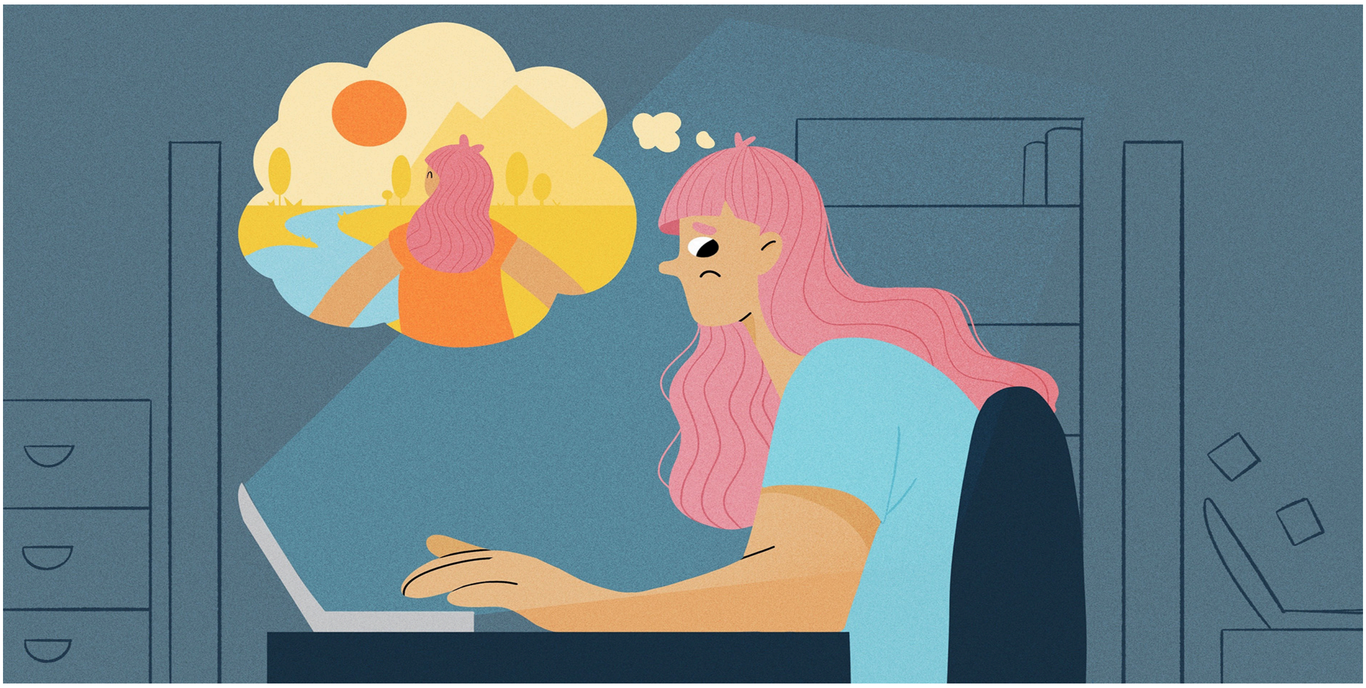
NEUROSCIENCE AND PSYCHOLOGY
Published: 20 November 2023
doi: 10.3389/frym.2023.1029373



DOES THE DESIGN OF BUILDINGS AFFECT OUR MINDS?

***Isabella S. Bower*[1,2,3*], *Aron T. Hill*[2,4], *Richard Tucker*[3] and *Peter G. Enticott*[2,4]**

[1] *Cognitive Ageing and Impairment Neurosciences Laboratory, Behaviour, Brain, and Body Research Centre, UniSA Justice and Society, University of South Australia, Adelaide, SA, Australia*

[2] *Cognitive Neuroscience Unit, School of Psychology, Faculty of Health, Deakin University, Geelong, VIC, Australia*

[3] *Faculty of Science, School of Architecture and Built Environment, Engineering and Built Environment, Deakin University, Geelong, VIC, Australia*

[4] *Department of Psychiatry, Faculty of Medicine, Nursing & Health Sciences, Central Clinical School, Monash University, Melbourne, VIC, Australia*

YOUNG REVIEWERS:

MAYUKHA
AGE: 14

MRITTIKA
AGE: 15

TARANG
AGE: 12

Do buildings affect how we feel and, if so, how can we tell? Currently, we can only ask people, which relies on them being able to accurately identify their emotions. As our emotions influence how we think, behave, and work, it is important to understand whether the places we spend time in, like our homes, offices, schools, and hospitals, affect us. We ran an experiment with more than 60 healthy adults. Participants sat in a virtual reality room, which we made larger or smaller, or we colored the walls. To understand if the size or color of the room affected their brains and bodies, we used sensors on the skin and asked participants to tell us about their emotions. We found that room size and color affected brain activity associated with concentration and emotion. This suggests that the buildings we spend time in impacts the ways we interact with the world.

Have you ever been in a certain room and felt uncomfortable or unable to concentrate? You might have needed to stand on the stage at a school assembly or sit for an exam in the gym. Sometimes, this can make us feel uncomfortable, but is that only because of the situation (being in front of a crowd or taking a test), or could the design of the building where the activity is happening also be affecting our emotions and ability to perform tasks? As we spend up to 90% of our lives inside buildings, it is important to understand if buildings affect our minds. If the design of buildings can change our emotions or our performance, maybe building designers could build spaces that help us perform at our highest level and feel our best!

BUILDINGS ARE COMPLEX ENVIRONMENTS

Buildings might seem like easy-to-understand human-made structures, but they are actually quite complex because they involve a lot more than just the building itself. For example, things that happen in buildings often influence our minds and emotions—think of how you feel when you imagine your home vs. a hospital or a classroom, for instance. Additionally, buildings have contents like furniture and other objects, and the conditions within a building, like temperature, lighting, and sound, can also influence us. There could also be people or animals inside, like your family or your pets!

Further, the memories that we have of buildings can also affect our minds and bodies. Our memories of a room or building can help us know how to interact and behave within that environment. Finally, buildings also have a complex mix of design characteristics, including color (painted walls), texture (wood floors or carpet), geometry (curved walls or straight ones) and scale (height and width of a room). All these complex factors make it hard for scientists to understand if a person's emotions or body reactions are due to the *design* of the building or if they are due to one of these other factors. So, it is tricky to design good scientific experiments to test how buildings themselves affect our brain and body functioning.

What if we removed as many of these complex factors as possible, and focused only on design characteristics? The aim of our study was to understand if scale and colour of a room impacts us.

THE DESIGN OF THE EXPERIMENT

During the experiment, we asked 60 healthy adult participants to sit in the middle of a **virtual reality** (VR) room for 20 min, while we measured how their brain and body responded to changes in the room's scale or color (Figure 1). As some people enjoy playing VR games and this might make them more comfortable, we asked how much VR experience people had beforehand. We did not see any difference between the

VIRTUAL REALITY (VR)

An artificial environment generated by a computer, with which users can interact. VR "tricks" the brain, giving the illusion of a three-dimensional space.

people who used VR a lot, compared to those that did not. Before we showed them the VR rooms the participants rested for 2 min, which gave us a baseline to compare to their brain and body responses to the rooms. The rooms were identical, other than their size and the color of the walls. Each VR room had only a door and a chair, with no other objects, people, or furnishings that could trigger memories. During the experiment, participants wore VR glasses with headtracking ability, which allowed the virtual room to move as the participants moved their heads. This made the experience feel realistic [1].

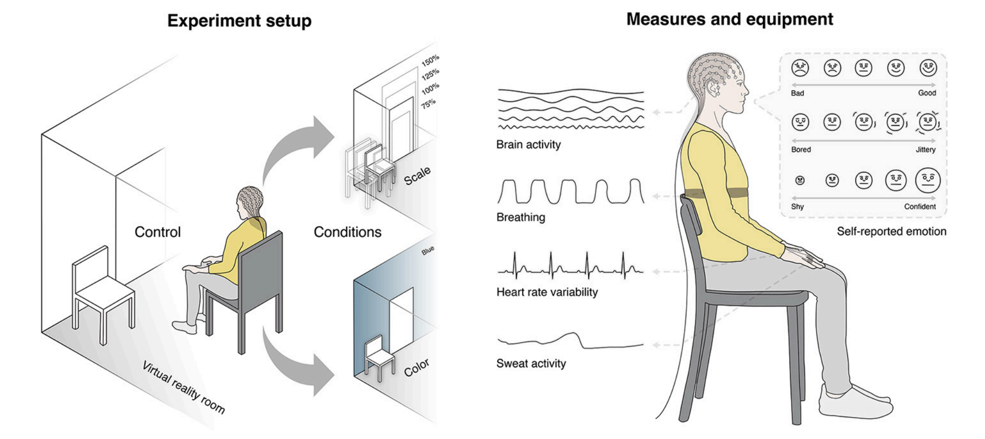


Figure 1

Figure 1

Participants sat in the middle of a virtual reality room. The space consisted of a floor and three wall surfaces on which the experimental scene was displayed. The control condition was a normal-sized room with white walls, a door and chair. The room was then made smaller or larger, to test the effect of scale on the emotional response. We also made the walls blue, to test the response to color. We used different measures and equipment to understand emotional response. This included brain activity, breathing, heart rate variability, sweat activity, and self-reported emotion using picture scales.

For color, we selected blue to compare to white. We chose blue because it is not often associated with behaviors or actions. For example, when people see a traffic light, they generally know red means “stop”. Blue is not often used for any sort of sign or signal, which makes it easier for us to understand if the color, rather than a a learnt behaviour to the color, causes a change in people’s emotions.

We had five rooms in total, which included a **control** (100% scale/normal size, white color), small condition (75% scale, white color), large condition (125% scale, white color), extra-large condition (150% scale, white color) and a color condition (100% scale, blue color). The control is a normal room with a door and chair that looks the same size as the doors in your own home, and we included this so we could compare whether the scale and color conditions made a difference. Each room was shown for 2 min, and the order in which the larger or smaller rooms were shown was different each time we ran the experiment. However, the blue condition was shown last as only some participants were shown it as a sample study. It was important that we changed the order the rooms were shown as over time participants can become bored or tired, which can influence the results. Between rooms, participants told us about their emotions using picture scales.

CONTROL

A condition used in scientific experiments to make sure that things other than those being studied do not affect the outcome. Controls help scientists to trust their results.

As participants’ emotions might also be influenced by how comfortable they feel, we also measured the room temperature, how quickly the air moved, how much humidity was in the air, the amount of carbon dioxide in the air (too much can make us feel sleepy), and the level of sound in the room. This helped us to make sure we were measuring the effects of scale and color, rather than accidently measuring the effect of something else that was affecting the participants. Surprisingly, no prior studies had accounted for all these factors [2].

HOW CAN WE MEASURE EMOTIONS?

Emotions are important as they influence how our body functions. They can also guide our behavior and thinking. For example, when we experience a negative emotion, signals from the brain can result in our body pumping blood around the body faster so that we can move quickly if we are in danger. In our study, we measured people's emotions in several ways (Figure 1). Most simply, we asked participants to report their emotions themselves. Participants used picture scales to rate what is called the "dimensions" in emotion. These were pleasure (rated bad to good), arousal (from bored to jittery) and dominance (from shy to confident) [3].

We also monitored changes in participants' bodies, specifically heart rate, the number of breaths they took, and the level of sweat on the skin of their fingers. Our heartbeat, breathing, and sweating are all **autonomic functions**, meaning we do not actively control them and are generally not aware they are happening. Finally, we looked at brain activity using a technique called **electroencephalography (EEG)**. In EEG, electrodes are placed on the scalp to measure the electrical messages the brain cells use to communicate (Figure 2). All these measures are quantitative, which means the data have numerical values, so we could determine whether any of these measures increased, decreased, or stayed the same during the experiment.

AUTONOMIC FUNCTIONS

Body functions that help to keep us alive, but that we do not have to think about. These include heartbeat, breathing, and control of body temperature.

ELECTROENCEPHALOGRAPHY (EEG)

A technique used to measure electrical activity within the brain. Electrodes placed on the scalp detect the electrical messages brain cells use to communicate with each other.

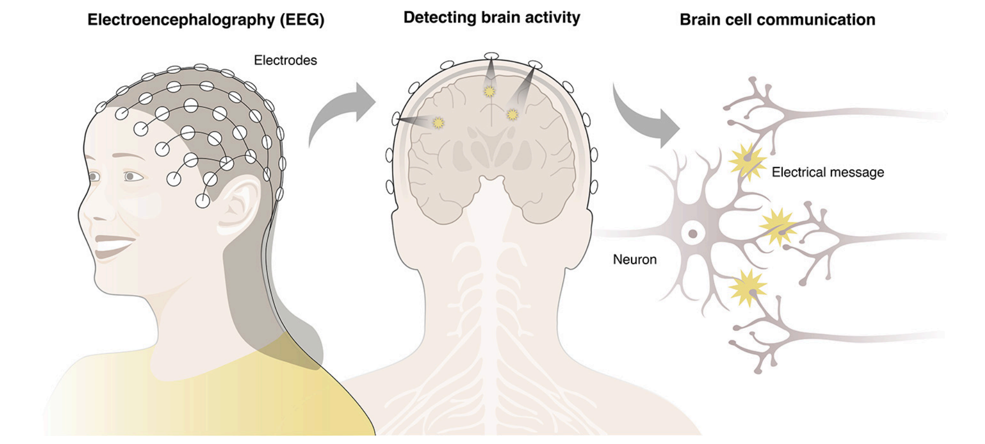


Figure 2

Figure 2

We can measure emotions through a variety of methods. Participants wore a cap on their head covered in electrodes. This is called electroencephalography (EEG for short). Electroencephalography detects electrical activity that occurs as brain cells (neurons) send messages to each other. These tiny electrical signals are recorded by the electrodes so that we can investigate which parts of the brain are communicating.

WHAT DID WE FIND?

Our results (Figure 3) showed that making the room bigger resulted in a type of brain activity which is usually found when we are concentrating [4]. We also found that the blue room resulted in brain activity that has been associated with positive emotion [5]. The rooms also changed the participants' autonomic functions (their patterns of breathing and sweating). Despite these observations, we found no change in what participants *told us* about their emotions. This suggests it's important to use other methods of measuring emotions, in addition to self-reporting.

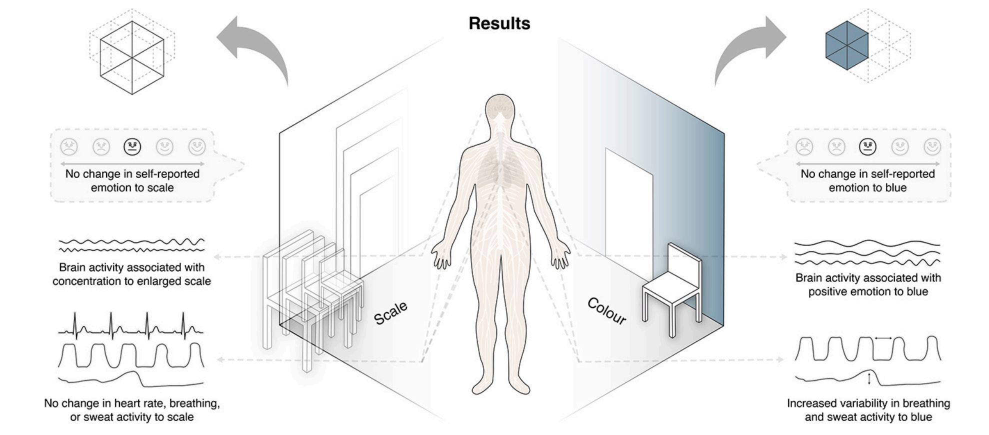


Figure 3

Figure 3

Our experiment showed that the larger room scale increased brain activity associated with concentration, while the blue room increased brain activity associated with positive emotion. We also found that participants showed more variability in both sweating and breathing when experiencing the blue-colored room, but we did not find any differences to these measures when making the room bigger or smaller. However, changing the scale or color of the room did not change what participants told us about their emotions. Overall, this tells us that enlarged room scale and changing the room color to blue affects the brain and body.

Overall, these results show our mind and body are affected by how we design buildings. However, we still need to understand if our ability to perform a task (like remembering information or understanding if other people around you are happy or sad) is affected by the scale and color of the room. We also know that other factors, such as how stressed we feel, can influence our response. This can lower a person's capacity to adjust to changes in their environments. For example, think of a classroom—might a cold-colored wall paint, like blue, make you feel different on an exam day (when you feel more stress) compared to a regular day?

Future experiments must be done to test if design impacts on our ability to do tasks and the role that additional factors like stress might play in the effect a building has on people's emotions. This research is exciting because hopefully, the results of our experiments will help designers to create buildings that help us to feel and perform at their best!

ACKNOWLEDGMENTS

The content of this manuscript has been informed by three publications from the thesis (Doctor of Philosophy, Psychology) of ISB.

All three source articles have been listed below. We would also like to thank Liam Enticott who reviewed the original draft of this article. ISB is currently supported by a postdoctoral research fellowship from the University of South Australia. During her PhD, she was supported by a postgraduate research scholarship from Deakin University, a fellowship from the Academy of Neuroscience for Architecture, and a Creativity and Innovation grant from Creative Futures Pty Ltd.

REFERENCES

1. Bohil, C. J., Alicea, B., and Biocca, F. A. 2011. Virtual reality in neuroscience research and therapy. *Nat. Revi. Neurosci*. 12:752–62. doi: 10.1038/nrn3122
2. Bower, I., Tucker, R., and Enticott, P. G. 2019. Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: a systematic review. *J. Environm. Psychol*. 66:101344. doi: 10.1016/j.jenvp.2019.101344
3. Bradley, M.M., and Lang, P. J. 1994. Measuring emotion: the self-assessment manikin and the semantic differential. *J. Behav. Therapy Exp. Psychiat.* 25:49–59. doi: 10.1016/0005-7916(94)90063-9
4. Bower, I. S., Clark, G. M., Tucker, R., Hill, A. T., Lum, J. A. G., Mortimer, M. A., et al. 2022. Enlarged interior built environment scale modulates high frequency EEG oscillations. *eNeuro*. 9:ENEURO.0104-22.2022. doi: 10.31234/osf.io/uzync
5. Bower, I. S., Clark, G. M., Tucker, R., Hill, A. T, Lum, J., Mortimer, M., et al. 2022. Built environment colour modulates autonomic and EEG indices of emotional response. *Psychophysiology*. 59:e14121. doi: 10.1111/psyp.14121

SUBMITTED: 27 August 2022; **ACCEPTED:** 30 October 2023;
PUBLISHED ONLINE: 20 November 2023.

EDITOR: Elizabeth Johnson, Northwestern University, United States

SCIENCE MENTORS: Deepa Cherukunnath and Mukul Mukherjee

CITATION: Bower IS, Hill AT, Tucker R and Enticott PG (2023) Does the Design of Buildings Affect Our Minds? Front. Young Minds 11:1029373. doi: 10.3389/frym.2023.1029373

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

MAYUKHA, AGE: 14

Hello! I am Mayukha, I enjoy dancing, singing, and playing lawn tennis. My interests include learning biomechanics of the human body and evolutionary history. I enjoy experiencing different cultures and traditions.

MRITTIKA, AGE: 15

Mrittika loves hanging out with friends and family. Her interests include: playing the viola, dancing, singing, reading, and calligraphy. Math, Social Studies, and Music are her favorite subjects and she enjoys volleyball, karate, and running. Mrittika's favorite accomplishment is becoming a part of her school's journalism team. She received an award for being the best foreign language student of the year in middle school and was a finalist in a nationwide computer science competition. Recently her high school team was semi-finalists in the Nebraska Writers Collective slam poetry contest. Mrittika aspires to be a more open-minded and knowledgeable person.

TARANG, AGE: 12

Hello I am Tarang. I do not like cake (except cheesecake, I like cheesecake). I like to read books that are not above 100 years old, cycle, wavebord, and play videogames but I do not play in 8 bit. I like astronomy and big fat atom bombs (not nuclear physics just atom and hydrogen bombs). I usually live a normal life and I play guitar. You can connect with me at... REDACTED.

AUTHORS

ISABELLA S. BOWER

Isabella is a researcher who studies neuroscience and architecture. She is interested in understanding whether we can design buildings to improve brain functioning and mental health, so we can perform our best and be happier and healthier.
*isabella.bower@unisa.edu.au

ARON T. HILL

Aron is a neuroscientist who studies the link between brain activity and thinking ability. To do this, he uses various techniques to get "pictures" of what is happening within the brain. He is particularly interested in understanding how brain activity is altered in psychiatric disorders, with the aim of developing better treatments for people with mental illnesses.

RICHARD TUCKER

Richard used to be an architect and is now a professor. He researches how buildings can be used to the greatest extent possible by all people, regardless of their age, size, ability, or disability. He leads a group of researchers from diverse backgrounds, who try to find solutions to make housing more affordable and allow for social inclusion.

PETER G. ENTICOTT
Peter is a psychologist and professor who is fascinated by the way the brain allows us to think, feel, and behave. He leads a research team that is particularly interested in emotion, social interactions, and young people with brain disorders such as autism.