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Differences in the perception of urban space via mental maps and Heart Rate Variation (HRV)

Abstract

The main objective of this research was to compare the perceptions that people have of urban space via two different types of approach. We contrasted results obtained using a subjective approach: mental maps, with a more objective one: measuring Heart Rate Variation (HRV). The results showed important differences between how citizens perceive and represent urban space through mental maps and the fluctuations in their Root Mean Square of Successive Differences (RMSSD), monitored using an objective measuring device (HRV). Comparing the results enabled us to reach beyond traditional descriptions and to identify new perceptions based on the emotions transmitted by different spaces in the city.

Keywords

Mental maps; Heart Rate Variation (HRV); emotions; urban space; Lleida

Introduction

Emotions contribute a very interesting variable to our understanding of behaviour and the management of experiences. When applied to urban space, emotions are essential for providing a richer, more comprehensive, and integrative understanding of the individual's experience of the city (Shoval et al., 2018). Measuring them, however, is quite a complex task. Mental maps have traditionally been used as a tool for describing perception, but they present several limitations, especially with regard to the manual compilation of information and the interpretation of results.

Recent changes in mobile and biosensing technologies have, however, opened new ways for improving how emotions are measured. Various authors have highlighted the importance of mobile experiments in real spaces, as opposed to the use of laboratories or virtual

environments, in order to correctly identify emotions (Mavros, et al., 2016). This approach is based on the argument that any urban journey implies the citizen seeing, listening to, smelling, tasting and touching “objects” on the way to their destination and thereby generating emotions (Winkielman & Berridge, 2004). Even so, our knowledge of citizens’ emotional responses in real-world settings still remains very limited (Lee & Kyle, 2012).

The present study forms part of the current line of research that seeks to characterise the importance of emotions in public space. It is based on a dual approach, which is currently being developed, aimed at identifying the complexity of emotions: “travelers’ perceptions of their physical and social environments are grounded in both the objective features of the environment and their subjective interpretations of it” (Kim & Fesenmaier, 2015, 419).

We used two different tools to achieve this dual aim. Firstly, we used mental maps to analyse subjective visions of the city. Secondly, we used automatic measurements of physiological factors to provide a more objective view, incorporating spatiotemporal data obtained from the public space. To achieve the latter, this study introduced a new approach for assessing citizen’s emotions relating to perceptions of natural settings in real time. We did this by measuring people’s Heart Rate Variation (HRV) to identify any changes in their emotional state. The information compiled related to the time, spatial location and HRV. Our study focused on 35 people who lived in the city of Lleida (in Catalonia, Spain).

The results obtained showed significant differences in perceptions of urban space according to whether they were analysed subjectively or objectively. We concluded that by combining the two approaches, we could provide a good instrument for improving our knowledge of the perception of urban space. The study provides knowledge that could help to improve the management of cities and to identify points where it is necessary to improve the relations that citizens have with their physical space and social setting.

2. Theoretical framework

2.1. Defining emotions in cities

There are different definitions of emotions. For some authors “emotions are considered to be a complex set of interactions among subjective and objective factors mediated by neural/hormonal systems” (Kim & Fesenmaier, 2015, 283). In general terms, emotions are considered elusive and difficult to observe (Davidson et al, 2005). Even so, from a revision of the

existing literature, Kleinginna & Kleinginna (1981) highlighted three aspects as common elements in over 100 definitions of emotion: subjective experience, an expressive component and physiological excitement. Everything therefore seems to indicate that emotions arise as a result of people experiencing certain stimuli which generate a series of specific feelings and responses (Li et al., 2015).

There is still some reluctance to measure emotions, above all due to the difficulties involved in defining the concept. In the current work, we considered emotions to be intense feelings of affection caused by a specific stimulus (person, object, event or situation) which result in a specific behavioural response (Prayag et al., 2017).

Emotions are related to urban spaces. Research in environmental psychology has established that people develop strong relationships with places (Yuksel, Yuksel & Bilim 2010). Recent studies have shown a correlation between the characteristics of the urban environment and stress levels (Fathullah & Willis, 2018). In one such relationship, defined as place attachment, emotions play a particularly important role (Altman & Low 1992). Emotions are therefore an affective phenomenon which is associated with a specific time and space and this opens the doors to its study as a mappable spatial variable. This vision has, in fact, led a number of authors to argue that emotions can be analysed as an instrument with which to understand relationships with places (Davidson et al. 2005), space (Straus, 1989) or the world as a whole (Smith et al., 2009).

The present work forms part of a line of studies that has analysed the role of emotions from multiple angles. As examples, we can cite: works carried out in the field of economics, focusing on “irrational” decisions and their consequences (Kahneman, 2012); studies in the field of tourism that have measured emotions to understand tourist experiences (Prayag, et al., 2017); and studies undertaken at real settings to analyse such phenomena as levels of stress in drivers (Healey & Picard, 2005), pedestrians (Hogertz, 2010) and shoppers (Alajmi et al, 2013).

2.2. The limitations of traditional and automated approaches

Perceptions of urban spaces have usually been obtained from sources such as interviews, self-reporting methods and activity diaries (Kwan, 2000). Mental maps form part of these sources and have particularly done so since the publication of *The Image of the City* by Kevin Lynch (1960). In that work, Lynch used five repetitive elements: paths, edges, districts, nodes and landmarks. After considering the relationships between these elements, the image of the city

begins to emerge as a sum of separate images. Each citizen tends to have a particular vision of their environment, which is transformed into a specific perception (Greenberg Raanan & Shoval, 2014).

However, these approaches present a number of limitations. First of all, they may distort the original emotional responses towards the destination or specific stimuli, as respondents are often asked to recall their emotions after their experiences (Nawijn et al. 2013). Various studies have shown that people tend to process information automatically, without too much cognitive processing. On the other hand, emotional data collected *a posteriori* capture a consumer's perception of their emotional response rather than the emotional response itself (Poels & Dewitte, 2006). Secondly, measurements are taken and related to a long list of affective adjectives in a process that limits emotional reactions to a pre-established list that might otherwise condition the compilation of certain data (Micu & Plummer, 2010). Finally, these measurements also call for the mobilisation of an important quantity of human resources and this makes data collection both more expensive and more complicated.

In the last decade, the perfecting of certain technologies, and especially the use of georeferenced data via GPS, has greatly simplified the process of measuring emotions (Shoval et al., 2018). This can now be done continuously, is not dependent on language, recall or interferences with message processing, and is more economical in the use of human resources (Ravaja, 2004). Furthermore, it makes it possible to go beyond studying individual cases and to map data in an aggregated way onto a rough grid (Zeile et al., 2009).

However, to date, there have been few studies that have measured emotions at real settings (Kim & Fesenmaier, 2015); the majority have been carried out in laboratories. This is something that has limited the capture of dynamic interactions between emotions, places, and people in real settings (Davidson et al., 2005). Furthermore, the studies undertaken outside the laboratory have tended to focus on clearly defined areas. We could, for example, cite the work of Loiterton and Bishop (2008), who used GPS and Personal Digital Assistant devices to track visitors to the Royal Botanic Gardens in Melbourne; the analysis of the emotions experienced at the different places during the Biathlon World Championships of 2008 (Pettersson & Zillinger, 2011); or the use of GPS and smartphone applications to map the "sense of security" and "positive/negative experiences" at an outdoor music event (Birenboim, 2016). The exception would be the Bio Mapping project (Nold, 2009). This was an initiative developed by a multi-disciplinary team of artists and academics, who worked with a wide group of people from 16 different countries.

They approached the task from several different angles, including essays, artistic interventions, and philosophical reflexions.

Along the same lines, we must also highlight some of the research that has analysed the perception of emotions in cities. However, in general terms, little attention has been given to very specific locations (such as squares or streets), with work instead tending to focus on an analysis of the wider picture (Shoval et al., 2018). This contrasts with a range of research which has highlighted the convenience of using real-time and real-world physiological measurements (Walls et al. 2011).

New instruments for analysis have progressively appeared which have been incorporated into academic research (Wilhelm and Grossman 2010). Two of the most outstanding works are by Sagl et al. (2015) and de Zeile et al. (2015). Both analyse how to use new medical technologies at real settings and not only in research laboratories. A series of new academic research was launched from this base and showed that these physiologically based measurements could prove more reliable for assessing emotions than existing self-report methods (Kim & Fesenmaier, 2015). Physiological adjustments form part of the emotion process and allow us to capture a more accurate visualisation of emotions (Picard 2010).

However, at present, there are no generally accepted research standards in this emerging field. This means that it is necessary to take care when adding new results. With this in mind, for the current research, we opted to go beyond normal studies based on a single technique. To be more specific, we used the two approaches previously highlighted to make a comparison between the subjective view of the city, provided by mental maps, and the objective view, provided by HRV measurements. In this way, it was possible to evaluate the degree of coincidence and divergence between the results obtained using the two approaches.

3. METHODOLOGY

3.1 Designing the itineraries

The research was carried out in the city of Lleida (137,000 inhabitants in 2017), which is a medium-sized Catalan city. To be more precise, the study area focused on two neighbourhoods which have recently been subjected to plans of urban improvement.

The first was the city's Historic Centre. This is an area of 15 hectares, which contains a mixture of historic and modern sub-areas. It used to be the functional centre of the city, but the

transformations of the 20th century led to it losing both its urban functions and population. It has passed from having 21,000 inhabitants in 1887 to having only 7,000 at present. It also has a relatively high low-income, immigrant population. Despite this, part of the area still maintains important commercial and symbolic functions.

The second neighbourhood analysed was La Mariola. This is a mainly residential area of social housing that was built between the 1950s and 1970s. The majority of its flats are smaller than 50 m² and lack lifts, while there are few, if any, commercial premises or amenities in the neighbourhood. La Mariola has over 10,000 inhabitants with a variety of different socio-economic types.

The itinerary was designed to include the greatest possible range of urban sub-areas: old and modern areas of housing, public space, green and commercial zones, degraded zones and recently remodelled areas.

The physical effort required to complete the route was also taken into consideration, as this could have affected the HRV (Shoval et al, 2018). The route through the Historic Centre was 2,500 metres long, with a variation in altitude of 30 metres. The route through La Mariola was about 2,000 metres long, without any significant variations in altitude. In order to prevent the effort made by walking influencing the measurements, part of the group did the route travelling clockwise, while the others followed it anti-clockwise. In this way, it was also possible to compare the effects of slopes and tiredness.

Each participant did the routes on different days and independently. The participants followed a pre-established route indicated on a map that was given to them at the beginning of the walk. In this way, it was possible to evaluate the results without excessive spatial dispersion and to give the participants a certain degree of freedom of movement.

3.2. The characteristics of the sample

The study involved 35 participants and was carried out between 25th June and 10th July 2018. As a result of technical problems in the data registration process, we were finally only able to compute 28 samples. This was a group of 13 women and 15 men, aged between 19 and 40. The consent of all the subjects was obtained after providing them with an explanation of the experiment. Each participant signed a consent form in which they declared that they had been

informed of the use that would be made of the data collected and of all their rights in this respect. The data were processed anonymously using a numeric code.

This number of participants was in line with other studies, such as those of: Shoval et al (2018), who analysed the behaviour of 68 tourists in the city of Jerusalem; Birenboim (2016), who analysed 25 participants to identify their feelings of crowdedness and security; the Emomap of the city of Mannheim, by Zeile et al. (2009), a project in which 20 aspiring urban planners and architects participated; and that based on the electrodermal activity (EDA) of 2 tourists visiting Philadelphia (USA) (Kim & Fesenmaier, 2015).

3.3. Measuring emotions

Historically, emotions have generally been measured according to three variables: one behavioural, another physiological, and the third cognitive (Lazarus, 1975). More recently, academic literature has tended towards a multilevel, pluri-disciplinary approach based on three measurable dimensions (Schweiger & Torregrosa, 2016): (1) emotional valence, which describes whether emotions are pleasant (joy, interest) or unpleasant (anger, fear, sadness); (2) activation or emotional intensity (arousal), which can range from less to more and which considers the widest field for the intervention of biometric sensors given their physiological expression (Lane & Nadel, 2000); and (3) dominance, which evaluates the level of self-control of emotions, or even of being controlled by others, and is also based on various psychometric tools (Mehrabian & Russell, 1974).

The majority of researchers tend to favour a two-dimensional model in which the main variables used are valence and arousal (Prayag, et al. 2017). In the present research, valence was obtained from the mental map, whereas arousal was determined from a spatial analysis of the level of intensity and emotional activation and measured by HRV.

We must be conscious, however, of the fact that a given situation may generate a different response in each person. Several studies have solved this problem by using prior laboratory calibration, based on different scenarios. The results obtained suggest a relationship between HRV and the physical effort involved (Exner et al., 2015). This calibration makes it possible to rule out variability and to compare individual results. The methodology used in the present research does not permit such comparisons. Even so, the fact that the trajectory, age, training and origin of the volunteers were similar, meant that we were able observe changes in average values. The objective was therefore to identify those spaces that caused changes in habitual

values. This is an approach that has already been used by such authors as Zeile et al. (2009) and Shoval et al. (2018).

3.4 Measuring arousal

In the present work, we spatially analysed the level of intensity or emotional activation (arousal) through observed fluctuations in cardiac rhythm relating to the intensity of the stimuli received (Roessler, Burch & Childers, 1966). More concretely, we geolocalised the time that elapsed between each pulse beat, which is known as Heart Rate Variability (HRV). This approach allowed us to obtain an important quantity of data; to be precise, 91,499 measurements were gathered from participants completing the routes.

When we say that a person presented a cardiac rhythm of 60 beats per minute, we assumed that the time between heartbeats was 1 second. In reality, however, there tends to be a dispersion of these values. The HRV is the variation between the intervals. This physiological phenomenon is caused by the intervention of the autonomic nervous system (ANS), which can be subdivided into the sympathetic system (SNS), whose role is to excite, and the parasympathetic system (PNS), whose action is inhibitive. We therefore have two antagonistic systems that adapt the cardiac rhythm to change. States of emotional excitation modify this equilibrium and can therefore be measured through changes in the HRV (Appelhans & Luecken, 2006).

HRV is a method which has been widely used in the academic literature. It reflects the state of ANS (Choi et al., 2017). It is therefore a good objective tool for assessing emotional responses (Valenza et al., 2012; Lane et al., 2009). There are a number of different measurements which are derived from the interval between heartbeats (RR) and that can be used to generate a series of statistical measurements:

- SDNN, or the standard deviation of the number of RR intervals
- RMSSD (Root Mean Square of Successive Differences), or the square root of the average values of the sum of the differences to the square of all the consecutive RR intervals.
- pNN50, or the percentage of consecutive RR intervals that differ by more than 50ms.
- pNN20 is the same as in the previous case but relating to differences of more than 20ms.

In the current research, we focused on RMSSD, as it was regarded as the most suitable measurement when it came to forming associations with subjective feelings (Levenson et al.,

2017). In preliminary tests, taken as a whole (XXXX, 2017), spatial patterns have been associated with all of these variables. We therefore considered that they were the most appropriate variables with which to cartographically represent levels of emotional activation.

3.5. The data compilation process

Before the agreed day and time, the participants received no information about the route that they were going to follow. On arriving, they were explained the characteristics of the equipment that they were to wear and provided with a map of their route and photographs of some of the main points of reference, to guide them. They were subsequently fitted with the instruments required to measure HRV and their geolocation, which consisted of a Heart Rate Sensor (HRS) and an Android smartphone which had been exclusively prepared for this purpose. To rule out any possible interference, whether related to the novelty of the apparatus or the nervousness of the participant, we treated the first 15 minutes after initiating the exercise as a “warm-up period” (Kim & Fesenmaier, 2015). All of the routes followed were recorded on video, which made it possible to review everything *a posteriori* and to thereby ensure that there had not been any problems. The volunteers all wore sport-style sunglasses equipped with cameras and USB flash drives. On reviewing the video footage of the routes followed, no external phenomena were observed that might have affected the registered values.

HRV is based on measuring the time between heartbeats. It is expressed in milliseconds and, in our study, was obtained with a Polar Electro H7 HRS. This measurement was then transmitted, in real time and using Bluetooth technology, to the mobile IoTTool application installed in the smartphone, which acted as the datalogger. The same application also registered the geolocalisation, in latitude and longitude, via the GPS incorporated into the mobile phone. Both measurements: heartbeat and geolocation, were then exported, in the form of CSV files.

The HRS registers were processed, by Matlab R2016b, to obtain the RMSSD and then, once more, synchronised with the geolocation. The time field, which was present in both variables, was used to synchronise the different GPS and HRS recording rhythms. The results were then mapped using ArcGis (version 10.6). To identify emotionally evocative areas of the city, the study area was divided into a series of 20 m × 20 m cells. Hexagon tessellations are often used as sampling units for spatial analysis (Feick & Robertson, 2015). They make it possible to identify the stress level of a particular area (going beyond behaviour at a specific point). With this in

mind, the metrics were calculated based on 60-second window values, which moved at a rate of approximately 1 second per RR (XXXX, 2019).

3.6. Mental maps

Once the participants had visited the testing area, they were asked to draw a mental map of it. This map was drawn on completely white DIN A4 paper, without any time limit. The participants were encouraged to go beyond the drawing itself and to also incorporate comments about their experiences.

The information from the maps was then digitalised. In order to draw parallels with the HRV information, the different elements registered on the mental maps were transformed into points. When an element was zonal or linear, it was mapped at the centre of the corresponding polygon or line (XXXX, 2016).

Positive, negative or neutral values were given to the different points on the map, based on the comments of the participants. In order to avoid subjectivity in the transformation process, the different elements were coded by two different people. If there were any differences in these values, a third person established the definitive value.

4. Results

Defining emotions is complex. Various studies have shown that having a feeling is not the same as being aware of it (Kim & Fesenmaier, 2015). An affective response can occur in the absence of, without any conscious awareness of, external stimuli (Winkielman and Berridge 2004). Some authors have suggested that measuring emotions may even limit our understanding of the processes that generate these emotions (Poh et al., 2011). It is therefore advisable to analyse the urban space based on dual approximations: subjective and objective. It was with this in mind that we have presented (below) the main results obtained on mental maps and as measures of HRV.

4.1. Results from the mental maps and RMSSD

Figure 1 shows the main results obtained from the mental map exercise. The participants referred to 69 spaces in the areas analysed and expressed 266 opinions about them (an average of 3.85 responses per space). Approximately half of the points referred to were only mentioned once or twice. Only 11 spaces were mentioned more than 10 times. The largest number of references to any single point was 21 (for the Santa Cecilia park).

The most common evaluation was neutral (73.7% of references), followed by negative (16.6%) and lastly positive (9.7%). The distribution of the neutral values was similar to that of all the values. This was the evaluation that tended to be given to the most iconic points along the route (such as squares, commercial premises and bars), which were cited as points of reference within this space.

There tended to be fewer negative values. Only 43.5% of the points received negative scores. Eight points concentrated over half of the negative comments. Above all, these were streets and areas in the centre of the Historic Centre and in some parts of the La Mariola neighbourhood. In both cases, the different points identified had a common casuistry: narrow streets, lacking recent physical action to modernise them, containing unoccupied housing (bricked up or uninhabitable).

Finally, the positively evaluated spaces tended to be few in number (only 20.3% of the total). They were also concentrated in the Historic Centre and particularly on its periphery. Special mention should be given to the most transited spaces (the commercial streets in the eastern part of the study area) and the Santa Cecilia public park, which has recently been renewed (in the northern part of the map).

Figure 1. Summary of the main results from the mental maps (The numbers correspond to video captures displayed in figures 5 and 6).

Cartographic base: *ICGC.cat*

The map shows several empty spaces, above all in the north-west part of the Historic Centre. It is also possible to highlight some central spaces in the La Mariola neighbourhood. As this is an area of almost identical blocks of housing, it is probable that the most centrally located units did not have the same impact on the participants as those on the periphery. Similarly, no values were assigned to the spaces that the participants had to pass through on their way from one neighbourhood to the other. This space on the mental maps was ignored as it did not constitute part of what officially formed part of the main study area. Finally, it should be mentioned that some of the participants highlighted areas on their mental maps that they did not actually visit. This was the case, for example, with the city's old cathedral (La Seu Vella) and with the castle of Gardeny. This is an example of how mental maps tend to produce a subjective vision and one potentially conditioned by previous knowledge.

In the case of the values obtained from the RMSSD (Figure 2), unlike with the mental maps, no empty spaces were recognised nor were there any references to spaces that the participants had not visited. To be precise, the mapped showed 253 hexagons covering a surface area of about 26.3 hectares.

Following the work of Michels et al. (2013), we interpreted low RMSSD values as indicating situations of stress. As can be observed from the map, the situation was different from that shown by the mental map. The La Mariola neighbourhood exhibited RMSSD values that were clearly lower than those for the Historic Centre. On the other hand, the mental map indicated a more negative perception of the Historic Centre than of La Mariola. In contrast, there were few areas in La Mariola which reached the higher values: those associated with less stress.

This difference was also observed along the route followed by the participants. The starting point for the route was the university. Those who then headed towards the Historic Centre showed higher RMSSD values. On the other hand, those who headed for La Mariola registered clearly lower values.

Figure 2. The main RMSSD measurement results

Cartographic base: *ICGC.cat*

4.2. Comparing the results

Comparing the results obtained from the mental maps and the RMSSD maps showed significant differences (Table 1). In general terms, it was possible to observe how the subjective vision of the mental maps tended to be more clearly seen in the Historic Centre. In contrast, the objective measurements of the RMSSD were more evenly spread. It is particularly illustrative to note how low RMSSD values, associated with situations of stress, were more clearly evident in La Mariola than in the Historic Centre.

Table 1. Comparison of extreme values on the mental and RMSSD maps (%)

	Positive mental map values	High RMSSD values (> 0.015127775)	Negative mental map values	Low RMSSD values (< 0.011146050)
Historic Centre	85.71	48.61	73.33	23.61
La Mariola	11.43	29.17	25.00	63.89
Route followed	2.86	22.22	1.67	12.50

The values objectively obtained clearly showed La Mariola to be an area of stress for the participants. Having said that, the fact that this neighbourhood is located on the periphery of the city and serves basically residential functions implies that the majority of the participants would not have had much knowledge of it. They would not, therefore, have had much previous information about it to reflect in their mental maps and would have tended to only reflect the experiences that they had at the time of the test.

In contrast, the Historic Centre, which performs leisure, commercial and cultural functions, would have been previously visited by the majority of the participants. They would therefore have had previous knowledge of it, which would have conditioned the images reflected in their mental maps, which may not always have corresponded to the RMSSD measurements that were observed.

This situation was clearly evident when we compared the negative (Figure 3) and positive (Figure 4) perceptions. As we can observe from the two maps, the coincidences at the spatial level between the information obtained from the mental map and that from the RMSSD were extremely limited, except in the case of the extreme values.

Figure 3. Comparing negative perceptions on the mental map and low RMSSD scores.

Cartographic base: *ICGC.cat*

Figure 4. Comparing positive perceptions on the mental map and high RMSSD scores.

Cartographic base: *ICGC.cat*

Figure 5. Video captures of the most significant points associated with negative perceptions on the mental map and low RMSSD scores

A small street in La Mariola (1) and the streets (carrers) called Companyia (2), Cavallers (3) and Múrcia (4) (in the historic centre)

Figure 6. Video captures of the most significant points associated with positive perceptions on the mental map and high RMSSD scores

Santa Cecília park (5) and the streets (carrers) called Carme (6), Magdalena (7) and Rambla d'Aragó (8).

The five values that obtained the greatest number of negative reports on the mental maps were also the five points where the lowest RMSDD scores were detected. One area in the southern part of the La Mariola neighbourhood particularly stood out for both indicators. This was a street, little more than one metre wide and 100 metres long, which is partially covered and runs between blocks of housing that contain some uninhabited and partially destroyed lower floor areas (figure 5).

At the other extreme, the four points that received the most positive scores on the mental map were also the ones that had the highest RMSSD scores. In this case, the Santa Cecília park, located to the north of the Historic Centre (figure 6), stood out as the most highly valued space on the mental maps and for having received the highest RMSSD scores. We also observed that

the majority of the gardened or open spaces along the route were the ones that obtained the most positive scores on the mental map and RMSSD.

Outside these extreme values, the coincidences between the two sources disappeared. As can be seen from Figure 7, there were spaces with neutral values on the mental maps that did not appear with intermediate RMSSD values. We identified spaces with good RMSSD measurements but without references on the mental map. The spaces which, based on their RMSSD scores, tended to be considered points of stress generally produced good values. These spatial differentiations led us to consider the two sources of information as being complementary. The perceptions of the various urban spaces that were identified on the mental maps were clearly different from those identified by the RMSSD values. To understand the wealth of the urban space, it is therefore necessary to be aware of the dual focus provided by RMSSD and mental maps.

Figure 7. Comparing neutral perceptions on the mental map and intermediate RMSSD scores.

Cartographic base: *ICGC.cat*

5. Conclusions

As commented with respect to the theoretical framework, there is a difference between having a particular feeling and being aware of it. The comparison between one method: mental maps, based on subjective aspects, and the other: objective RMSSD measurements, clearly illustrate these differences.

Emotions play a key role in understanding urban behaviour and have a direct impact on how the urban space is perceived. Having said that, these emotions tend not to coincide with what is really experienced when we are at a particular place. An analysis solely based on one of the aspects may condition the reading that is made of the whole. In this respect, neither the mental maps, nor the RMSSD measurement, alone, make it possible to summarise the perception of the urban space in all of its complexity. There is evidently a need for analyses that can take into account both subjective and objective visions of urban space. This will help us to avoid reaching erroneous conclusions based only on either the subjective or objective visions of citizens.

Various authors have shown how the behaviour of citizens in the urban space can be influenced by previous perceptions (Davidson et al., 2005). Having said that, experience *in situ* may also generate measurable reactions that cause stress or relaxation and this may condition how the space studied is perceived. This work demonstrated how these two visions only coincided in the most extreme cases; in the other situations, the results of subjective and objective visions diverged.

This constitutes a limitation in current studies, particularly as they tend to be based on a single data source. This has recently been noted by several authors and, for example, in relation to tourism (Shoval et al., 2018). The present research shows how, in the day-to-day lives of citizens, these differences also exist and this is something that can condition their use of urban space.

The study therefore shows the potential for HRV data collection. The city is a continuum in which it is often difficult to compile specific information using other approaches. HRV makes it possible to obtain information about “empty moments” (Kim & Fesenmaier, 2015). These aspects show the future potential for this instrument, which will increase if work continues to improve the interpretation of the results obtained. We also show how it is necessary to complement HRV results with a more qualitative approach in order to obtain an accurate representation of urban complexity.

This information could help planners to detect spaces that, on account of their design or use, cause alterations in the emotional states of a large percentage of inhabitants. In this way, it

could be seen as a new way to enable citizens to participate in the governance of their cities (Fathullah & Willis, 2018). It would also make it possible to take action to create areas that neighbours find welcoming (which could include protecting existing spaces) or to avoid repeating spaces that provoke feelings of stress (for example, by improving the design of pedestrian crossings). Whatever the case, whether provoking positive and negative emotions, these different spaces will continue to form part of our cities as each inhabitant experiences public space in a different way.

There do, however, remain aspects on which it is necessary to continue working. Firstly, we need to establish how HRV may affect the privacy of the participants and add a geographical dimension to the surveillance society (Lyon, 2001). Similarly, it will be necessary to analyse other types of habitual behaviour in the urban space in order to obtain segregated information. By way of example, differences in perception may be found according to whether a person walks alone or in company, at different times of day, at different times of the year, or under different meteorological conditions. However, despite these current limitations, new ways of measuring and mapping the urban space based on a combination of subjective and objective data should help us to better understand the urban environment.

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