Biometric Responses to Green and Complete Street Elements in Devens, Massachusetts

A Report from The Department of Urban and Environmental Policy and Planning at Tufts University

By Justin B. Hollander, Maria Christofi, Ann Sussman, Lisa Carlson-Hill, and Lydia Eldridge

For Devens Enterprise Commission

January 28, 2024

Overview

Today's biometric tools can help us understand the human experience of place by revealing the hidden, unconscious mechanisms that direct our behavior in the built environment. This study delved into the influence of Green and Complete Streets, which are strategies for promoting more sustainable, human-centric developments, on users' unconscious reactions and subjective emotions. Focusing on the redevelopment of a former army base in Devens, MA, the work studied streets with varying levels of green and complete street design elements (GCS). It captured the walking and visual experience on these streets with pictures and videos and then, using biometric software (iMotions-online), explored how these designs impact us unconsciously. Through understanding these hidden reactions, we aspire to design streets that are not only functional but foster positive emotional experiences, promoting individual and community wellbeing.

Streets Redefined: Green and Complete Design

The way our streets are designed greatly impacts how we live our lives, an observation amplified during the COVID-19 lockdown. This unprecedented period, confining many indoors, dramatically impacted our activity and use of space. In this manner, the pandemic's impact underscored the need for pedestrian and cycling-friendly environments and led to renewed interest and attention to GCS (Bristowe et al. 2023; Jevtic 2022; Levinger et al. 2022, Paydar et al. 2021, Wang, Y. et al. 2021).

Rather than the more traditional auto-centric approach to street design, which has dominated development for decades, complete streets aim to make roads safe for everyone. By promoting walking and cycling, these designs can lead to more physical activity. Moreover, increasing foot and bicycle travel can reduce congestion, fuel usage, and carbon emissions. Green streets also focus on incorporating environmentally responsible stormwater management, adding street trees, vegetation, and building with more sustainable materials.

Together, these factors help reduce the urban heat island effect, stormwater run-off, vehicle speeds, and urban noise, improving mental and physical health and reducing stress.

By combining two previously separate concepts – “green” and “complete”, the “green and complete streets” paradigm aims to accomplish the goals of both to create road networks that are safe and accessible for all users and environmentally responsible. Moreover, biometric tools can help us better understand how people interact with their environment: eye tracking reveals where and how long people focus on different aspects of their environment both unconsciously and consciously, while facial analysis follows our emotional responses in multiple spatial stimuli. Put simply, these tools show us what catches our eye, at first glance, and how we react emotionally to our surroundings.

Research Insights and Methodology:

We evaluated design proposals with varying GCS for a portion of the Goddard Street in Devens, MA. We asked: does a relationship exist between design proposals with low and high green and complete street design elements (GCS) and how people respond unconsciously? Using eye-tracking and facial-expression analysis software, we recorded unconscious biometric responses while surveys asked people where they were from (urban vs. rural) and gauged subjective reactions, enabling us to compare responses across design conditions (i.e. low vs high GCS).

Figure 1. Image examples. Top: original image showing no GCS. Bottom left: original image showing low GCE. Bottom right: altered duplicate of the previous image showing high GCS. High GCS images included adding grass, brick pavers and trees.

To understand how GCS affects perceptions, we copied images of streets with no and low GCS, altering them to create high GCS images[1] (Figure 1), and used videos simulating pedestrian viewpoints in each condition (no, low, and high GCS). These materials were analyzed in two levels through unconscious and subjective responses of the participants. The unconscious responses came through the analysis of eye tracking recording (gaze patterns, fixation points, etc.) while subjective responses were analyzed through a research survey where participants had to give an emoji value to their feelings about specific stimuli randomly (seven-point facial emoji scale survey) (Figure 2).

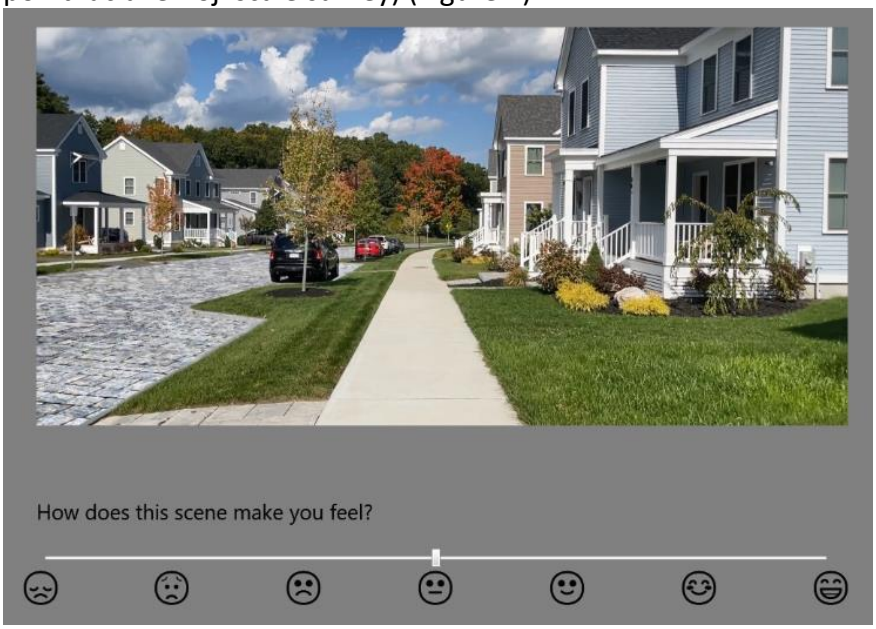

Figure 2. Example of Image with subjective survey question.

[1] Adding grass, pavers, trees, flowers, color editing, and road design elements.

Findings

In images with high GCS, substantial attention gravitated towards sidewalks and adjacent greenery, with trees, grass, and flowers garnering significant focus. Eye-tracking and heatmap analyses revealed heightened fixation on natural elements and less emphasis on streets in high GCS images (Figure 3). Notably, high GCS images elicited increased fixation counts (how much participants focused on elements), especially on sidewalks, while low GCS images primarily directed attention towards streets (where low GCS images included streets with traditional asphalt, high GCS images depicted streets with brick and stone textures). Moreover, prolonged observation of sidewalks in high GCS images correlated with more dispersed attention, signifying their important role in influencing gaze patterns and navigation in street scenes.

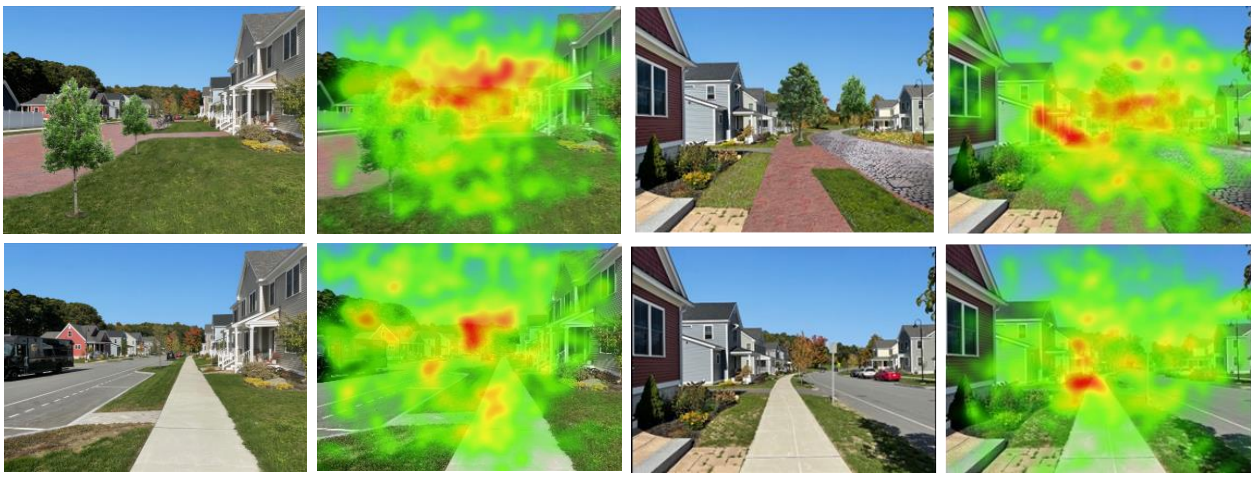

Figure 3. Original and heatmap images of high GCS (top row) and low GCS (bottom row) samples

Facial analysis unveiled nuanced emotional responses, showcasing elevated positive emotions like joy in high GCS images, albeit occasionally intermixed with negative feelings such as fear. Urban or rural backgrounds influenced emotional reactions, with urban dwellers expressing more positive sentiments across various image categories. Interestingly, participants reported predominantly positive sentiments using a subjective emoji-anchored scale, despite the unconscious reactions indicating nuanced emotional responses. Statistical analyses revealed higher emoji ratings for images with greater GCS elements, but no significant emotional differences emerged between high and low GCS images.

Conclusion

This research highlights intriguing patterns in how street design elements influence human unconscious reactions and emotions. Our findings underscore the need for further exploration into the discrepancies between unconscious reactions and conscious assessments, the role of materials, textures, and patterns in visual preferences, and the broader generalizability of our results to diverse urban settings. By elucidating the intricate relationship between nature, street design, and human reactions, our research contributes valuable insights to inform future

urban planning strategies and enhance the quality of urban spaces using green infrastructure and more natural elements. This study demonstrates that green infrastructure can have a direct and measurable psychological impact on those who see it: residents, visitors, workers. By offering empirical evidence of ways that green infrastructure supports our mental health and well-being, this research supports policies that encourage green infrastructure investments. Moreover, our study's implications extend beyond Devens, confirming broader literature on environmental planning and human behavior.

Understanding how street designs influence human behavior stands as a cornerstone for crafting urban spaces that consider feelings as well as functionality. Integrating these insights into urban planning strategies can pave the way for more inclusive and sustainable development that promote wellbeing worldwide.

Bibliography

Dolin, Marissa, Melody Cerraci, Jacque Henrikson, Lesile Phemister, Sirita Render, Heather Schady, and Amanda Woodall, eds. *Complete Streets Rural Contexts*. Active Transportation Policy: Active Transportation Alliance, CSCN Rural Companion, v3, 2014). http://atpolicy.org/resources/design-guides/complete-streets-rural-contexts/.

Alismail, Sarah, and Hengwei Zhang. "Exploring and understanding participants' perceptions of facial emoji Likert scales in online surveys: A qualitative study." *ACM Transactions on Social Computing*, Vol. 3, no. 2 (2020): 1-12.

Bristowe, Amanda, and Megan Heckert. "How the COVID-19 pandemic changed patterns of green infrastructure use: A scoping review." *Urban Forestry & Urban Greening*, Vol. 81, 127848 (2023). https://doi.org/10.1016/j.ufug.2023.127848.

"Devens Green and Complete Streets Policy." Tufts University, August 5, 2021. https://tufts.app.box.com/file/916789138558.

Vincent, Angela, Neil Angus, Malithi Fernando, Sang Cho, Halley Reeves, Noemie Sportiche, Kim Lundgren, Edward Sanderson, Jan Henderson, Peter Lowitt, Karla Chaffee, and Karen Kao, eds. *Green Streets Lawrence, Massachusetts: A Health Impact Assessment of the Lawrence Green Streets Program*. HIA Report, March 2017. https://apascd.files.wordpress.com/2017/08/gwl-green-streets-hia-report-final-with-appendices.pdf.

Dupont, Lien, Marc Antrop, and Veerle Van Eetvelde. "Eye-tracking analysis in landscape perception research: influence of photograph properties and landscape characteristics." *Landscape Research*, Vol. 39, no. 4 (2013):417– 432. https://doi.org/10.1080/01426397.2013.773966.

Glazener, Andrew, and Haneen Khreis. "Transforming Our Cities: Best Practices Towards Clean Air and Active Transportation." *Current Environmental Health Reports*, Vol. 6, no 1 (2019): 22–37. https://doi.org/10.1007/s40572-019-0228-1.

Gregg, Kelly, and Paul Hess. "Complete streets at the municipal level: A review of American municipal Complete Street Policy." *International Journal of Sustainable Transportation*, Vol. 13, no. 6 (2019): 407–418.

Hollander, Justin B., Ann Sussman, Peter Lowitt, Neil Angus, and Minyu Situ. "Analyzing Walkability Through Biometrics: Insights Into Sustainable Transportation Through the Use of Eye-Tracking Emulation Software." *Journal of Physical Activity and Health*, Vol. 17, no. 11 (2020): 1153– 1161. https://doi.org/10.1123/jpah.2020-0127.

Hollander, Justin B., Ann Sussman, Peter Lowitt, Neil Angus, and Minyu Situ. "Eye-tracking emulation software: a promising urban design tool. " *Architectural Science Review*, Vol. 64, no. 4, (2021): 383–393. https://doi.org/10.1080/00038628.2021.1929055.

Jevtic, Marija, Vlatka Matkovic, Milica Paut Kusturica, and Catherine Bouland. "Build Healthier: Post-COVID-19 Urban Requirements for Healthy and Sustainable Living." *Sustainability*, Special Issue: Sustainable Built Environment Management and Urban Public Health Outcomes 9274, Vol. 14, no. 15 (2022). https://doi.org/10.3390/su14159274

Kiefer, Peter, Ioannis Giannopoulos, Martin Raubal, and Andrew Duchowski. "Eye tracking for spatial research: Cognition, computation, challenges." *Spatial Cognition & Computation*, Vol. 17, nos. 1-2: Eye Tracking for Spatial Research (2017): 1–19. https://doi.org/10.1080/13875868.2016.1254634

Kuo, Frances E., and William C. Sullivan. "Aggression and Violence in the Inner City: Effects of Environment via Mental Fatigue." *Environment and Behavior*, Vol. 33, no. 4 (2001): 543– 571. https://doi.org/10.1177/00139160121973124.

De Lucio, José Vicente, M. Mohamadian, Juan Pedro Ruiz, J. Banayas, Fernando González Bernaldez. "Visual landscape exploration as revealed by eye movement tracking." *Landscape Urban Planning*, Vol. 34, no. 2 (1996):135– 142. https://doi.org/10.1016/0169-2046(95)00208-1.

Oeschger, Giulia, Páraic Carroll, and Brian Caulfield. "Micromobility and public transport integration: The current state of knowledge." *Transportation Research Part D: Transport and Environment*, Vol. 89, 102628 (2020).

Paydar, Mohammad, and Asal Kamani Fard. "The Hierarchy of Walking Needs and the COVID-19 Pandemic." *International Journal of Environmental Research and Public Health*, Vol. 18, no. 14, 7461 (2021). https://doi.org/10.3390/ijerph18147461

Phan, Wei Ming Jonathan, Rachel Amrhein, James Rounds, and Phil Lewis. "Contextualizing Interest Scales With Emojis: Implications for Measurement and Validity." *Journal of Career Assessment*, Vol. 27, no. 1 (2019): 114-133. https://doi.org/10.1177/1069072717748647

Tufts Devens Project team. "A road to a greener Devens: Implementing green and complete streets." Report to the Devens Enterprise Commission. May 2022. https://devensec.com/news/Devens_FinalReport_OnlineVersion.pdf

Simpson, James. "Street DNA: The who, where and what of visual engagement with the urban Street." *Journal of Landscape Architecture*, Vol. 13, no. 1 (2018): 50–57. https://doi.org/10.1080/18626033.2018.1476032

Simpson, James, Megan Freeth, Kimberley J. Simpson, and Kevin Thwaites. "Visual engagement with urban street edges: insights using mobile eye-tracking." *Journal of Urbanism*: *International Research on Placemaking and Urban Sustainability*, Vol. 12, no. 3 (2019): 259–278. https://doi.org/10.1080/17549175.2018.1552884.

Simpson, James, Kevin Thwaites, and Megan Freeth. "Understanding Visual Engagement with Urban Street Edges Along Non-Pedestrianised and Pedestrianised Streets Using Mobile Eye-Tracking." *Sustainability*, Vol. 11, no. 15, 4251 (2019). https://doi.org/10.3390/su11154251.

Rosas, Hernan J., Ann Sussman, Abigail C. Sekely, and Alexandros A. Lavdas. "Using Eye Tracking to Reveal Responses to the Built Environment and Its Constituents." *Applied Sciences*, Vol. 13, no. 21, 12071 (2023). https://www.mdpi.com/2076-3417/13/21/12071.

Sussman, Ann, and Justin B. Hollander. *Cognitive architecture: Designing for how we respond to the built environment*. 2nd edition, Routledge, 2021.

Van den Berg, Agnes E., Hartig Terry, and Staats Henk. "Preference for Nature in Urbanized Societies: Stress, Restoration, and the Pursuit of Sustainability." *Journal of Social Issues*, Vol. 63, no. 1 (2007): 79– 96. https://doi.org/10.1111/j.1540-4560.2007.00497.x.

Wang, Ding, Mohammad Tayarani, Brian Yueshuai He, Jingqin Gao, Joseph Y.J. Chow, H. Oliver Gao, and Kaan Ozbay. "Mobility in post-pandemic economic reopening under social distancing guidelines: Congestion, emissions, and contact exposure in public transit." *Transportation Research Part A: Policy and Practice*, Vol. 153, (2021): 151–70. https://doi.org/10.1016/j.tra.2021.09.005

Williams, Sarah C.P. "Humans may harbor more than 100 genes from other organisms." *Science*, last modified March 12, 2015, accessed January 1, 2024. https://www.science.org/content/article/humans-may-harbor-more-100-genes-other-organisms.

Y. Wang, Chi Kwan Chau, Waiyin Ng, and Tzeming M. Leung, "A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods." *Cities*, Vol. 50, 0264-2751 (2016): 1–15. https://doi.org/10.1016/j.cities.2015.08.004.

Zaccaro, Heather N., and Emiko Atherton. "Bright spots, physical activity investments that work—Complete Streets: redesigning the built environment to promote health." *British Journal*

of Sports Medicine, Vol. 52, no. 18 (2018): 1168– 1169. https://doi.org/10.1136/bjsports-2017-097717.

Notes on Methodology

The study aimed for diverse participation beyond lab settings using an online platform (iMotions Online) accessible to anyone with a laptop or desktop with a camera. While this method is cost-effective, it faces challenges such as attrition due to poor data quality influenced by various factors like visual impairment, lighting, and adherence to instructions. Specific guidelines were implemented to optimize participant performance, including calibration and debriefing processes. Ninety-three (n=93) participants responded to social media advertisements and completed the study through the iMotions platform. Biometric data from thirty-nine (39) participants met quality metrics and was processed using iMotions' algorithm on a secure university computer. In the end, study participants were mostly female (66%), young (between ages 18-34, 89%), and had at least a bachelor's degree (69%). Most also grew up in suburban (59%) or urban (28%) neighborhoods, though at the time of the study, most lived in urban neighborhoods (74%).

Acknowledgements

Support on this research was provided by the following Research Assistants: David Michel, Jo Riddle, Tony Duong, Abigail Lim, Colleen Greer, Diya Wheeler. Special thanks to Peter Lowitt, Neil Angus, and Beth Suedmeyer.