low relative humidity 17.4% and low wind speed 0.3 m/s. The lowest temperature of 30.5°C was recorded at 09:00 at point P1, with a maximum relative humidity value of 56% and a low wind speed of 0.5 m /s. It can be concluded that the study period experienced a major heat wave. The microclimatic parameters measured are represented in Table 1.

Table 1. General weather during the investigation period

Air Temperature (C°)			Relative Humidity (%)			Wind speed (m/s)		
Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
36.9	42.9	30.5	30.5	56.0	16.5	0.6	1.5	0.3

3.2. Satisfaction with the Thermal Environment

Five sensual options were used to determine the thermal comfort sensation in summer, of which the "Neutral" option is used to express an average sensation state which means that the environment is neither comfortable nor uncomfortable.

The results indicate that the urban thermal environment is mostly voted as "a little comfortable" and "neutral" for the morning session, from 9:00 a.m. to 11:00 a.m., as well as the evening session, from 7:00 p.m. to 9:00 p.m.: 00. Moreover, the five options were used in the flowing session from 11:00 to 13:00. The feeling of discomfort is most dominant during the afternoon hours, with the feeling of “neutral” around 7:00 p.m., which often announces the start of the daily shift after long hours of thermal stress (Figure 2).

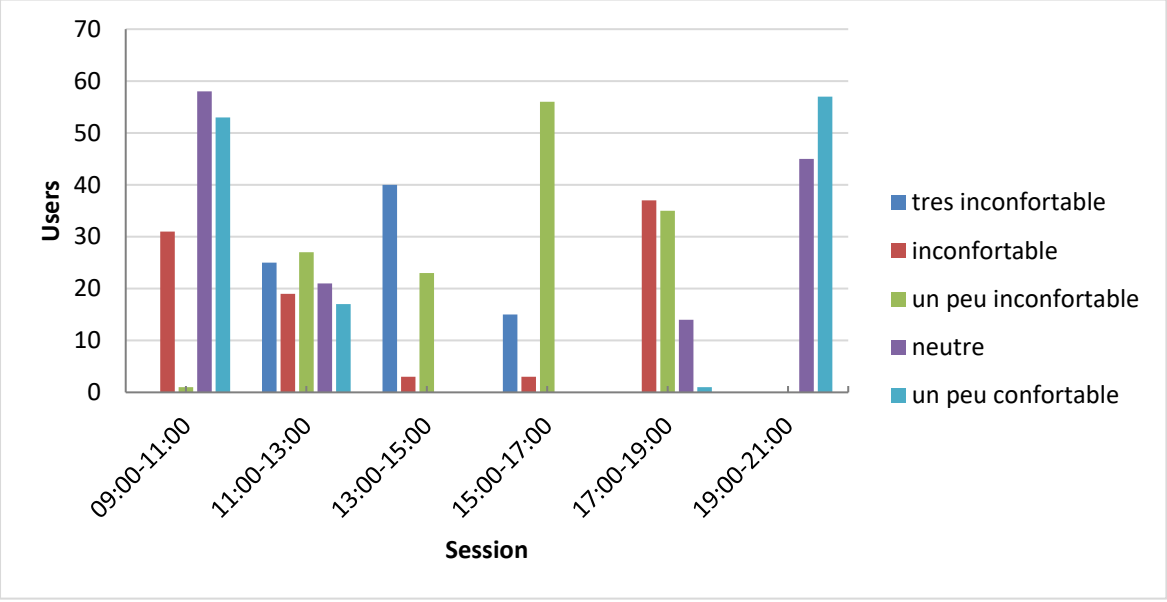

Figure 2. Thermal comfort sensation.

The assessment of the urban thermal environment was carried out through three options, with the aim of exploring the thermal acceptability throughout the hot summer days following six sessions from 09:00 to 21:00. (Figure 3).

For the first session, the urban thermal environment is largely voted as "acceptable and neutral" with a minority who see it as "unacceptable". Contrary to the following session, where the urban thermal environment is voted mainly as "unacceptable". The two sessions from 1:00 p.m. to 5:00 p.m. are judged almost totally as "unacceptable". The sessions after experienced the shift towards appreciation, hence the acceptable option is the dominant one during the last session from 7:00 p.m. to 9:00 p.m.

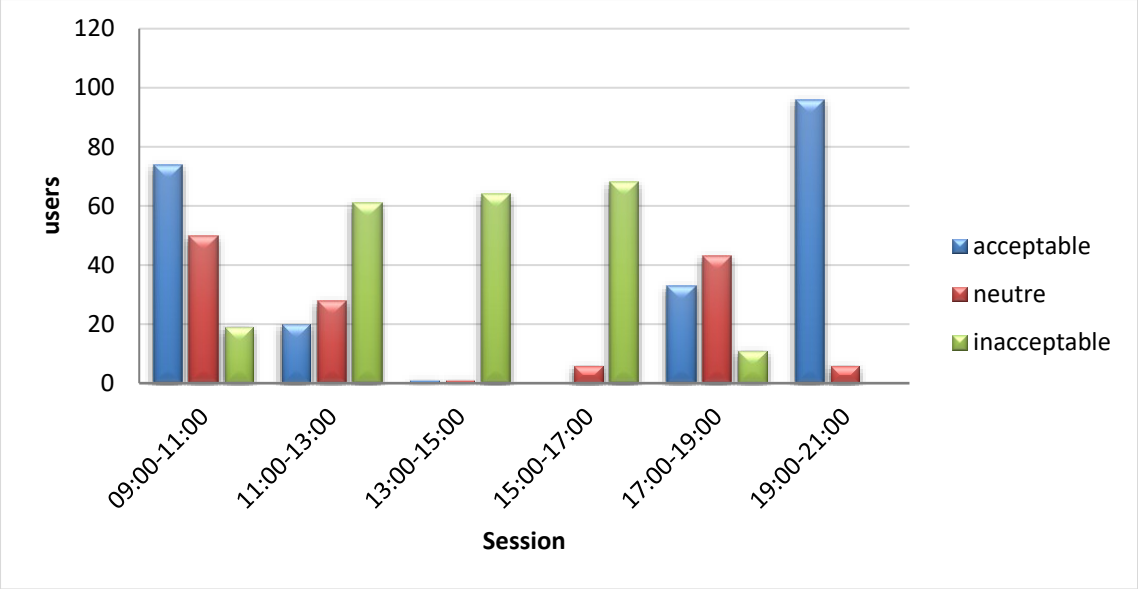

Figure 3. Thermal acceptability.

Users' thermal preferences were explored by asking the question "For better conditions, you suggest!" with three response options; more freshness, no change or more heat.
Only two options were used as shown in the histogram (Figure IV.17). The "no change" response was widely used by users during the morning session, from 9:00 a.m. to 11:00 a.m., as well as the evening session from 7:00 p.m. to 9:00 p.m. While, the majority prefers more freshness during the sessions, from 11:00 to 17:00. For the session, from 5:00 p.m. to 7:00 p.m., the thermal preferences are almost evenly split between the two options.

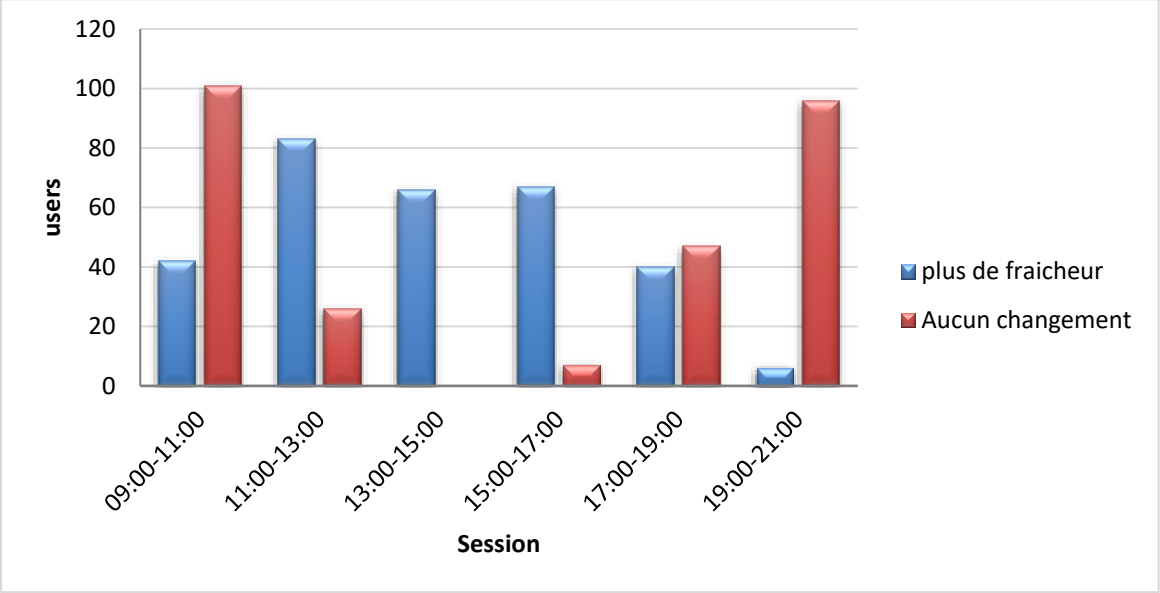

Figure 4. Thermal preferences.

3.3. Thermal Sensation of Microclimatic Conditions

The sensation of microclimatic conditions involves the use of five sensual options to judge or appreciate the following parameters: the air temperature, the relative humidity and the wind speed. As the case with the thermal comfort sensation, the "Neutral" option is used to express an average sensation state of each parameter along the six sessions from 09:00 to 21:00.
The histogram below presents the results of the sensation of air temperatures per session (Figure 5). For the first session, three sensual options were used; "neutral", "a little fresh" and "a little warm" with a dominance of the first. The second session from 11:00 a.m. to 1:00 p.m. involves the five sensual options, including the two options; "a little hot" and "hot" dominate equally. The urban thermal environment is voted by the majority of users as "very hot" and

"hot" during the period from 1:00 p.m. to 5:00 p.m. The following session from 5:00 p.m. to 7:00 p.m. is voted as "a little hot" by the majority of users. For the last session, the appreciation of the urban thermal environment is made according to the two sensual options; "neutral" and "a little cool", expressing a state of feeling that often tends towards thermal satisfaction.

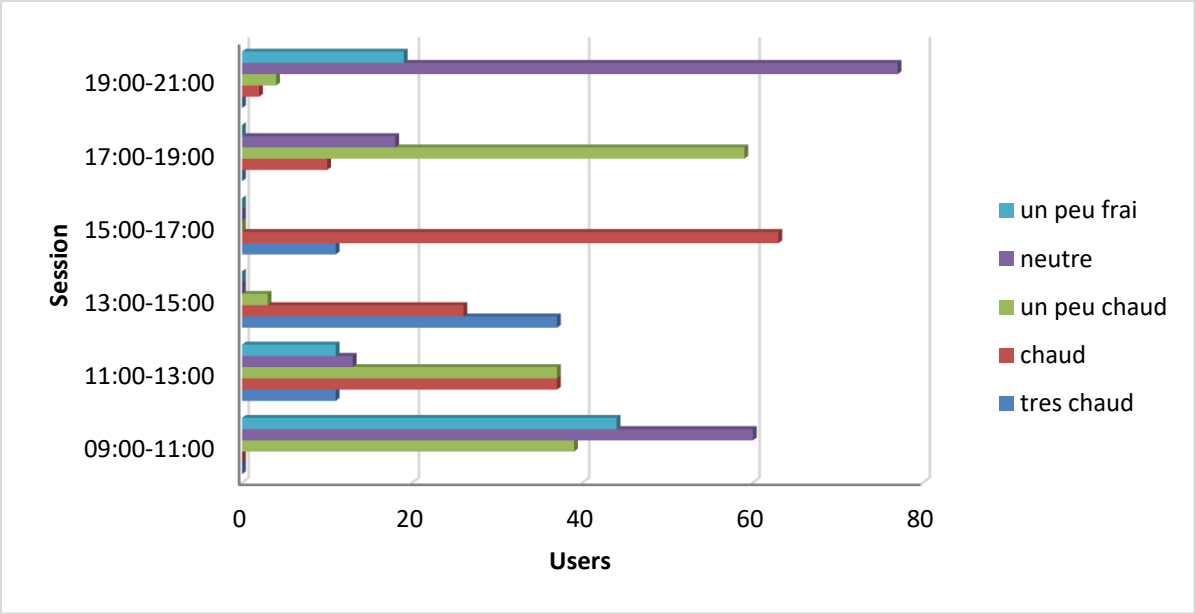

Figure 5. Thermal sensation of the air temperature.

Following the example of air temperatures, the sensation of relative humidity was explored according to a response scale composed of five sensual options. The results are presented in the histogram on the next page (Figure 6).
The first session is characterized by two dominant sensations; "neutral" and "a little wet". Overall, the urban thermal environment experienced a dry feeling during the three sessions from 11:00 a.m. to 5:00 p.m. Hence the "a little dry" option was widely used during the three sessions, while the "dry" option was greatly raised in the session from 1:00 p.m. to 3:00 p.m. The wet feeling is the dominant during the last two sessions, especially that from 7:00 p.m. to 9:00 p.m., where more than 90% of the votes were for the "a little wet" feeling.

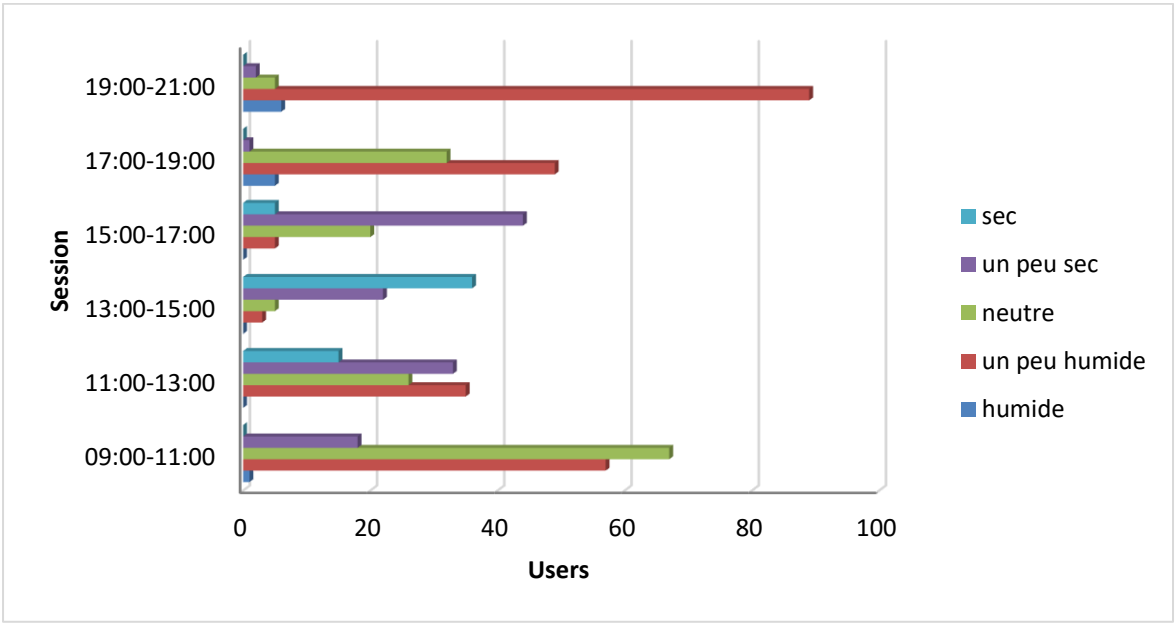

Figure 6. Thermal sensation of the relative humidity.

Overall, the thermal sensation of the wind speed was voted as “a little soft” and “neutral” for the first session, the flowing session from 11:00 a.m. to 5:00 p.m. were voted mostly as “stagnant”. The session from 5:00 p.m. to 7: 00 p.m. was voted as “a little stagnant” and “neutral”, while the last session was greatly voted as “a little stagnant”.

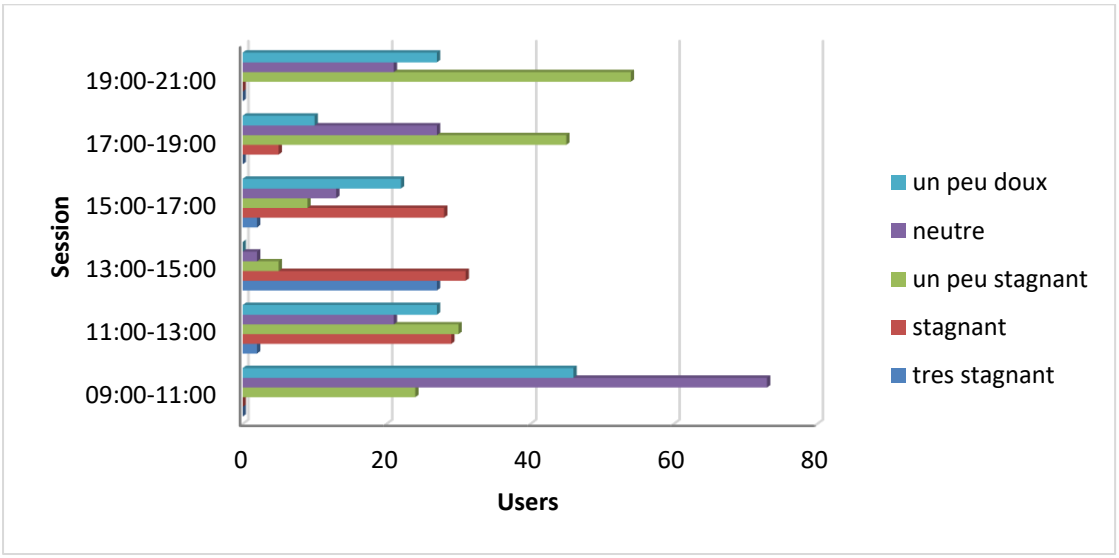

Figure 7. Thermal sensation of the wind speed.

4. Conclusions

In our study we have assessed the thermal comfort levels in downtown Guelma during the summer heatwave, based on qualitative and quantitative collected data, the main conclusions are as follows:

- The microclimatic variations that exist between successive places make it possible to relate the composition of the urban thermal environment and the level of comfort expected in that place.
- The thermal sensation per session of the microclimatic parameters provides information on the bi-hourly level of climatic comfort to be provided.
- The use of sensual response options makes it possible to conclude on the effect caused by the urban thermal environment in space and time.

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