THE IMAGE OF THE CITY INTERPRETED THROUGH BIOSENSORS PATH ANALYSIS AND IDENTIFICATION OF PERCEPTUAL POLES IN THE NARNI CASE STUDY

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ABSTRACT:
The research aims to interpret the image of the city, according to the conventions defined by Kevin Lynch, obtained from the analysis of the impact of environmental stimuli on the person. The study relates the digital reconstruction of the spaces analysed with the detection of the trend of valence obtained on a statistical sample using an EEG helmet. The monitoring of the degree of attraction or aversion to the stimuli of the surrounding environment is processed through algorithmic procedures to identify along a path the perceptual poles. This path, reported in GIS environment, allows to reconstruct georeferenced maps that interpret the brain data, synchronized with GNSS. The spatial poles thus identified are further investigated using eye-tracker to understand the reasons for the impact of the environment on humans.

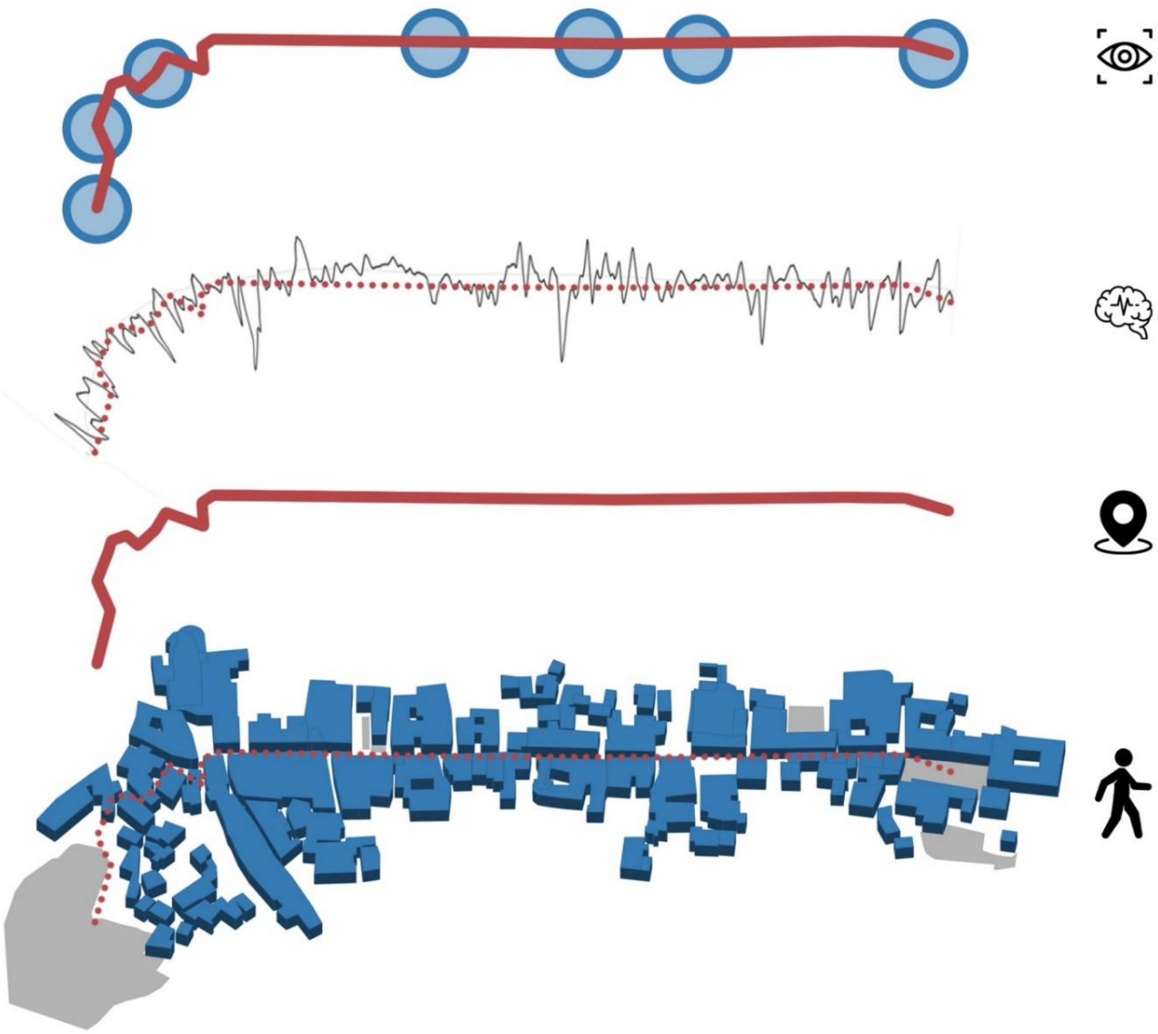

Figure 1. Methodology used: route taken on foot during data acquisition, spatial data acquisition (GNSS), EEG data acquisition, eye-tracker data acquisition.

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1. INTRODUCTION

The environment where we live, architecture and landscape, urban or natural, always have an impact on man, positive or negative, never neutral. (Goldhagen, 2017). From ecological psychology it emerges how the flow of information from the space around us continually influences the human experience (Gibson, 1983). Thus, humans are like sensors, "registering" those received signals and reprocessing them, with the support of memory, to determine the experience and contextual processing of the concept of place (Norberg-Schulz, 2000), a cultural process that is based on sensory reasons.
The sensory and emotional experience, so related to images (Mitchell, 1980), is mitigated by the rationality of interpretation (von Balthasar, 1961) that leads us to filter information (Arnheim, 1965) to define patterns, in the need to understand the world to orient oneself, not only spatially but also humanly (Kepes, 1944, p. 18). Through this path originates the figuration (Filippucci, 2013), the interpretation of the sequence of images (Cullen, 1961) that allow the mind to draw through lines and points a path related to the urban map.
Considering Kevin Lynch's theories on the image of the city (Lynch, 1962), given the importance of the related figurative theories linked to the artistic movements of the early twentieth century (Kandinsky, 1926; Klee, 1956), the line correlates to dynamism, to displacement, and the point to the being, to what is identified: it thus correlates identification to orientation, key actions for the interpretation of urban space.
The thesis that we want to demonstrate here is that the identification of points is related to a transformation of the emotional state, of the sensations generated by the environment. The interpretive process of the mind that transforms images into patterns (Lynch, 1984) can indeed be analysed in new technologies the tools to understand the impact on emotions (Picanço and Tonneau, 2018), using in particular the analysis of stimuli on the cerebral cortex through EEG helmets (Berka et al., n.d.; Chen et al., 2019; Hunter et al., 2000; Roe et al., 2013; Sharma et al., 2017; Shin et al., 2015; Vecchiato et al., 2015; Wang et al., 2015). Starting with tools and methodologies specific to neuromarketing (Huddleston et al., 2018; Yadava et al., 2017; Zamani et al., 2016), it is possible to obtain results that describe underlying and implicit spatial information (Dupont et al., 2016) extrapolated with the support of a statistical sample of subjects involved in the experience who are asked to walk (Amati et al., 2018; Mavros et al., 2016).
At points where substantial variation in stimuli and thus sensations occurs, an additional layer of analysis can be overlaid through the use of eye-trackers (Crosby and Hermens, 2018; Duchowski, 2017; Wolbers et al., 2008) o understand what attracts of the specific space (Simpson et al., 2019) extending research originally developed in neuromarketing (dos Santos et al., 2015; Lahmiri, 2018; Li et al., 2016).
The analyses of urban and landscape character obtainable with this combination of different biosensors (F Bianconi et al., 2021; Fabio Bianconi et al., 2021; Seccaroni et al., 2021) thus bring out "unconscious" emotions that arise from what we are attracted to. Their impact on the person can be interpreted as a measure of well-being (Badland and Pearce, 2019; Bechtel and Churchman, 2002) and of the health that an environment generates (Byrne et al., 2014; Lee and Maheswaran, 2011; Pedersen Zari, 2015; Schram-Bijkerk et al., 2018), thus opening to the theme of the quality of places and the value of the landscape (Bianconi and Filippucci, 2019), quantified and qualified for an underlying design heuristics projected to the redevelopment of the environment in which we live.

2. MATERIAL AND METHOD

2.1 Data Acquisition

The experimental course carried out to demonstrate the proposed thesis, is based on empirical analysis implemented with a significant sample of subjects. The investigation carried out proposed to each person, met at the starting point, to reach a final goal.
The experience is carried out through the simultaneous monitoring of three classes of data (figure 1):

- Visual
- Cerebral
- GNSS

Figure 2. Tools used for data acquisition.

The first type of data was acquired using the eye-tracker Pupil, composed of two cameras, the first infrared that records the movement of the pupil at 30hz the second that records the surrounding environment with 60° field of view.
For EEG data, Emotiv Epoc+ was used, which allows to record 14 channels (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4).
The spatial position was acquired with the help of the Samsung Gear S3 smartwatch (figure 2).

2.2 Data analysis

Empirical analysis finds its center in the analysis of neuronal stimuli. These stimuli are interpreted through the calculation (Ramirez and Vamvakousis, 2012) of Valence (1), understood as the degree of attraction or aversion to current stimuli, environment, or activity (Niemic, 2002).

$$\text{Valence} = \frac{\alpha F4}{\beta F4} - \frac{\alpha F3}{\beta F3} \quad (1)$$

where α_{F4} = α power in channel F4
β_{F4} = β power in channel F4
α_{F3} = α power in channel F3
β_{F3} = β power in channel F3

A methodology was developed to compare the data acquired in the different experiments as a function of spatial location. Using timestamps, the script synchronizes the EEG and GNSS data in order to have the Valence value geolocalized;

The experiences of the sample of volunteers involved was compared and homogenized using the geographical position. A specific script elaborated in Python identifies all the experimentations close to each other and gives an average value of Valence, to compare the n EEG data of the n experimentations. Subsequently we went to individuate in which parts of the path on average we obtained a value of Valence greater than the standard deviation for at least five seconds. This condition was imposed as an interpretative criterion because during the crossing of the urban space the observer is continuously stimulated and there are rapid variations of Valence not due to fixed elements of the urban space.

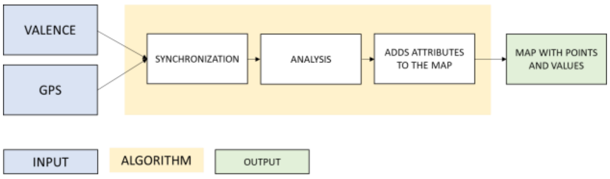

Figure 3. Algorithm logic diagram.

Once the areas with the greatest activation were identified, we went to evaluate punctually with eye-tracker which elements of the urban space characterized this variation. Through the software Pupil Player, the gaze and the possible fixations were analysed with a maximum value of dispersion of 1.5° and a duration interval between 80 and 220 milliseconds.
Reprojected the data inside Grasshopper with consolidated procedures (Bianconi et al., 2020, 2019; F Bianconi et al., 2021; Seccaroni et al., 2021), planimetric heatmaps describing the correlation between environmental stimuli and space were created.

Figure 4. Data acquisition process in the case study.

2.3 Case Study - Narni

The described methodology has been verified taking as case study the entrance to the historical center of Narni. As point of departure has been individualized the principal parking of the city and the arrival is the center of the University of the Studies of Perugia to Narni (figure 5).
The route runs through the historic center and is 655 meters long. The sample consisted of 40 people, including 19 women and 21 men between the ages of 21 and 39. Participation criteria for this study required participants to adhere to the following: (1) no brain or psychiatric disorders; (2) no drug use (3) no smoking or heavy drinking (4) have normal vision or corrected by contact lenses (5) be able to walk for at least 25 minutes (6) have no anxiety in enclosed areas (7) have no knowledge of the experimental site (Cheon et al., 2019; Olszewska-Guizzo et al., 2018; Wang et al., 2015). On average, recordings lasted 20' and position, EEG, and eye-tracker data were acquired.

Figure 5. Followed path.

3. RESULTS

From the analysis of the data acquired during the route, 9 areas were identified where the valence value was for more than 5 seconds consecutively greater than the standard deviation (0.89) (figure 7).
The first area is the entrance area and has obtained a maximum mean value of -1.8, therefore negative, where there is a transition from an open space to a covered and dimly lit corridor. The fixations (figure 6) highlight the observers look at the end of the entrance, that is the most illuminated part of the environment which is dark.
The second area identified is near the entrance, also here by virtue of poor lighting, cramped spaces and the presence of buckets mean that we have a maximum score of -4.
These most perceived elements can be identified from the heatmaps processed (figure 6).
The third area has a value of -2.5, this is always due to dark environments and narrow spaces, as can be seen from the fixations observers are attracted by crumbling walls and advertising arranged in a chaotic manner (figure 6).
The maximum negative value is present in the fourth area, here valence is -5, this value is due to two components, one architectural, that is, the space leading to the elevator is poorly lit and narrow. The other one is due to a little comfort of the elevator, in fact through a survey it has been found that it has a very abrupt departure and arrival coinciding with the detected valence data.
Leaving this area, we get the first positive value of +2.5. This area is an open space where fixations are centered on the green landscape in the background (figure 6).
Going through the historical center we find average values between +- 0.92 until we get to the central area near the town square where the value is +1.8. From the heatmaps it emerges that the ample space and the street furniture are the elements most perceived.
The continuum of the route remains for the most part positive until the arrival, which has a value of -1.2. due to the chaotic presence of cars, as shown by the results of the eyetracker (figure 6) In its complexity the city of Narni can therefore be broken down into nine points, and three macro areas two negative and one positive. The common component of the negative areas is the persistent presence of chaotic elements that overshadow the urban architecture. The positive area has a semantic coherence of wide spaces and the presence of green views or valuable architecture that are not overpowered by the chaos as is the case in the arrival area.

4. CONCLUSIONS

The relationship between man, space and emotions has been studied through the creation of a replicable digital procedure which, starting from the data, proposes interpretations of the values of the place. The methodology proposed through the combined use of various biosensors has the objective of identifying the areas in urban space that elicit a greater positive or negative activation. These areas are therefore those that for an observer represent the image of the city and therefore identify it. Here, using the eye-tracker, it was possible to identify which are the disturbing or positive elements that arouse the detected emotion.
The objective of this approach is to provide an objective data of the urban space that is to support the design going then to intervene and modify the negative elements and enhance the positive ones. This approach can in a targeted manner change the key to reading the urban hermeneutics going to make explicit the relationships first point and then areal in order to make explicit those immaterial relationships that exist between urban space and man.

Figure 6 - Some elaboration made with the eye-tracker.

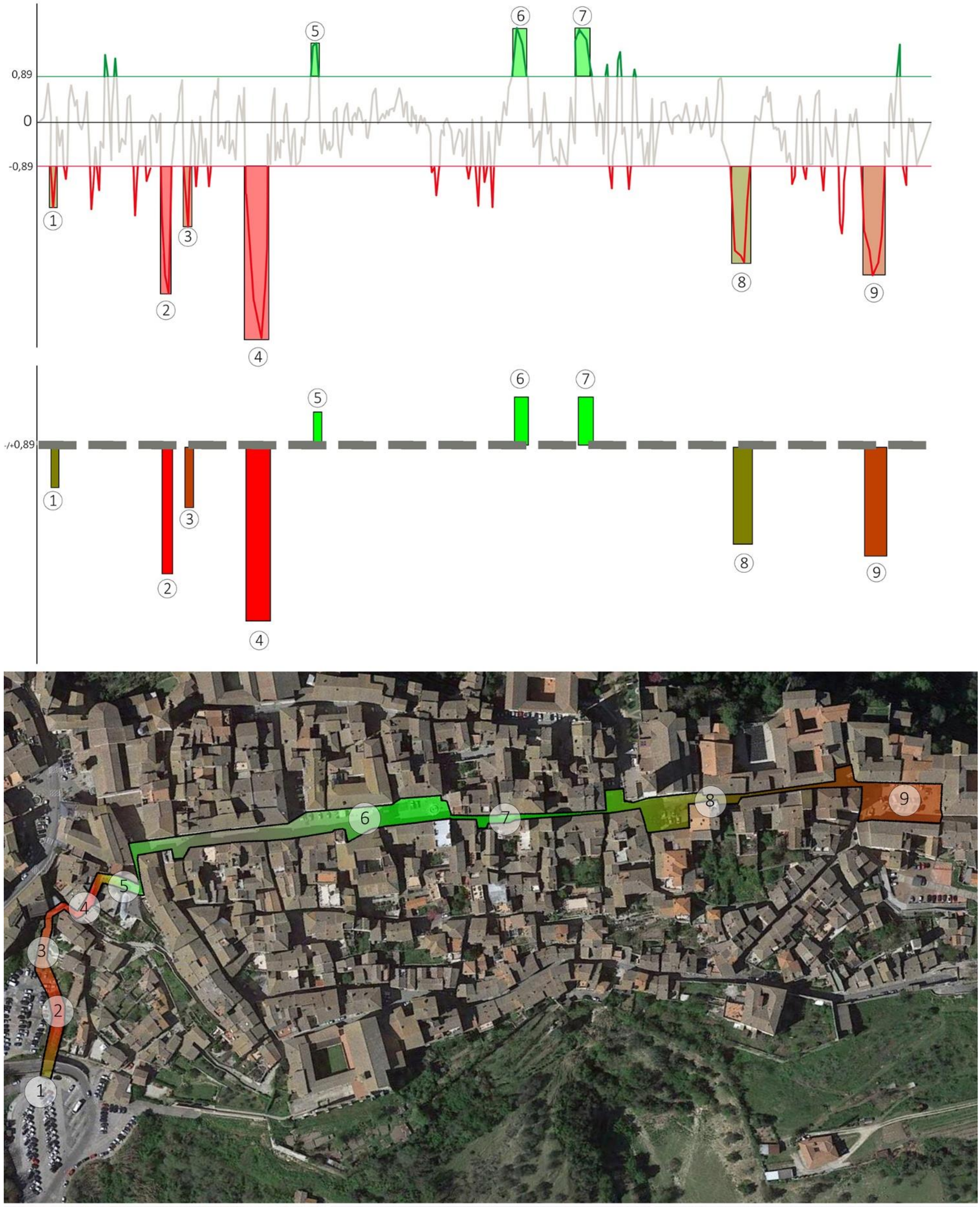

Figure 7. Valence time-dependent variation and map representation with linear interpolation.

REFERENCES

Amati, M., Ghanbari Parmehr, E., McCarthy, C., Sita, J., 2018. How eye-catching are natural features when walking through a park? Eye-tracking responses to videos of walks. *Urban For. Urban Green.* 31, 67–78. https://doi.org/10.1016/j.ufug.2017.12.013

Arnheim, R., 1965. *Art and visual perception: A psychology of the creative eye*. Univresity of California Press, Los Angeles.

Badland, H., Pearce, J., 2019. Liveable for whom? Prospects of urban liveability to address health inequities. *Soc. Sci. Med.* https://doi.org/10.1016/j.socscimed.2019.05.001

Bechtel, R.B., Churchman, A., 2002. *Handbook of environmental psychology*. J. Wiley & Sons, New York.

Berka, C., Levendowski, D.J., … M.M.C.-… J. of H., 2004, U., n.d. Real-time analysis of EEG indexes of alertness, cognition, and memory acquired with a wireless EEG headset. *Taylor Fr.*

Bianconi, F., Filippucci, M., 2019. *Landscape Lab. Drawing, Perception and Design for the Next Landscape Models*. Springer Nature, Basingstoke.

Bianconi, Fabio, Filippucci, M., Seccaroni, M., 2021. New Interpretative Models for the Study of Urban Space, in: DISEGNO. FrancoAngeli, pp. 235–240. https://doi.org/10.3280/oa-686.37

Bianconi, F., Filippucci, M., Seccaroni, M., 2020. Il rilievo digitale della percezione. Reinterpretazioni parametriche dell'impatto dell'ambiente sull'uomo. The digital survey of perception. Parametrics reinterpentations of the impact of the environment on men., in: 3D MODELING - DATA MODELING & MANAGEMENT FOR AECO INDUSTRY. DEI s.r.l. TIPOGRAFIA DEL GENIO CIVILE, Roma, pp. 228–243.

Bianconi, F., Filippucci, M., Seccaroni, M., 2019. SURVEY and CO-DESIGN the URBAN LANDSCAPE. INNOVATIVE DIGITAL PATH for PERCEPTION ANALYSIS and DATA-DRIVEN PROJECT, in: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives. https://doi.org/10.5194/isprs-archives-XLII-2-W15-165-2019

Bianconi, F, Filippucci, M., Seccaroni, M., Aquinardi, C.M., 2021. Urban parametric perception. The case study of the historic centre of Perugia. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* XLIII-B2-2, 839–846. https://doi.org/10.5194/isprs-archives-XLIII-B2-2021-839-2021

Byrne, J., Newell, J., Wolch, J., 2014. Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities "Just Green Enough." *Landsc. Urban Plan.* 234–244.

Chen, J., Wang, H., Wang, Q., Hua, C., 2019. Exploring the fatigue affecting electroencephalography based functional brain networks during real driving in young males. *Neuropsychologia* 129, 200–211. https://doi.org/10.1016/j.neuropsychologia.2019.04.004

Cheon, S.H., Han, S., Kim, M., Kwon, Y., 2019. Comparison between daytime and nighttime scenery focusing on restorative and recovery effect. *Sustain.* 11. https://doi.org/10.3390/su10023326

Crosby, F., Hermens, F., 2018. Does it look safe? An eye tracking study into the visual aspects of fear of crime. *Q. J. Exp. Psychol.* 174702181876920. https://doi.org/10.1177/1747021818769203

Cullen, G., 1961. *Townscape*. The Architectural Press, London.

dos Santos, R.D.O.J., de Oliveira, J.H.C., Rocha, J.B., Giraldi, J.D.M.E., 2015. Eye Tracking in Neuromarketing: A Research Agenda for Marketing Studies. *Int. J. Psychol. Stud.* 7. https://doi.org/10.5539/ijps.v7n1p32

Duchowski, A.T., 2017. *Eye Tracking Methodology*. Springer-Verlag, London. https://doi.org/10.1007/978-3-319-57883-5

Dupont, L., Ooms, K., Antrop, M., Van Eetvelde, V., 2016. Comparing saliency maps and eye-tracking focus maps: The potential use in visual impact assessment based on landscape photographs. *Landsc. Urban Plan.* 148, 17–26. https://doi.org/10.1016/j.landurbplan.2015.12.007

Filippucci, M., 2013. Disegno e figurazione, scrittura e oralità. L'immagine della città e il valore della percezione per la ricerca delle scienze della rappresentazione, in: Linee Di Ricerca Nell'area Del Disegno. Approfondimenti Dalle Tesi Di Dottorato. Aracne, Roma, pp. 300–308.

Gibson, J.J., 1983. *The senses considered as perceptual systems*. Houghton Mifflin, Boston.

Goldhagen, S.W., 2017. *Welcome to Your World. How the Built Environment Shapes Our Lives*. HarperCollins, New York.

Huddleston, P.T., Behe, B.K., Driesener, C., Minahan, S., 2018. Inside-outside: Using eye-tracking to investigate search-choice processes in the retail environment. *J. Retail. Consum. Serv.* 43, 85–93. https://doi.org/10.1016/j.jretconser.2018.03.006

Hunter, D., McCarraher, K., … K.F.-U.P., 2000, U., 2000. Headset for EEG measurements. *Google Patents*.

Kandinsky, W., 1926. Punkt und Linie zu Fläche. Beitrag zur Analyse der malerischen Elemente, etc. *Beitrag zur Anal. der malerischen Elem.* 9.

Kepes, G., 1944. *Language of vision*. Paul Theobald, Chicago.

Klee, P., 1956. *Das bildnerische Denken.* Benno Schwabe & Co., Basel.

Lahmiri, S., 2018. Neuromarketing Perspective of Consumer Choice, in: Applications of Neuroscience. pp. 286–295. https://doi.org/10.4018/978-1-5225-5478-3.ch013

Lee, A.C.K., Maheswaran, R., 2011. The health benefits of urban green spaces. *J. Public Health (Bangkok).* 33, 212–222.

Li, B., Wang, Y., Wang, K., 2016. Data fusion and analysis techniques of neuromarketing. *WIT Trans. Eng. Sci.* 113, 396 – 404. https://doi.org/10.2495/IWAMA150461

Lynch, K., 1984. *Good city form*. Harvard-MIT, Cambridge.

Lynch, K., 1962. *The Image of the City*, The Journal of Aesthetics and Art Criticism. MIT Press, Massachusetts. https://doi.org/10.2307/427643

Mavros, P., Austwick, M.Z., Smith, A.H., 2016. Geo-EEG: Towards the Use of EEG in the Study of Urban Behaviour. *Appl. Spat. Anal. Policy* 9, 191–212. https://doi.org/10.1007/s12061-

015-9181-z

Mitchell, W.J.T., 1980. *The Language of images*. University of Chicago Press.

Niemic, C.P., 2002. Studies of emotion: A theoretical and empirical review of psychophysiological studies of emotion.

Norberg-Schulz, C., 2000. *Architecture : presence, language and place*, Skira architecture library. Skira, Losanna.

Olszewska-Guizzo, A., Escoffier, N., Chan, J., Yok, T.P., 2018. Window view and the brain: Effects of floor level and green cover on the alpha and beta rhythms in a passive exposure eeg experiment. *Int. J. Environ. Res. Public Health* 15. https://doi.org/10.3390/ijerph15112358

Pedersen Zari, M., 2015. Ecosystem processes for biomimetic architectural and urban design. *Archit. Sci. Rev.* 58, 106–119. https://doi.org/10.1080/00038628.2014.968086

Picanço, C.R., Tonneau, F., 2018. A low-cost platform for eye-tracking research: Using Pupil© in behavior analysis. *J. Exp. Anal. Behav.* 110, 157–170. https://doi.org/10.1002/jeab.448

Ramirez, R., Vamvakousis, Z., 2012. Brain informatic. *IEEE Intell. Syst.* 26, 16–21. https://doi.org/10.1109/MIS.2011.83

Roe, J.J., Aspinall, P.A., Mavros, P., Coyne, R., 2013. Engaging the brain: the impact of natural versus urban scenes using novel EEG methods in an experimental setting. *Environ. Sci.* 1, 93–104. https://doi.org/10.12988/es.2013.3109

Schram-Bijkerk, D., Otte, P., Dirven, L., Breure, A.M., 2018. Indicators to support healthy urban gardening in urban management. *Sci. Total Environ.* 621, 863–871. https://doi.org/10.1016/j.scitotenv.2017.11.160

Seccaroni, M., Aquinardi, C.M., Bettollini, E., 2021. Urban Atmospheres: Representation of Intangible Relations, in: Lecture Notes in Civil Engineering. Springer Science and Business Media Deutschland GmbH, pp. 1111–1128. https://doi.org/10.1007/978-3-030-59743-6_52

Sharma, G., Kaushal, Y., Chandra, S., Singh, V., Mittal, A.P., Dutt, V., 2017. Influence of landmarks on wayfinding and brain connectivity in immersive virtual reality environment. *Front. Psychol.* 8. https://doi.org/10.3389/fpsyg.2017.01220

Shin, Y. Bin, Woo, S.H., Kim, D.H., Kim, J., Kim, J.J., Park, J.Y., 2015. The effect on emotions and brain activity by the direct/indirect lighting in the residential environment. *Neurosci. Lett.* 584, 28–32. https://doi.org/10.1016/j.neulet.2014.09.046

Simpson, J., Freeth, M., Simpson, K.J., Thwaites, K., 2019. Visual engagement with urban street edges: insights using mobile eye-tracking. *J. Urban.* 12. https://doi.org/10.1080/17549175.2018.1552884

Vecchiato, G., Tieri, G., Jelic, A., De Matteis, F., Maglione, A.G., Babiloni, F., 2015. Electroencephalographic correlates of sensorimotor integration and embodiment during the appreciation of virtual architectural environments. *Front. Psychol.* 6. https://doi.org/10.3389/fpsyg.2015.01944

von Balthasar, H.U., 1961. *Herrlichkeit. Schau der Gestalt*. Johannes Verlag, freiburg.

Wang, D., Chen, Z., Yang, C., Liu, J., Mo, F., Zhang, Y., 2015. Validation of the mobile emotiv device using a neuroscan event-related potential system. *J. Med. Imaging Heal. Informatics* 5, 1553–1557. https://doi.org/10.1166/jmihi.2015.1563

Wolbers, T., Hegarty, M., Büchel, C., Loomis, J.M., 2008. Spatial updating: How the brain keeps track of changing object locations during observer motion. *Nat. Neurosci.* 11, 1223–1230. https://doi.org/10.1038/nn.2189

Yadava, M., Kumar, P., Saini, R., Roy, P.P., Prosad Dogra, D., 2017. Analysis of EEG signals and its application to neuromarketing. *Multimed. Tools Appl.* 76, 19087–19111. https://doi.org/10.1007/s11042-017-4580-6

Zamani, H., Abas, A., M.Amin, M.K., 2016. Eye Tracking Application on Emotion Analysis for Marketing Strategy. *J. Telecommun. Electron. Comput. Eng.* 8, 87–91. https://doi.org/10.1016/j.joen.2010.11.016