

CRTKL

MICROGRANTS

RESEARCH JOURNAL VOLUME II



ORIGINAL RESEARCH • APPLIED RESEARCH • DESIGN RESEARCH
MAY 2022

CRTKL's vision, *People, Planet, Positive Design*, is a response to the rapid pace of change in our world – fundamental research fuels data-rich solutions, offering informed insights that will empower our teams to deliver bold and innovative solutions. The success of the MicroGrant program has and continues to provide research-based solutions creating positive outcomes for our communities and people.

Kim Heartwell
President & CEO



INTRODUCTION

This study was produced as part of the CRTKL Research MicroGrant Program, which fosters knowledge generation across the firm by supporting small, focused research ideas and projects. The program is also intended to identify new ideas, insights or pivot points that enable us to inform how we think and approach our work. The format is intended to be a safe space for evolving thought leaders to ideate, test out research approaches, and investigate emerging topics for our projects, business or culture. The grants represent one of several firmwide research programs that promote, support, and inspire research-related endeavors.

The 2021 cohort represents a diverse set of grantees, which were selected from a pool of 35 total applicants by an esteemed jury of design, innovation, and architectural thought leaders. These individuals and teams investigated a wide range of topics with support from internal mentors firm-wide, CRTKL Research Fellows, and the program jurors.

The Microgrant program was made possible by the Microgrant Committee, comprised of Sarah Wicker, James Poppell, and Camila Simas.

Editing of the journal was provided by Tarek Rakha, an Associate Professor at Georgia Tech.

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POST-COVID HOUSING DEMANDS

Investigating how the pandemic has changed how people use domestic spaces

ABSTRACT

Our team conducted research during 2021 to investigate the ways in which the COVID-19 pandemic influenced how people used their homes and the activities that took place there. The research included an informal survey, a literature review and a formal survey undertaken during November 2021. The survey focused on whether people were working from home, involved in home schooling, how much they were using outdoor space, how they were exercising and whether they were getting more deliveries to the home. The work also examined people who had moved home during this period to establish whether any lifestyle changes caused by the pandemic had informed their decisions when choosing their new home.

This project has found that there have been noticeable changes in people's habits. In general, more activities are taking place in the home, while replacing activities which formerly took place outside the home. At a stage when the country is opening up and 'normal life' is resuming, these changes still remain. It is possible that there will be a permanent shift to enable people to maintain this more home-centred lifestyle, at least for a proportion of the population, and understanding this will help to inform future home designs.

CONTEXT

As architects on the UK Residential team, our design work is centred on creating homes, and we wanted to understand how the pandemic might change what people want from the design of their housing. We undertook this research in 2021, with the main survey data coming from responses during November. At this stage, although the pandemic was still ongoing, restrictions in the UK had mainly been lifted and people had the opportunity to go out, go to work and socialise.

During the pandemic, there have been changes to our ways of living on an unprecedented scale -- with people spending much more time at home during lockdown, many people suddenly working from home, children attending school from home and many of our usual activities outside the house curtailed or stopped altogether.

This research investigates how these lifestyle changes would be reflected in different requirements for future housing design. Although, to some extent, we may revert to previous behaviours once the pandemic is over, there is research to suggest that there will be significant permanent changes to cities at an urban scale following the pandemic (Salama, 2020). Changes following previous pandemics included the introduction of modern sanitation systems after a 19th

century cholera pandemic in London (van den Berg, 2020). The 1918 Spanish flu pandemic in New York was followed by 'The Sunshine movement' which had a strong influence on modernist design (Frost, 2020).

Although it is difficult for us to predict changes in the longer term, changes in people's behaviour and attitudes now, as restrictions are being lifted in the UK, can give us indicators towards more permanent changes.

APPROACH

Step 1 - Informal survey data

The research team had access to data from a survey undertaken in 2018 which investigated living preferences among colleagues and friends with 113 respondents. As a first step in our research, we recirculated this survey to see if there had been any changes due to the pandemic, with the recirculated survey reaching 52 respondents. Although this informal survey had a small sample size, and there were no controls on the participants, this directed ideas for areas which would be worth further investigation.

The team analysed outputs that would indicate significant changes between the surveys conducted in 2018 and 2021. Examples of critical shifts we found are identified below:

Access to Outdoor Space

- More respondents wanted to live close to a park - 23% up from 11%
- More respondents said a garden was an important space - 71% up from 61%
- More respondents did not want to share a garden - 61% up from 21%

Homeworking

- More respondents are working from home for 3-5 days per week - 84% up from 10%
- More respondents had a workspace at home - 61% up from 50%
- Fewer respondents would not share a workspace - 21% down from 28%

Step 2 - Literature review

Next, the team conducted a literature review to identify where previous research had already been undertaken in this area. This showcased where we thought changes in behaviour might benefit from design changes to housing, which identified additional areas for further study.

Workspaces

Working from home has become much more common during the pandemic, with social isolation forming a "push" to encourage people to develop new digital skills (Nguyen, et al., 2020), it is now being suggested (Klaus, 2020) that digital infrastructure will become one of the main changes following the current

pandemic, as it has become essential to keep people connected and businesses able to function throughout lockdowns. Separating activities within the home has also been difficult. For example, home working and home schooling happening at the same time has led to acoustical issues (Bettaieb & Alsabban, 2021).

Activity and Outdoor Access

In many cases during the pandemic, people have reduced the frequency with which they leave the house, and many of these activities have been changed to virtual activities (Bin, Andruetto, Susilo, & Pernestal, 2021). Physical activity has been found to decrease during populations' self-isolating (Reshetnikov, et al., 2021) with a consequent increase in weight gain (Ekpanyaskul & Padungtod, 2021). Another study found families increased acquisition of electronic devices as a means of compensation for not practicing external activities (Bettaieb & Alsabban, 2021) which led to changing and adapting space requirements in the home to accommodate new activities. There is evidence to suggest that, if encouraged, people could adapt to exercising at home to replace lost outdoor activities (Iannaccone, et al., 2020).

Online Shopping

There has been a significant increase in online shopping. For example, total online sales in the United States reached \$73.2 billion in June 2021, up from

\$41.5 billion the year before (Srinivas & Marathe, 2021). Food has been more frequently purchased online during the pandemic, and there is evidence to support the idea that this may continue after the pandemic (Alaimo, Fiore, & Galati, 2020). To facilitate deliveries, a "reception box" or similar facility is now more common to allow for ease of deliveries, long after the initial proposal that this is what would be required to enable the e-grocery business. (Kämäräinen, Saranen, & Holmström, 2001).

Step 3 – Larger Scale Survey

To take the themes established from the informal survey and the literature review and develop them further, we commissioned an online survey through Qualtrics to ask respondents in more detail about their living arrangements during the pandemic. The survey was conducted during November 2021, and 920 responses were received.

FINDINGS

We chose to investigate the two cities where we are based -- London and Manchester -- and we limited our respondents to those living in apartments and flats, so they would more closely reflect the type of people who live in the buildings we design. Of our participants, approximately 50% lived in London and 50% lived in Manchester (Figure 1).

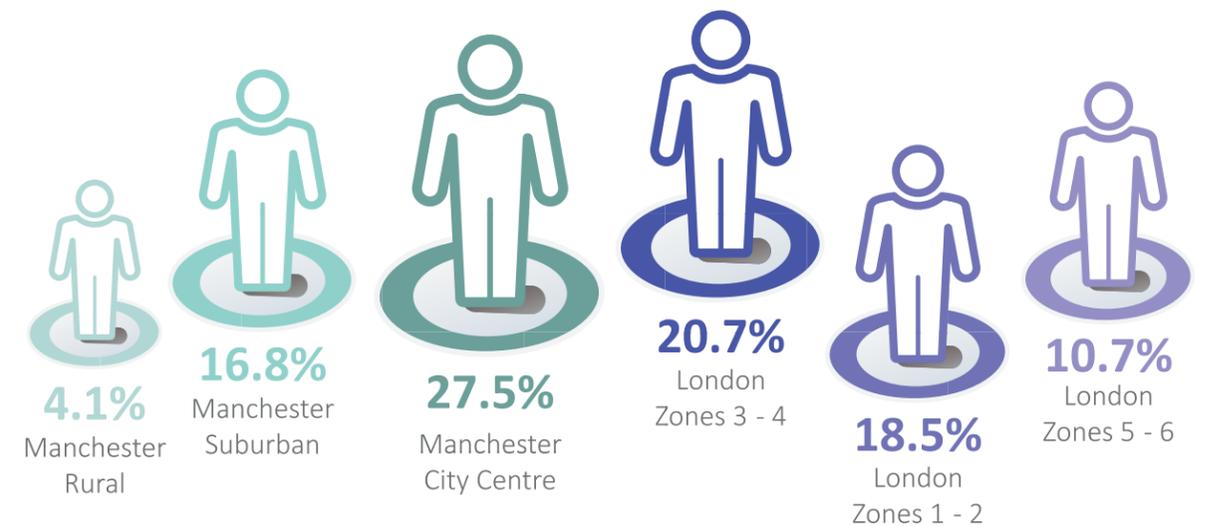


Figure 1: Survey respondent locations.

We also asked participants some general questions about the size of their household and who they lived with (Figure 2).

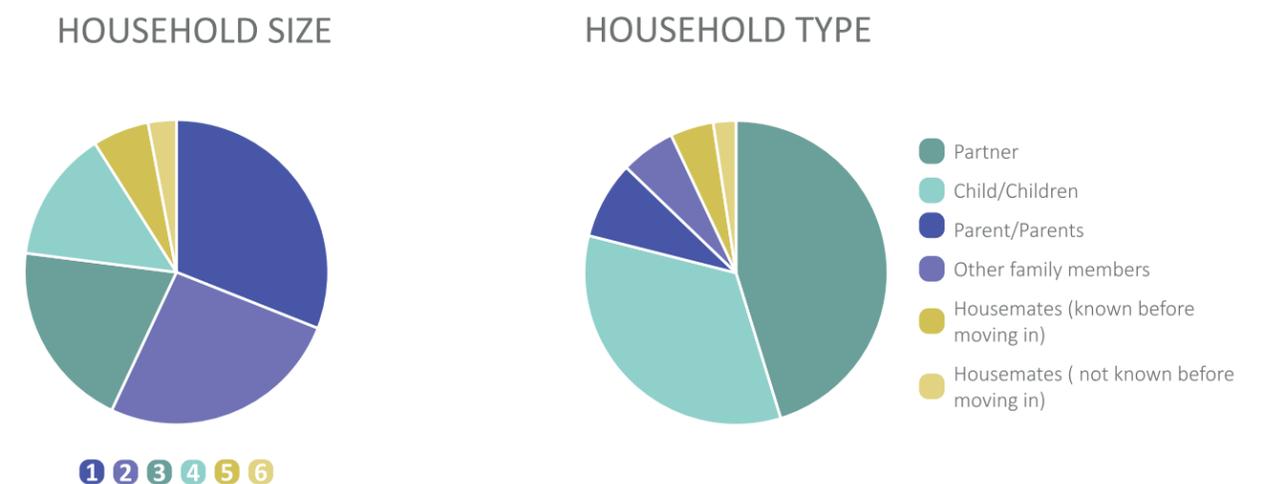


Figure 2: Survey respondent household setup.

Regionally, we found that more respondents in Manchester lived with a partner and a child/children than London (45% rather than 28%), more people live with just their partner in London (29% vs 25%) (Figure 3).



Figure 3: Survey respondent living arrangement.

We learned that around 50% of respondents had moved in the last 24 months or were in the process of moving homes at the time of the survey (Figure 4). This represents a large proportion of people who had decided to move during a period when they have been influenced by changes in lifestyle brought about by the pandemic.



Figure 4: Survey respondent relocation data.

We asked those who had moved home for their motivation to move. Space was a big driver, as well as changing activities in the home (home schooling, home working etc.). We were not sure whether the changes associated with the pandemic would result in people making changes to their home, but the large volume of people who moved and their reasons for doing so indicate that people have responded to pandemic conditions with longer term lifestyle changes (Figure 5 and 6).

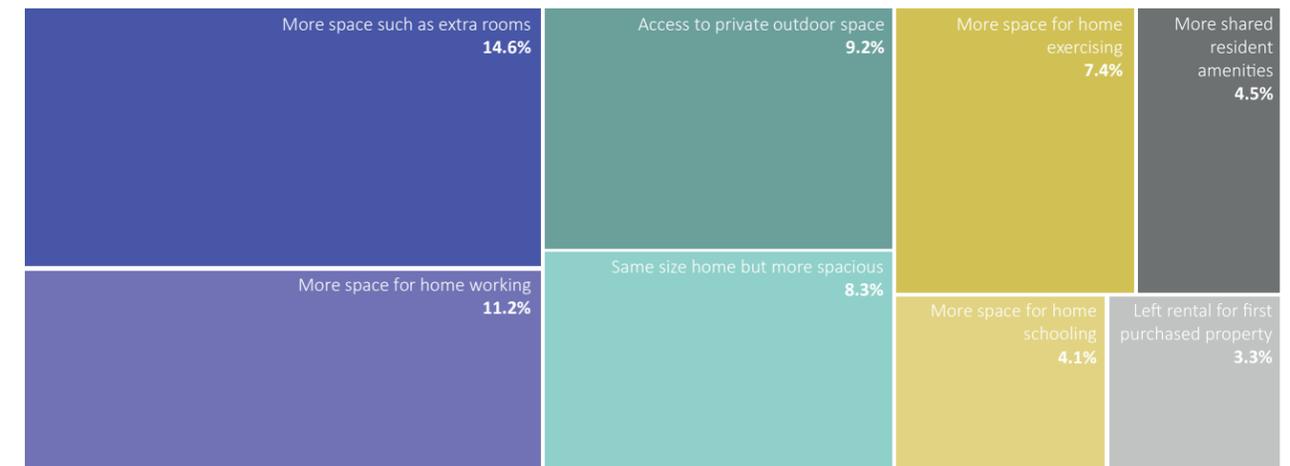


Figure 5: Understanding survey respondent relocation reasons.

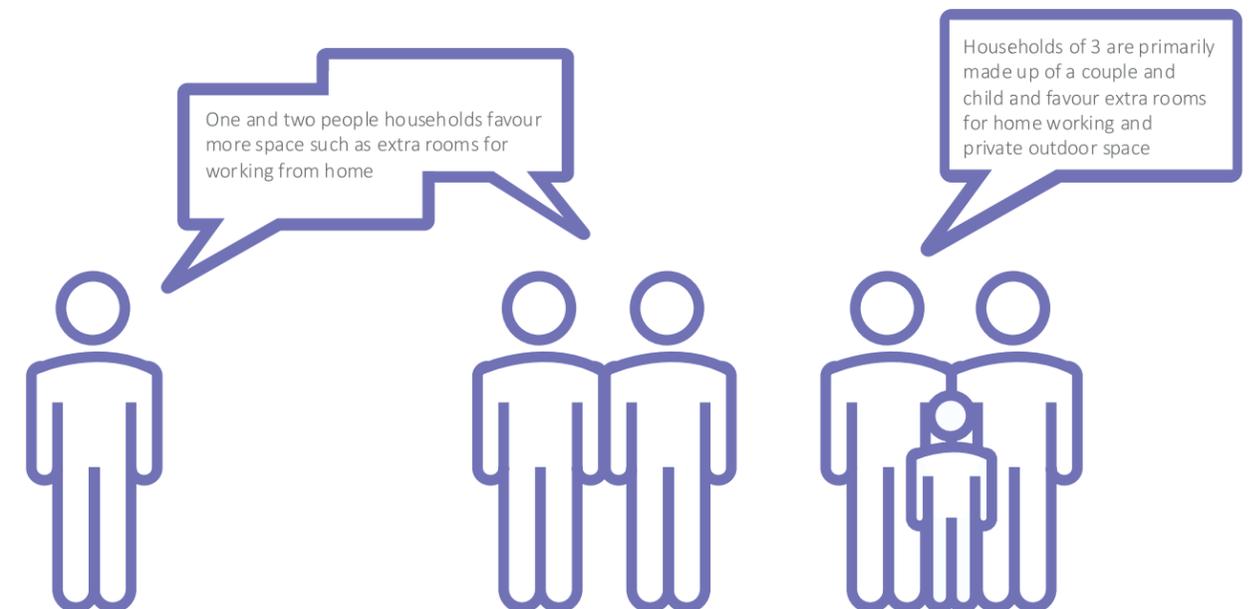


Figure 6: Understanding respondent persona profiles and reasons for moving.

When asking about pets, 61% of people said they were allowed to keep a pet in their building, and 55% said they owned a pet. (Figure 7)

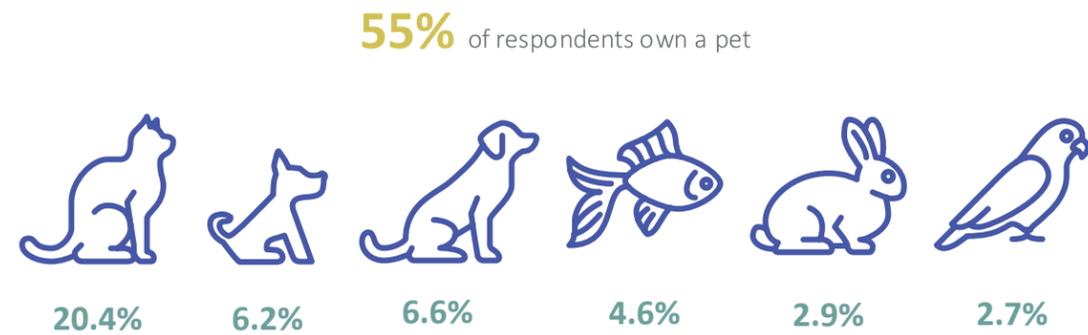


Figure 7: Pet ownership distribution.

Space for Home Working

We noticed a rise in the number of people who say they are currently working from home regularly (a few days a week to full time). We also asked people where in their home they worked, most people worked in their living room, with smaller proportions using other rooms, as shown in Figure 8 and 9.

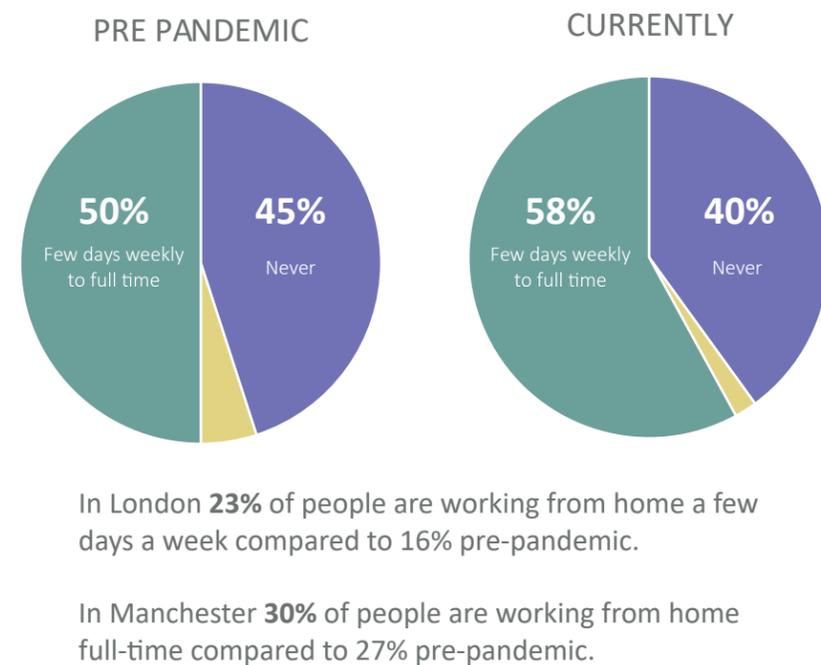


Figure 8: Frequency working from home pre and post pandemic.

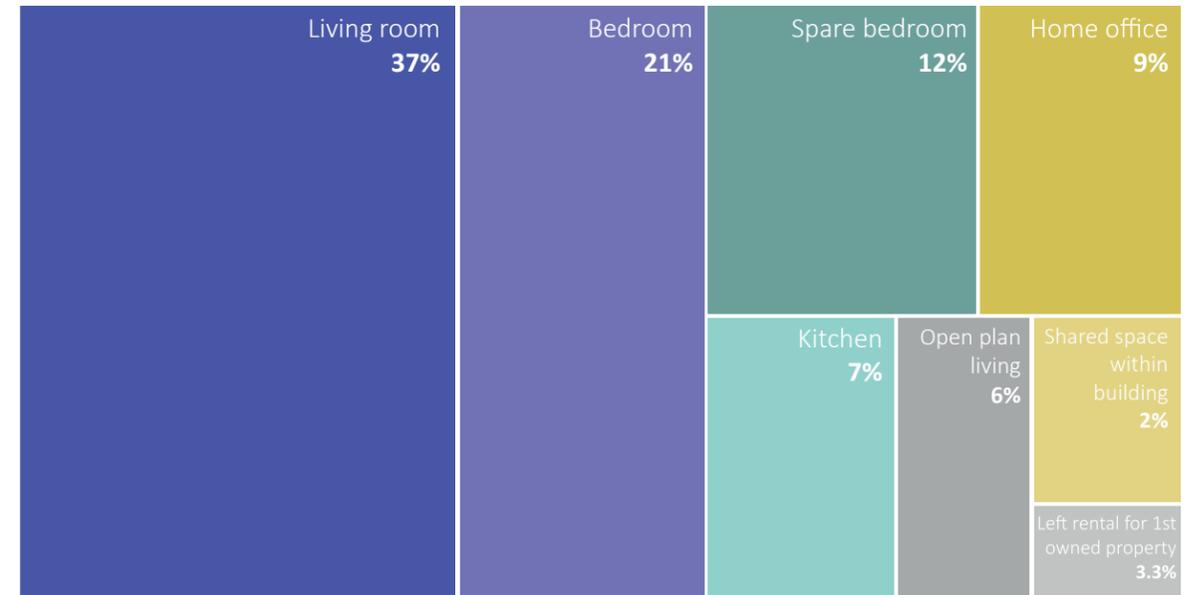


Figure 9: Where people work from within their home.

We went on to ask those who worked at home whether they thought home, or the office were preferable for a range of reasons. We found that in most cases, the home environment was preferred, with the only option where respondents were close to evenly split being their workstation or furniture (Figure 10).

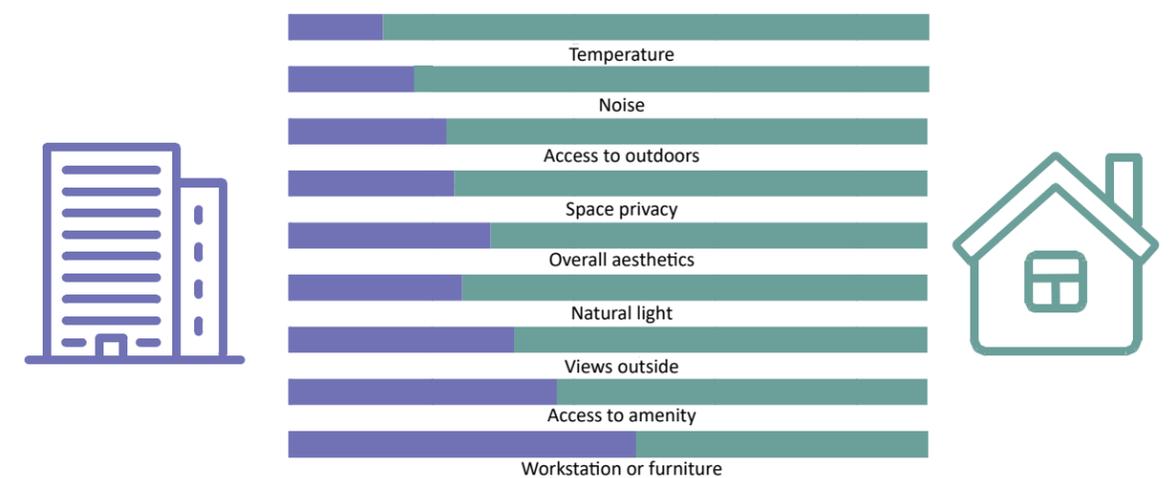


Figure 10: Workspace satisfaction comparison between respondents' office and home work setup.

Space for Home Schooling

We found that 37% of respondents had been home schooling during the past year (Figure 11). For those who were home schooling, the most popular locations for home schooling were living rooms and bedrooms (Figure 12). Most people who were home schooling had someone working from home in the house at the same time (Figure 13). Having work and schooling taking place at the same time caused a few issues. Visual disturbance and acoustical disturbance on both video calls and phone calls were identified as issues (Figure 14).



Figure 12: Home schooling preferred rooms.

HOMESCHOOLING

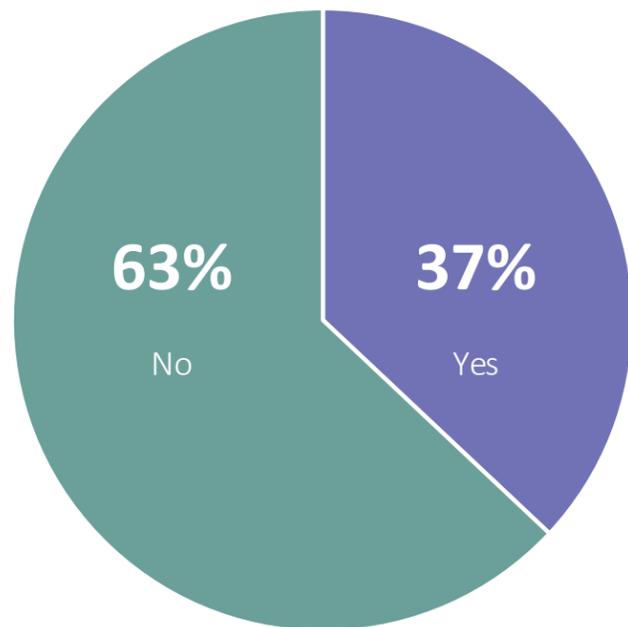


Figure 11: Respondents that home schooled.

Home schooling & WFH

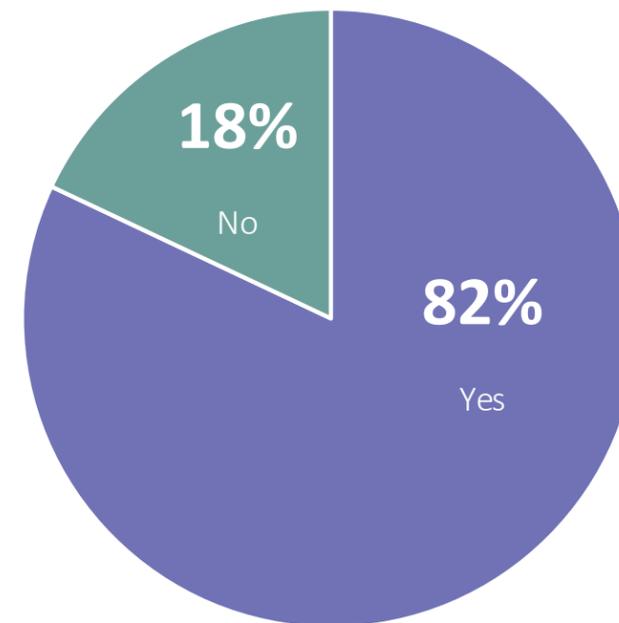


Figure 13: Respondents that simultaneously worked from home while home schooling.

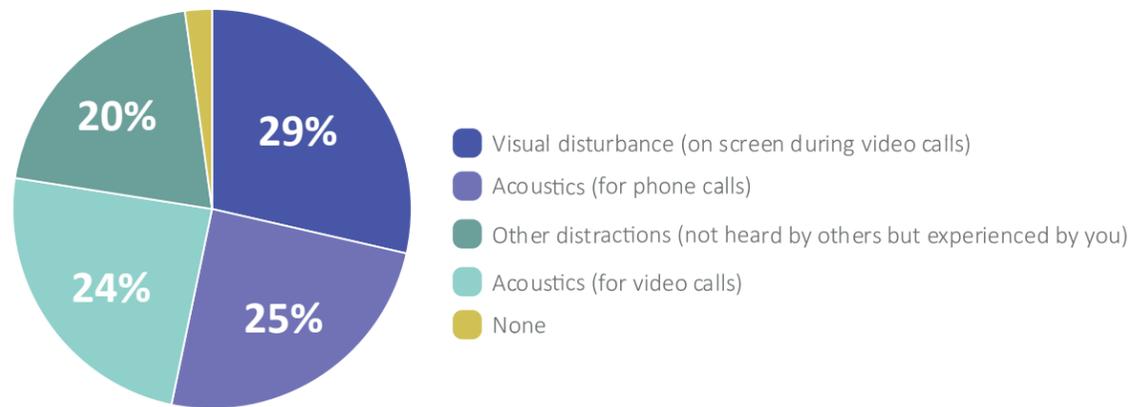


Figure 14: Issues felt while simultaneously working from home and home schooling.

Online Shopping/Deliveries

Increase in home deliveries during the pandemic is anecdotally well known, and we found that in our data there had been an increase in the number of parcels which households were getting delivered each week (Figure 15).



Figure 15: Home delivery key findings.

With this increase in the number of parcels received, we wanted to understand how easy it was for people to receive these parcels -- particularly if they were not in their residence at the time. Mostly, respondents were notified that a parcel had arrived through an intercom, then met the delivery staff either at their front door or the main door to their building. Just under a third of respondents had delivery via a concierge (Figure 16). When people are out, 44% of respondents are left a message to arrange redelivery of a parcel while 43% can have the parcel left for them (Figure 17). As a subset of deliveries to the home, fresh food deliveries are becoming more common, we found that 59% of people currently receive this type of delivery (Figure 18).

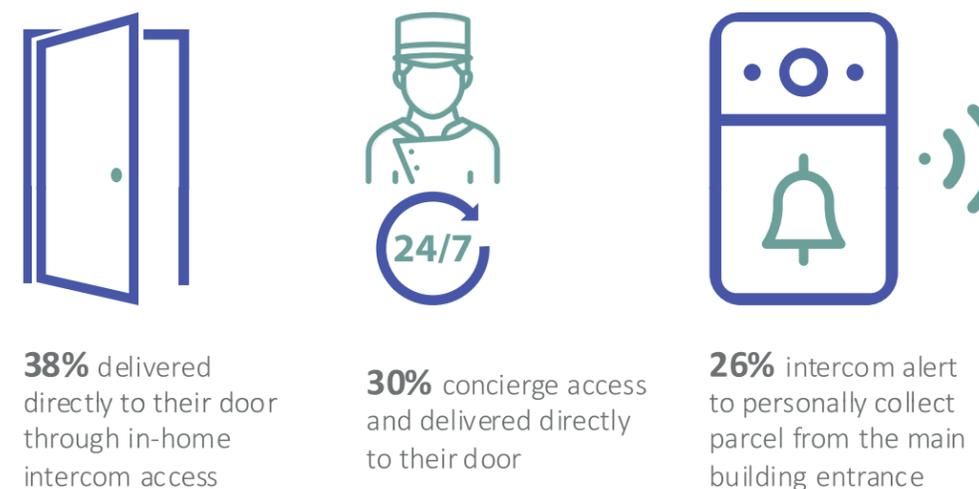


Figure 16: Receiving home deliveries.

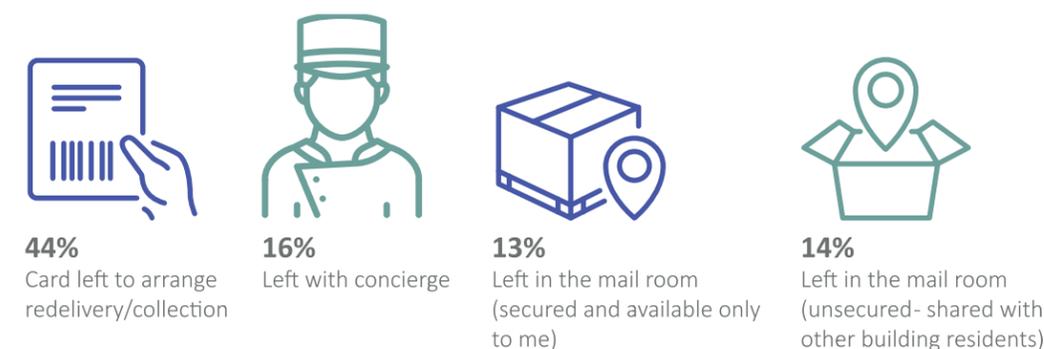


Figure 17: Receiving home deliveries when not home.



59% of people receive regular fresh produce and home cooking meal box deliveries

Figure 18: Receiving fresh produce and home cooking boxes.

This type of delivery is slightly different, in that they are normally arranged for a specific time. When we further investigated these deliveries, we found that 36% of people said they are always in to receive these, but other respondents were able to have them delivered and left for them while they were out (Figure 19).

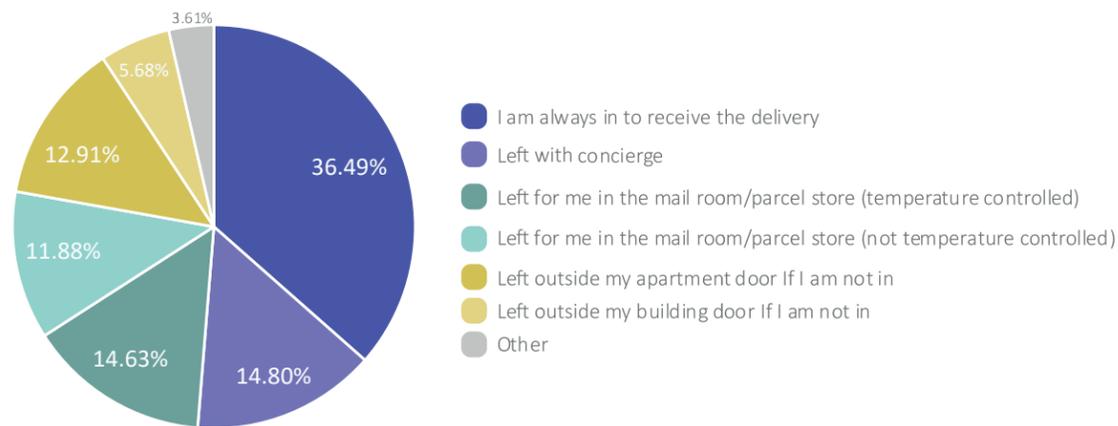


Figure 19: Receiving fresh produce home deliveries.

Space for Exercise within the Home

The proportion of respondents who exercised at home once a week or more increased by 4% during the pandemic, with those exercising outdoors increasing by 3%. The number of people exercising at a gym during the same period decreased by 7% (Figure 20).

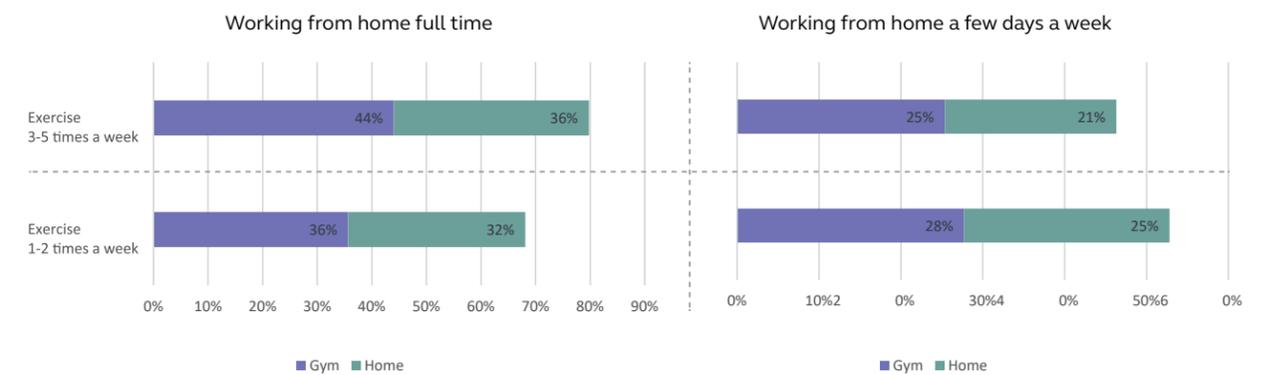


Figure 20: Understanding the relationship between work location and exercise habits.



People exercise more often when working from home full time :
3 - 5 times a week

People exercise less with hybrid home/office working routines :
1 - 2 times a week

Figure 21: Understanding exercising habits when working from home full time and when working in hybrid home/office setting.

The most common exercise equipment owned by respondents are weights, yoga mats and an exercise bike. In each case, around a third of these were purchased in the last 12 months (Figure 22).

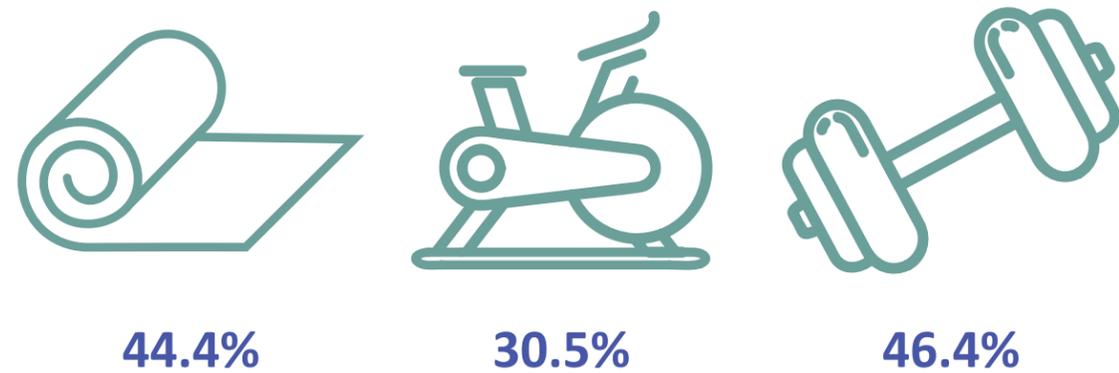


Figure 22: Common exercise equipment in the home, procured during the pandemic.

There has been an increase in cycling activities during the pandemic, as detailed in Figure 23.

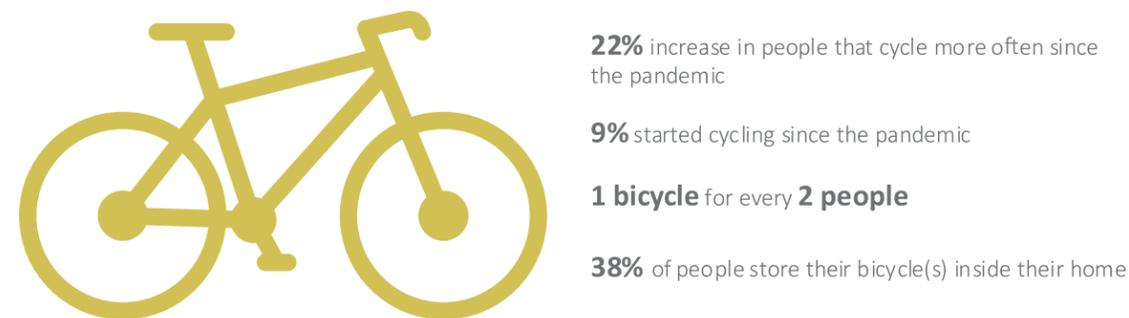


Figure 23: Understanding cycling activities due to pandemic settings.

Access to Outdoor Space

From the initial informal conducted survey, we expected outdoor space to become more important. Where we did find that people valued private external space, we found that people were less likely to use any form of shared outdoor space (Figure 24 and 25).

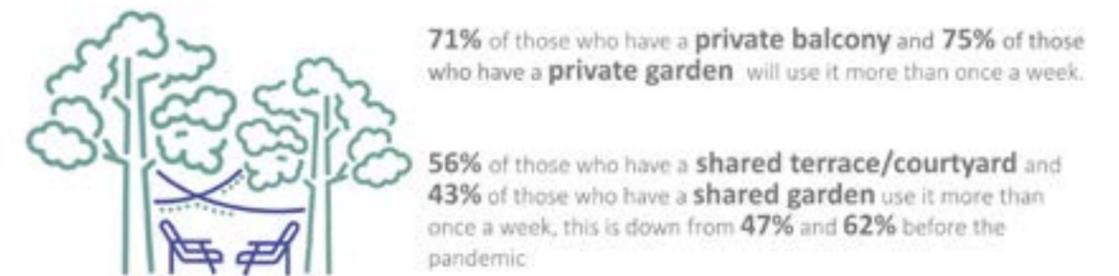


Figure 24: Key findings on outdoor space usage.

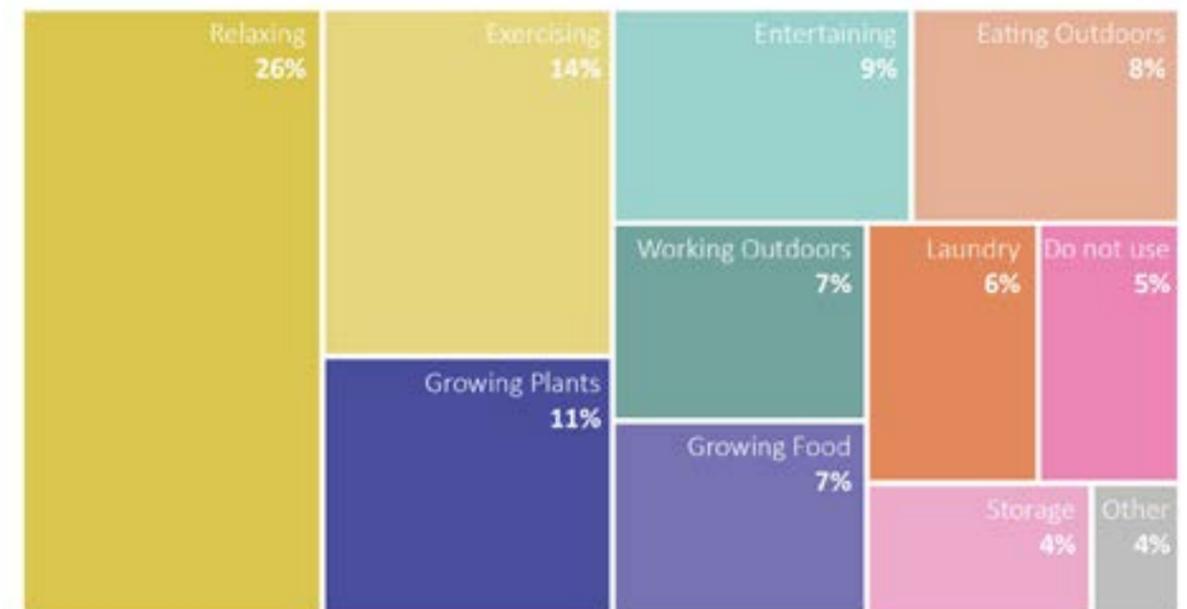


Figure 25: Main current uses for respondents' outdoor space.

CONCLUSIONS, IMPLICATIONS FOR PRACTICE, & NEXT STEPS

From the collected data, we gained a greater understanding of the changes in people's lifestyles brought about by the pandemic. It is still not clear what will be the more permanent changes in the longer term, but we know that at this stage there have certainly been some changes we can incorporate when thinking about apartment design.

From the data, we have seen that people are spending more time in their residences and are undertaking a wider range of activities in their own homes. This is reflected in the fact that those who have chosen to move during this period are generally looking for more rooms or more space in their home to facilitate this. We were also able to demonstrate the types of activities which may need to be accommodated more in the future: such as working from home, home schooling and exercising at home. If these continue to be more permanent changes, it will be important that potential residents can find homes where they can easily undertake these activities. We also observed that people have become more interested in having private outdoor space and less interested in sharing outdoor space with others. Although the shifts in what people want from their space seem relatively small, it may be that

enabling these changes will become more common in the future design of housing.

Future work can now employ these data and findings to inform future designs. This would ensure our ability to accommodate residents' needs and allow them appropriate space to carry out activities within the home. Such changes may increase the appeal of a home to prospective homeowners/tenants. As this research has been undertaken at an intermediate stage in the pandemic, future investigations can repeat this research in a year or two years' time, to understand if any of these changes are reversing, or if they have become more permanent changes in the way people live. It will also be interesting to keep reviewing any other research in this area and see what else we can learn about how people are responding to changes brought about by the COVID-19 pandemic.

In summary,

- Design functional spaces for residents that include homeworking, exercise, and managing deliveries.
- Consider replicating the study to measure trends over a longer duration.

Acknowledgments

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REFERENCES

- Alaimo, L. S., Fiore, M., & Galati, A. (2020). How the Covid-19 pandemic is changing online food shopping human behaviour in Italy. *Sustainability*, 12(22):9594 <https://doi.org/10.3390/su12229594>.
- Bettaieb, D. M., & Alsabban, R. (2021). Emerging living styles post-COVID-19: housing flexibility as a fundamental requirement for apartments in Jeddah. *Archnet-IJAR*, Vol. 15 No. 1, pp. 28-50. <https://doi.org/10.1108/ARCH-07-2020-0144>.
- Bin, E., Andruetto, C., Susilo, Y., & Pernestel, A. (2021). The trade-off behaviours between virtual and physical activities during the first wave of the COVID-19 pandemic period. *European Transport Research Review* 13, Article number 14.
- Ekpanyaskul, C., & Padungtod, C. (2021). Occupational Health Problems and Lifestyle Changes Among Novice Working-From-Home Workers Amid the COVID-19 Pandemic. *Safety and Health at Work*, <https://doi.org/10.1016/j.shaw.2021.01.010>.
- Frost, P. (2020). An accelerant of Social Change? The Spanish flu of 1918-19. *International Political Anthropology journal*, Vol. (13) 2, 123-133 <http://doi.org/10.5281/zenodo.4295574>.
- Iannaccone, A., Fusco, A., Jaime, S. J., Baldassano, S., Cooper, J., Proia, P., & Cortis, C. (2020). Stay Home, Stay Active with SuperJump®: A Home-Based Activity to Prevent Sedentary Lifestyle during COVID-19 Outbreak. *Sustainability*, 12(23), 10135; <https://doi.org/10.3390/su122310135>.
- Kämäräinen, V., Saranen, J., & Holmström, J. (2001). The reception box impact on home delivery efficiency in the e-grocery business. *International Journal of Physical Distribution & Logistics Management*, Vol. 31 No. 6, pp. 414-426. <https://doi.org/10.1108/09600030110399414>.
- Klaus, I. (2020, March 6). *Pandemics are also an urban planning problem*. Retrieved from Bloomberg CityLab: [bloomberg.com/news/articles/2020-03/how-the-coronavirus-could-change-city-planning](https://www.bloomberg.com/news/articles/2020-03/how-the-coronavirus-could-change-city-planning)
- Nguyen, M. H., Gruber, J., Fuchs, J., Marler, W., Hunsaker, A., & Hargittai, E. (2020). Changes in digital communication during the COVID-19 global pandemic: Implications for digital inequality and future research. *Social Media + Society*, doi:10.1177/2056305120948255.
- Reshetnikov, V., Mitrokhin, O., Mikhailovsky, V., Mikerova, M., Alsaegh, A., Yakushina, I., & Royuk, V. (2021). Indoor Environmental Quality in Dwellings and Lifestyle Behaviors during the COVID-19 Pandemic: Russian Perspective. *International Journal of Environmental Research and Public Health*, 18(11):5975. <https://doi.org/10.3390/ijerph18115975>.
- Salama, A. M. (2020). Coronavirus questions that will not go away: interrogating urban and socio-spatial implications of COVID-19 measures [version 1; peer review: 3 approved]. *Emerald Open Res*, 2:14 (<https://doi.org/10.35241/emeraldopenres.13561.1>).
- Srinivas, S. S., & Marathe, R. R. (2021). Moving towards "mobile warehouse": Last-mile logistics during COVID-19 and beyond. *Transportation Research Interdisciplinary Perspectives volume 10*, 100339 <https://www.sciencedirect.com/science/article/pii/S2590198221000464>.
- van den Berg, R. (2020). How will COVID-19 affect urban planning. *The city fix*, <https://thecityfix.com/blog/will-covid-19-affect-urban-planning-rogier-van-den-berg/>.



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UNPACKING FUTURE WORKPLACE TRENDS

How does working outdoors contribute to employee wellbeing and productivity?

ABSTRACT

COVID-19 was declared as a pandemic and a continuous issue by the World Health Organization (WHO) in March and May 2020, respectively. The pandemic forced businesses to shift their work environment to become primarily remote and increased the concern and awareness among employees about their health and wellbeing in workplace. As vaccination rates increased in the United States, companies began to implement the hybrid and in-person work strategies with having health and wellbeing of the employees in mind. As a result, there has been an ever-increasing trend for companies enhance flexibility and reassess the workplace conditions to improve employees' productivity and workflow. The possibilities of the physical working space have extended into the public domain; people can work anywhere, but how effectively can they work outside?

This paper is a case study, which aims to understand the possibilities of working in an outdoor setting by analyzing the outdoor-office trends that are currently taking place. This study also attains results from a global survey to understand how people used outdoor spaces before returning to the office, how having outdoor office facility relates to employees' productivity and satisfaction and how this feature might increase talent attraction in the companies. The

result of this study shows that an outdoor component to the design of commercial buildings positively impacts employees' health and wellbeing and enriches the design deliverables at CRTKL. The study also discusses that capitalizing the duality of indoor and outdoor work environments establishes an increasingly valuable leasable spaces for the clients.

CONTEXT

COVID-19 has led us to differentiate the events related to our workplace as "pre" and "post" pandemic periods. As countries are opening to global travel, reaching their vaccination targets and people are becoming more comfortable interacting within public spaces, companies are showing an increased concern with workplace flexibility and autonomy, provision of clean air and surfaces and employee mental health and wellbeing. These new perspectives towards workplaces show great promise for the buildings to be responsive to the needs of a post-pandemic workforce.

Wellbeing in Workplace

Research shows that office environment has an impact on employees' health, wellbeing and productivity (Veitch, 2011; Al-Shammari, 2015; Atmaja and Puspitawati, 2018). Traditionally, the lighting, spatial quality, overall design, air quality, temperature and workstations were of primary focus to architects and designers. These metrics for design are

expanding -- incorporating different kinds of wellness spaces to reduce employee stress and increase mental wellbeing and productivity. Research conducted by WeWork (Zhai, 2021) shows that outdoor work areas reduce the chance of disease transmission and have positive impact on employees' cognitive function and wellbeing by having access to the fresh air. These spaces also improve employees' exposure to the sun, which lowers their heart rate and blood pressure while stimulating neurons in the brain to improve productivity and creativity. The COVID-19 pandemic also helps employees realize the importance of outdoor breaks and flexibility in their work schedule (Anderer, 2020). A study "Recommended Daily Nature Allowance" (RDNA) conducted by Lancaster-James who was commissioned by Lenovo shows that spending 20 active minutes in the nature, 40 mindful minutes spent outside, or an hour spend working under the sun has positive impact on employees' wellbeing (Anderer, 2020). This study also shows that 40% of employees surveyed in this research feel much more productive at work if they spend time outside to work out or jog before standing their workday, and 56% of the surveyed employees have prioritized spending time outdoors daily to improve their health and wellbeing.

Office Design Evolution as a Response to Wellbeing in Workplace

Office design has evolved over the past 200 years to incorporate different strategies from assembly lines sweeping across large factory floor to the cubicle office to the activity-based open-office plan pre-pandemic. One of the main goals of these evolutions was to provide a cost-effective solution to improve employees' productivity and companies' growth (Morgan Lovell, NA). As the COVID-19 pandemic shifted office design approaches to focus more on workplace wellbeing, companies realized that the productivity begins with their employees. Thus, employees have become the center for the office design and the businesses paying more attention to their employees' wellbeing and skill development to encourage them to retain at the company. Office trends suggest that in future offices may include more biophilia, fresh air and access to outdoors.

Jodi Williams – Principal and DC Office Lean at CallisonRTKL – mentioned that staff costs (salaries and benefits) typically account for 90% of a business operation cost (Williams, NA). She states that, as a result, companies are seeking ways to make their real estate performance better rather than cost less, especially considering the pandemic. An article published in CoStar (Luck, 2021) mentioned that incorporating outdoor

spaces into design of existing and new commercial office projects and provide full access to Wi-Fi, food, electricity and other activities are becoming a standard practice and a trend in office building design. Thus, developers committing more dollars to outdoor spaces and focus more on health and wellbeing to attract larger companies.

Outdoor Facilities and Premium Rents

According to a study conducted by the Massachusetts Institute of Technology (MIT) - which includes office buildings in 10 major cities - states that buildings with Fitwell and WELL buildings certification have 4.4% - 7.7% higher rents than office buildings without them (Luck, 2021). "In some places, we're seeing an added emphasis on outdoor space, and developers are willing to spend that money if they believe that is something that will bring value to it so they can increase rents", said Ian Zapata, design director and global practice area leader at Gensler. "Whereas before, you could find a tenant that would take the outdoor space but didn't want to pay for it, I think that you're seeing a lot of these West Coast companies or West Coast-influenced companies understand the value to their employees and are willing to pay for outdoor space," said Zapata. She also mentioned that these spaces

can be used as social space to foster connection and drive innovation in the company (Luck, 2021).

APPROACH

This study investigates how office workspace will change and adapt to the employees' wellbeing needs. It conducted in three phases: (1) secondary data, (2) survey, and (3) data analysis.

The secondary data in this research includes relevant articles and studies conducted by other consultant firms on wellbeing and outdoor workspaces, and precedent design studies exploring outdoor office trends. We formulate the hypothesis of this study based on the secondary data to understand the contribution of outdoor workspaces to employees' wellbeing. Then, to test the hypothesis of this study, we developed an online survey which recruited approximately 700 respondents from developed countries in each continent. These countries include United Arab Emirates (UAE), United State (US), Australia, United Kingdom, South Korea, and South Africa (Figure 1). The respondents are between 18-65 years old and have varied amount of professional work experience within the office setting in different industries (Figure 2 and 3).

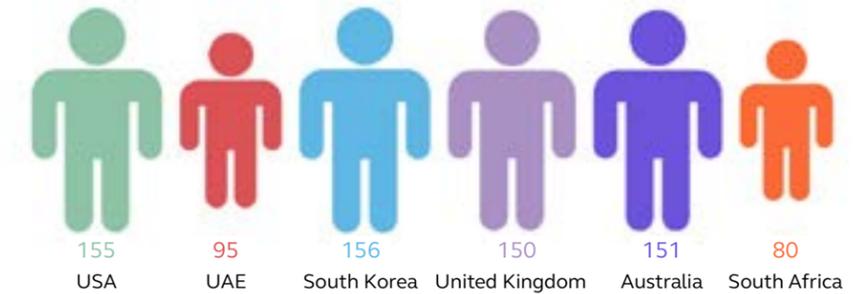


Figure 1: Countries and number of participants in this study

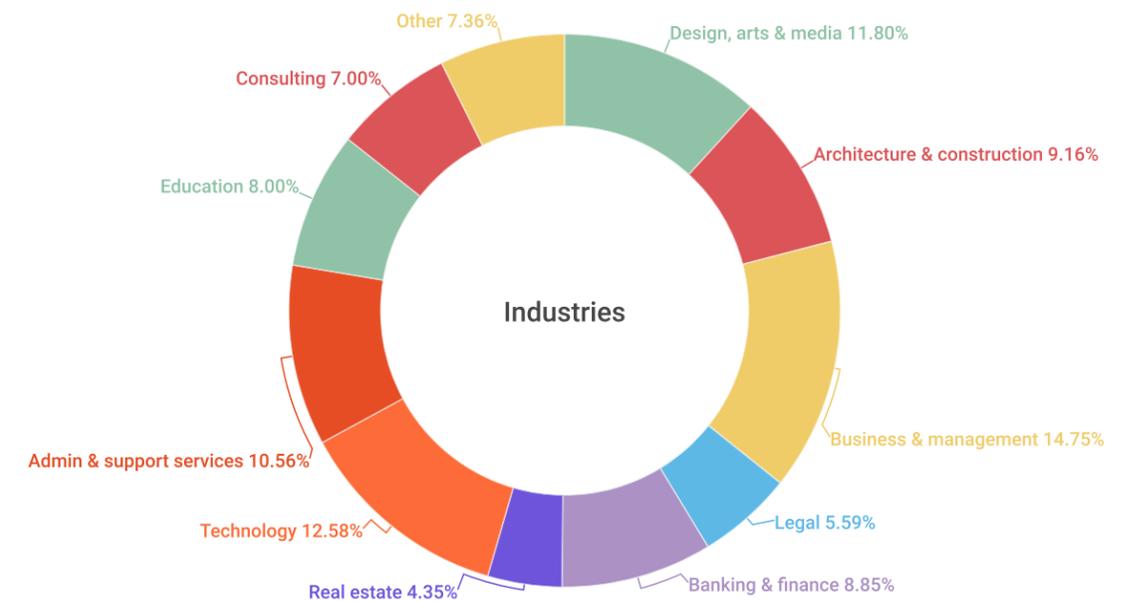


Figure 2: Industries included in this study

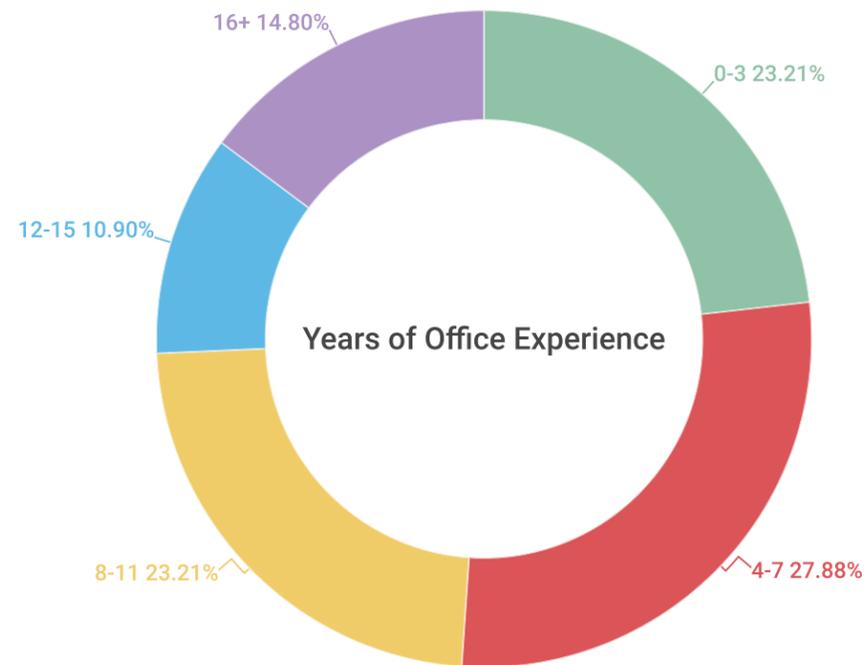


Figure 3: Years of professional experience in office setting

FINDINGS

In this section, we discuss the secondary and survey data which helps the reader have a better understanding of current trends in the office spaces and how employees perceive the impact of outdoor workspace on their wellbeing.

Secondary Data

Secondary data includes research conducted by consultant firms on workspace and wellbeing, and case studies of best practices of utilizing outdoor workspace.

Gensler (2021) suggested to utilize “mid-door spaces” in workspaces as an indoor-outdoor collaboration and social space which can be a space for team meetings,

coffee breaks with colleagues and for quiet moments to check the messages. Brian Stromquist – Technology Practice Area Leader at Gensler – states that “the formalize nature of the space provides a structured environment for these things to happen organically”. Figure 4 shows the functional workplace – indoor and outdoor – which is a less dense smaller floor plate providing space for external entries and outdoor terraces. It is important to provide multiple entry points to this space to give employees choose the level of their interaction with others based on their preference (Gensler, 2021).

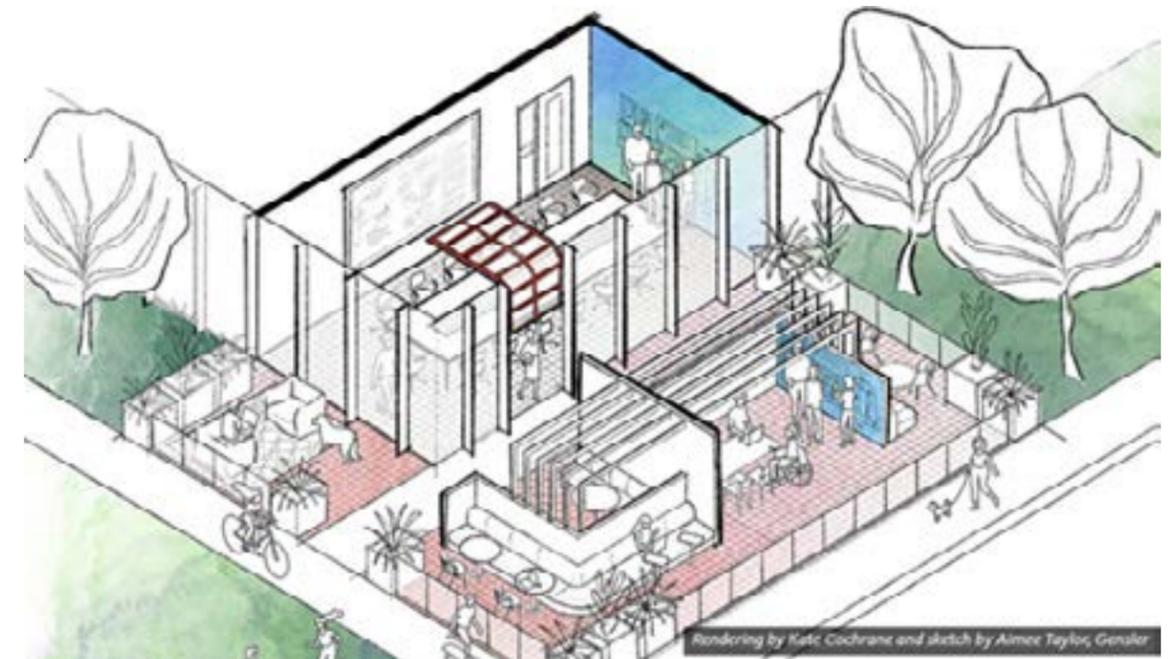


Figure 4: A stretch of mid-door spaces for collaboration and socialization (Source: Gensler, 2021)

Another study conducted by Hassel Studio (Davis, 2021) surveyed 2300 employees in Australia, United States and Singapore to understand what employees want from their workplace when they get back to “normal.” The results show three main parameters drives employees’ preferences and choices (Figure 5):

1) 63% of the respondents want to have a better workplace which include more space to focus (37% of surveyed participants), more space to collaborate (24% of surveyed participants), more sustainable workspace (21% of surveyed respondents), and better meeting facilities (20% of surveyed respondents).

2) 58% of respondents want to have better building amenities including

gardens and greenspace (28% of surveyed respondents), private gym (22% of surveyed respondents), a wellness space (14% of surveyed respondents), and showers and bike racks (11% of surveyed respondents)

3) 42% of respondents want to have better urban amenities including better coffee (24% of surveyed respondents), better retail nearby (18% of surveyed respondents) and a great bar and restaurant (11% of surveyed respondents)

According to the survey data (Figure 5), 28% of the respondents want to have a better building with garden and green spaces when getting back to the office post-COVID, which is the focus of this article.

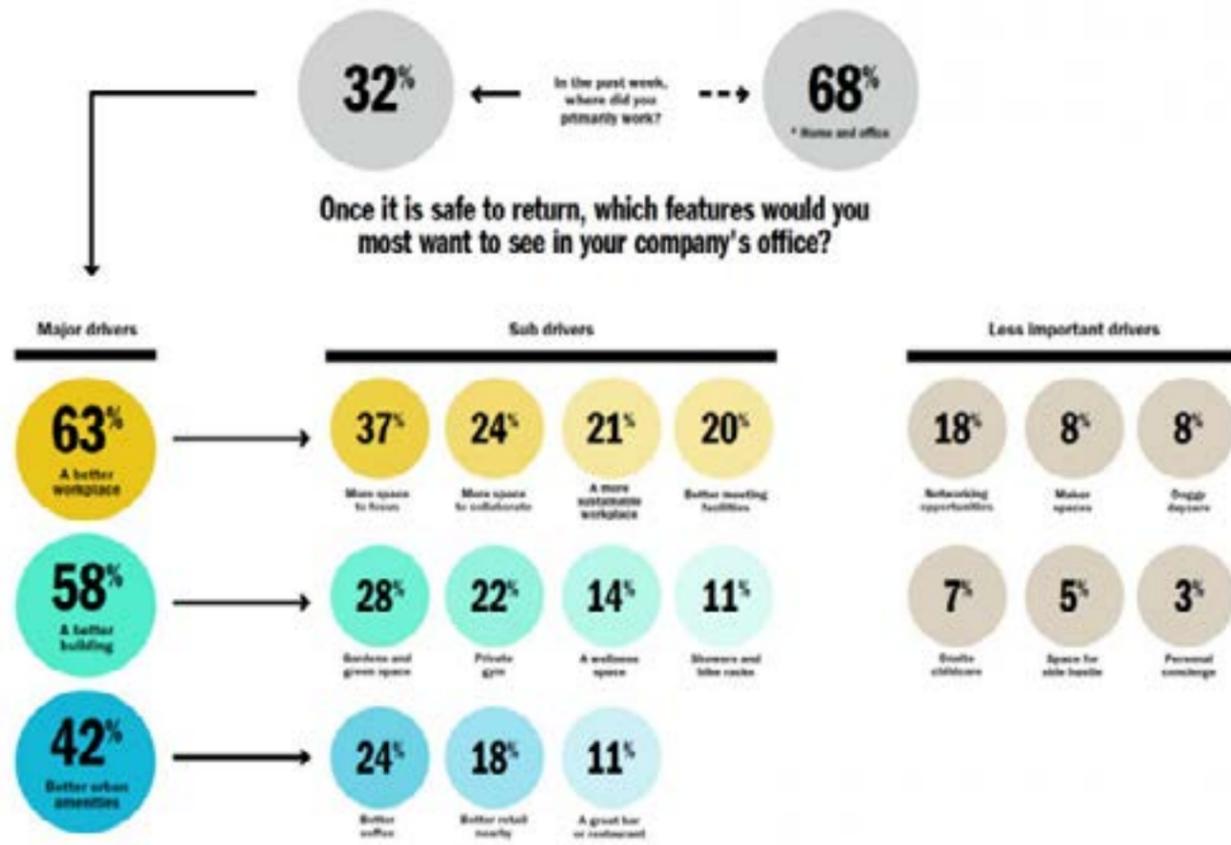


Figure 5: Results of the Hassell Studio Office Survey (Source: Davis, 2021)

Case Studies

In this section, we discuss three of the best practices in designing outdoor workspaces. The case studies include: 1) WeWork offices, and 2) TREExOFFICE, and 3) M-K-T office-retail project

WeWork Office

WeWork is a popular co-working space which added outdoor spaces into many of their locations. These spaces are equipped with any facilities businesses need to succeed such as high-speed Wi-Fi, powers for charging devices, outdoor spaces for collaboration, and large screens for presentation. Figures 6 and 7 shows two of WeWork offices where outdoor spaces are being properly utilized to help the businesses succeed.



Figure 6: WeWork outdoor workspace – Lantana, CA (Source: Zhai, 2021)

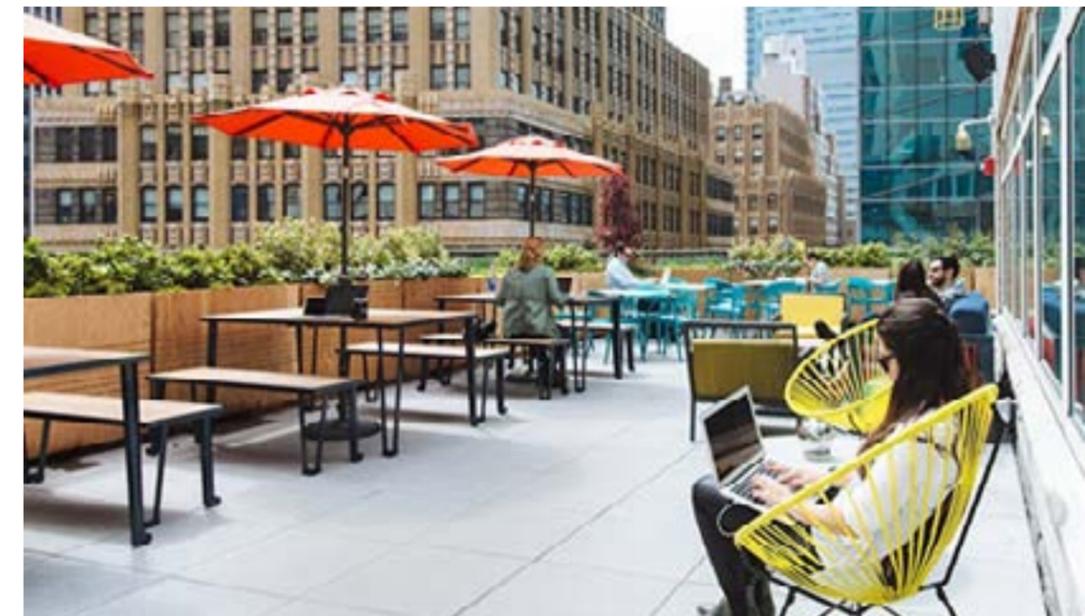


Figure 7: WeWork outdoor workspace - New York (Source: Zhai, 2021)

TREExOFFICE

This outdoor workspace is a translucent pod wrapped around a tree trunk located in London, UK (Figures 8 and 9). It provides a temporary office space for people in the park and encourage them to get the work done. This space is equipped with wooden benches, electricity and Wi-Fi. Businesses can rent this place, but this space is free for community groups in the weekends.

The money raised from renting this space to the businesses supported the maintenance of the park where this office is located. “The innovative design of the TREExOFFICE will provide a space not only where people can work and meet, but also to interact with the natural environment,” said health, social care, and culture councilor Jonathan McShane, describing it as “a vastly different experience from working in a modern office” (Dezeen, 2015).



Figure 8 (left): Exterior view of the TREExOFFICE;
Figure 9 (right): Interior view of the TREExOFFICE (Source: Dezeen, 2015)

M-K-T Office-Retail Project

Two Houston-based developers – Radom Capital and Triten Real Estate – turned an industrial complex into an adaptive-reuse project called M-K-T which connects office and retail spaces into hiking and biking trails. Access to outdoor spaces and the trails attracted new office tenants to the M-K-T project even during the pandemic. The trail also offers a space for farmers markets and outdoor events while it connects two buildings (Figure 10).



Figure 10 (left): View of the trail - connecting buildings;
Figure 11 (right): View of the M-K-T outdoor terrace that also acts as a workspace (Source: Luck, 2021)

Survey Findings

In this section, we will discuss about the results of the survey which includes approximately 700 respondents from seven countries – UAW, US, Australia, United Kingdom, South Korea and South Africa. The respondents are between 18-65 years old and have different work experiences in various industries (Figures 1 – 3).

Impacts of the Pandemic on Employees' Preferences

The result of the survey shows that 56% of surveyed respondents have used some form of outdoor spaces during the work from home for work-related tasks, 33% of surveyed participants have moved their premises because of the change in their needs during the pandemic and 12% of survey respondents moved particularly for a better working space (Figure 12). Also, this study shows that 51% of the participants are more conscious about spending more time outdoors to work from home as the result of the pandemic; 26% surveyed participants have started spending more time indoors and the rest of surveyed respondents (23%) haven't experienced any changes in their preferences of using indoors or outdoors during the pandemic (Figure 12 and 13).

The result of the survey shows that 84% of survey respondents have some sort of outdoor space in their residence premises during the pandemic. Figure 14 shows the factors which drives employees to change their premises during and after the pandemic. As shows in the Figure 14, 16.5% of participants change their premises because they need for a bigger space, 14.5% of survey respondents need more quiet space, 12.3% of survey respondents need working spaces, 8.9% of respondents need an exercise space, 7.1% of participants need an access to outdoor space, 5.8% of respondents need cheaper rental and mortgage and 5.7% of participants need less crowded area.



Figure 12: Survey results - impacts of the pandemic on employees' preference

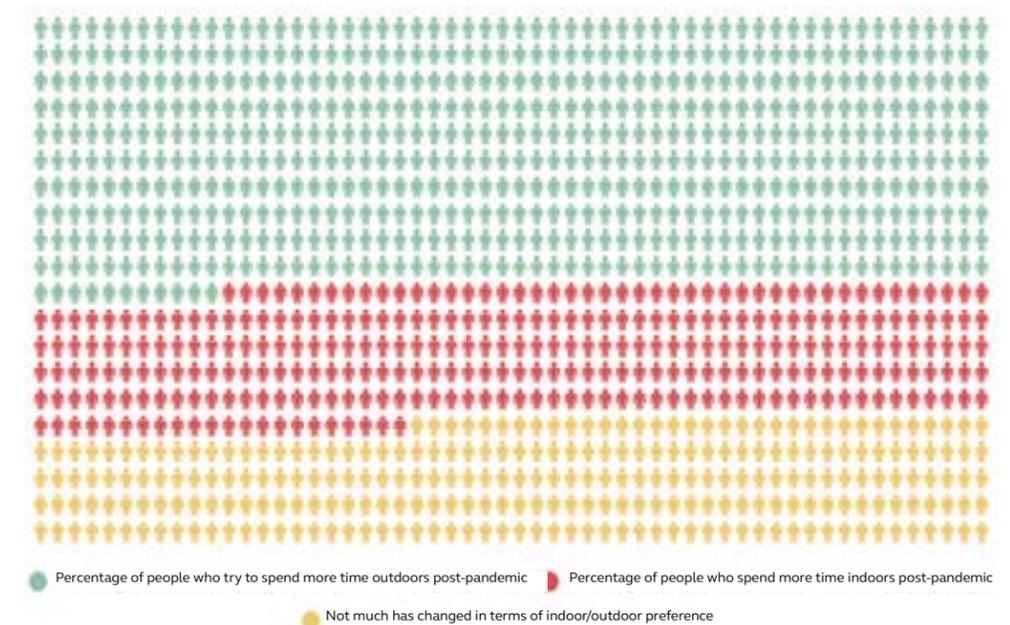


Figure 13: Survey results - employees' preferences in using indoors and outdoors to work at home during the pandemic



Figure 14: Survey results – employees’ driving parameters to change their residential premises to work from home during and after the pandemic.

Employees also asked about the tasks which performed outdoors (i.e., balcony, patio, garden) while working from home during the pandemic (Figure 15). The results shows that 30.4% of participants use outdoor space to send emails, 19.6% of respondents utilize outdoor spaces to attend online meetings and workshops, 16.4% of participants use outdoor spaces to engage in their productions and individual tasks. Respondents also mentioned other task which are performed outdoor such as research and development (10%), training (10.4%), and business development (9%).

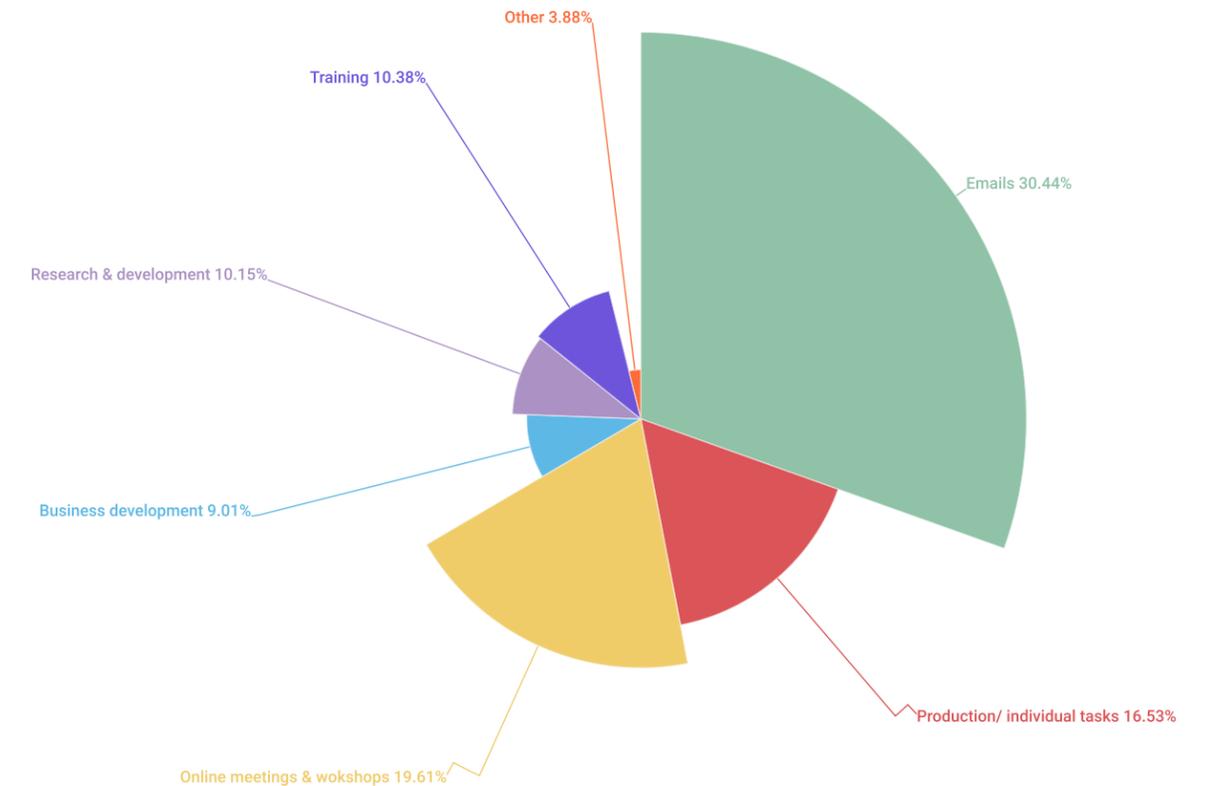


Figure 15: Survey results -tasks performed outdoors during work from home

Potentials for Enhancing Post-Covid Workplace

The results of the survey show that currently 38% of participants worked in the offices located in the medium-rise buildings, 34% of the surveyed respondents worked in offices located in the low-rise buildings and 21% of respondents worked in the offices located in the high-rise towers. The results also shows that 57% of participants would prefer to work in a ground-floor office

with access to outdoor (i.e., garden and patio) and 43% of the respondents would prefer to work in high-rise tower with beautiful view outside (Figure 16). Figure 17 shows the employees’ seating preferences. The results show that 62.5% of respondents prefer fixed seating at their office spaces and the rest (37.5%) prefer to have hot-desking.

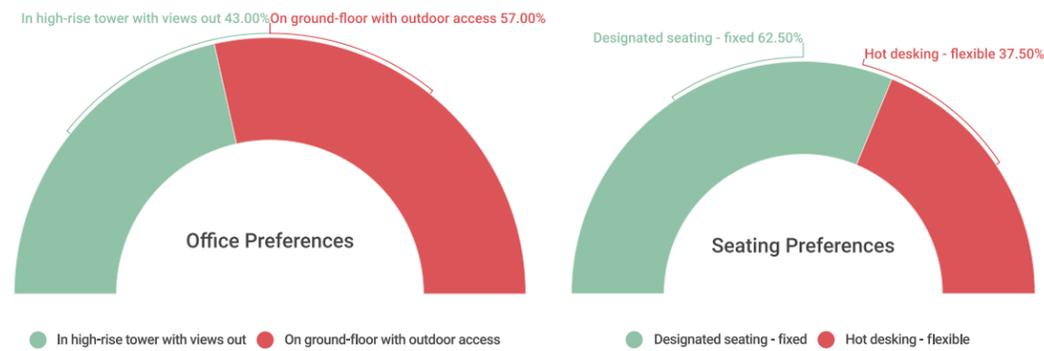


Figure 16 (left): Survey- employees' office preference;
Figure 17 (right): Survey- employees' seating preference

This survey also asked participants about the barriers of working outdoors. The result of the survey is shown in the Figure 18 illustrates that 23.7% of participants believe that the noise is the barrier of working outside; and distraction is a barrier for 19.1% of respondents to work outside. Other barriers mentioned by participants are lack of the focus (12.7%), temperature alternation throughout the day (12.7%), procrastination (11.2%), lack of employee and peer awareness (7.1%), declining company culture (5.9%) and less mentoring opportunities (5.8%).

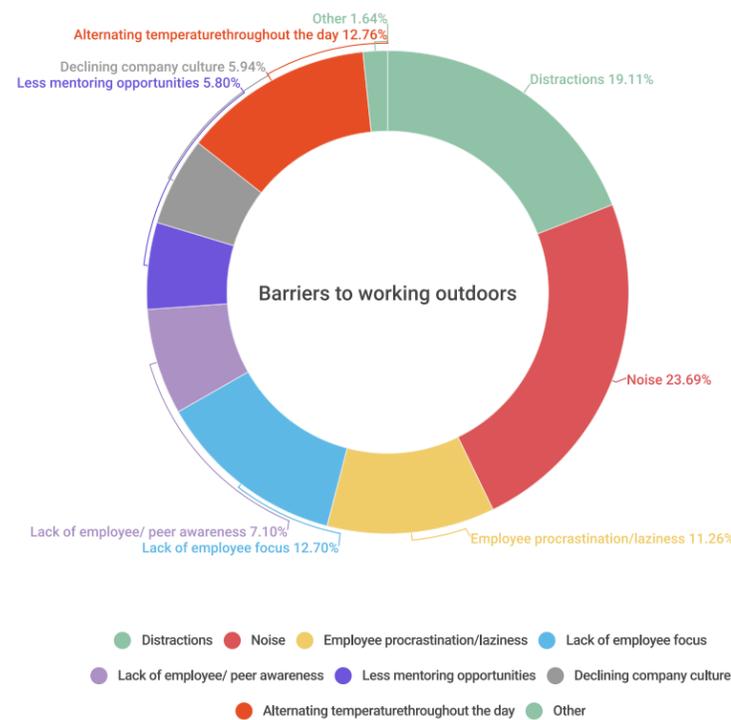


Figure 18: Survey results - barriers of working outdoors

Participants also asked about the opportunities of working outdoors. The results (shown in the Figure 19) show overall increase in wellbeing (23.8% of participants), feeling of freedom and flexibility (20.6%), improving creativity and engagement (19%), increasing productivity (14.8%), increasing concentration and focus (12.3%) and enhancing company culture (8.8%) are opportunities mentioned by survey participants.

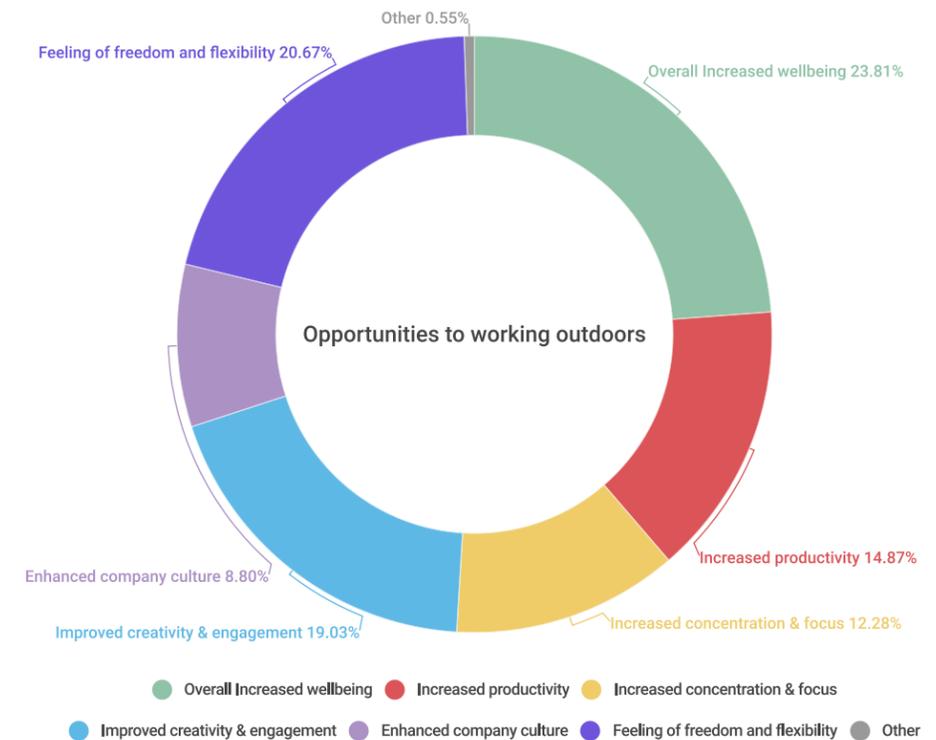


Figure 19: Survey results - opportunities of working outdoors

Employees also asked if they have any preferences in working indoor and outdoor to engage with various work activities. The results shown in the Figure 20 illustrates that employees prefer to perform tasks which involved social activities outdoor (i.e., physical meetings, workshops and trainings), while they prefer to perform other tasks such as sending emails, online meetings, business development, research and human resources management indoors.

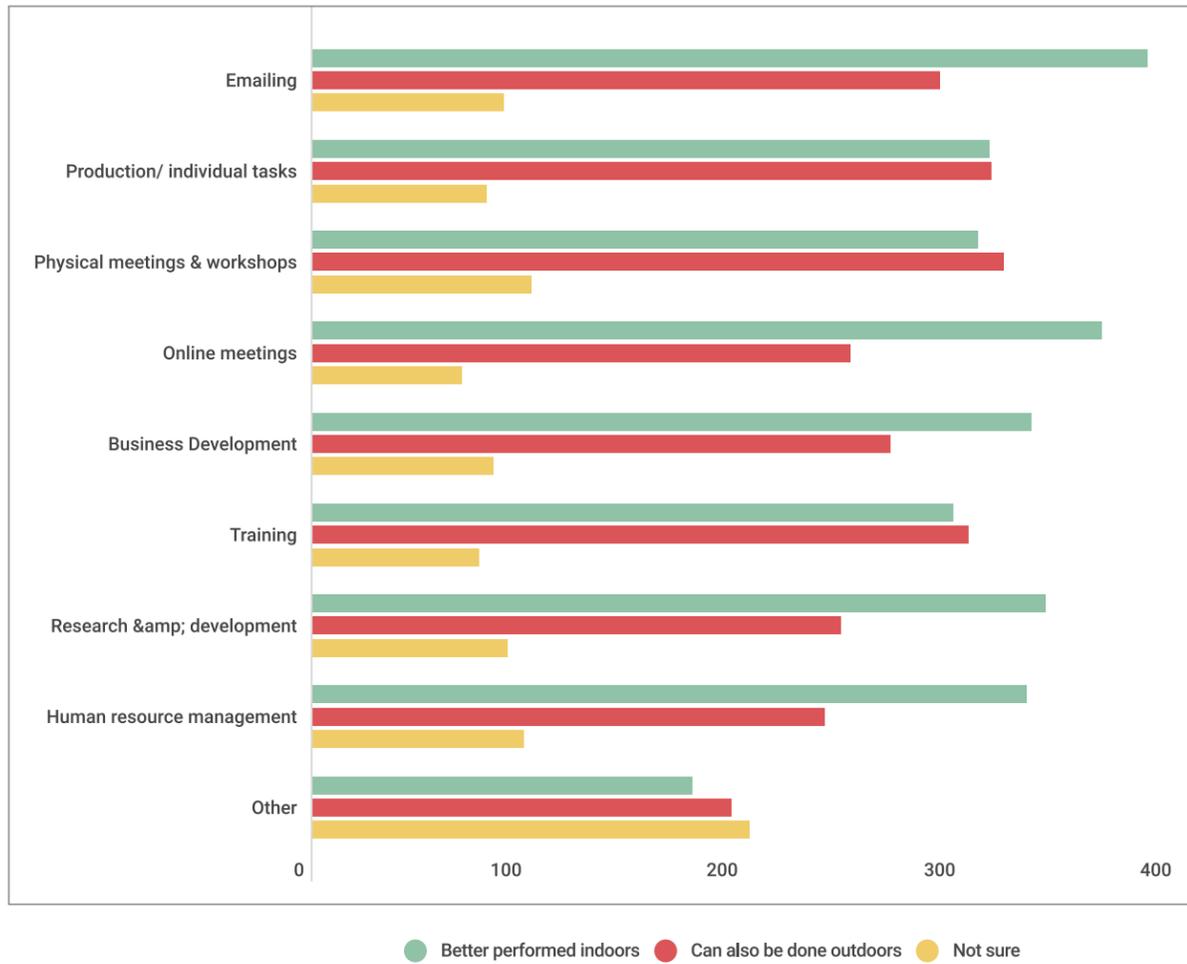


Figure 20: Survey results - work-related tasks and employees' preferences between indoors and outdoors

The survey also asked respondents if working outdoor has any positive or negative impact on their productivity, wellbeing, mental health, etc. Figure 21 shows that participants believe their productivity, focus, motivation, sociability, mental health, connection with peers

and clients will be increase if they were provided with an outdoor workspace. Many participants also believe that their stress and tiredness would be decrease if they have the option of working outside.

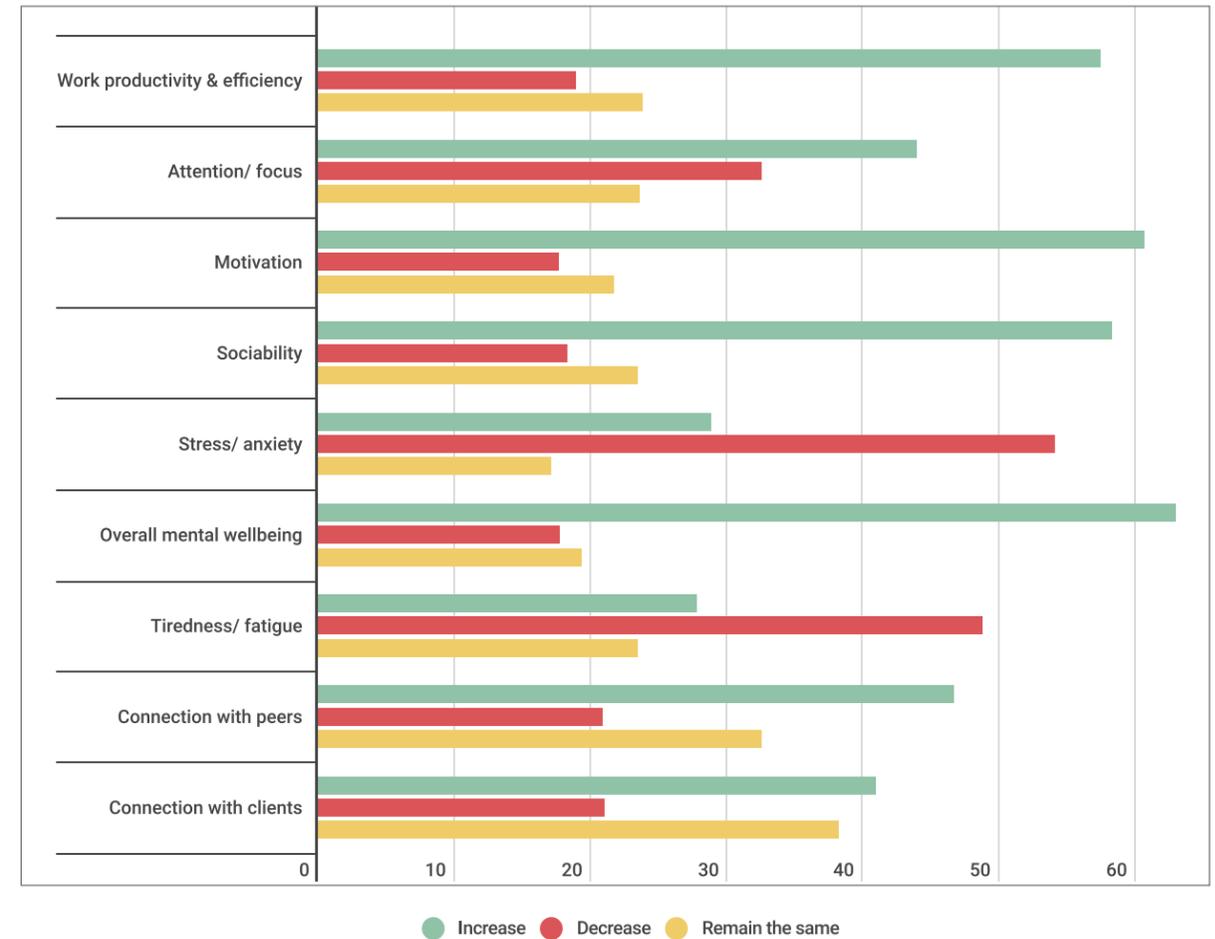


Figure 21: Survey results - the impact of having outdoor working space on employee's productivity, wellbeing, etc.

The respondents were also asked about the spaces they would prefer to have in a post-COVID office. The results show that participants would prefer to have wellness space (20.3% of participants), better social space (20.5%), outdoor workspace (19.7%), more collaboration space (14.7%), more spaces to focus (13.2%) and better meeting space (10.5%) (Figure 22). The employees also asked if they would consider an

outdoor workspace as a criterion in choosing an employer. The results show that 46% of the participants will absolutely choose employer if they have an outdoor workspace as an option, 33.8% of participants wouldn't base their choice on outdoor workspace, and 20% of the respondents are indifferent about outdoor workspace when it comes to choosing an employer (Figure 23).

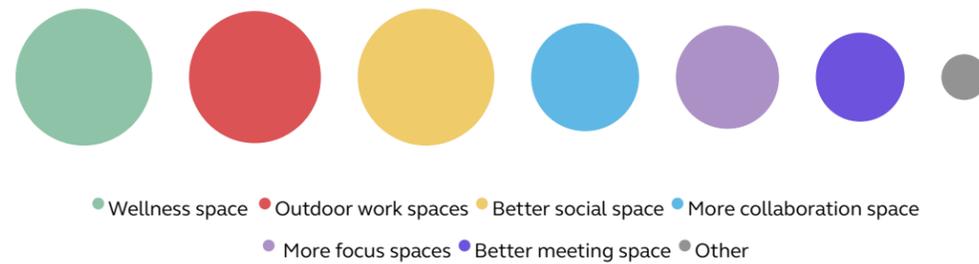


Figure 22: Survey results - employees' preferred spaces in a post-COVID office

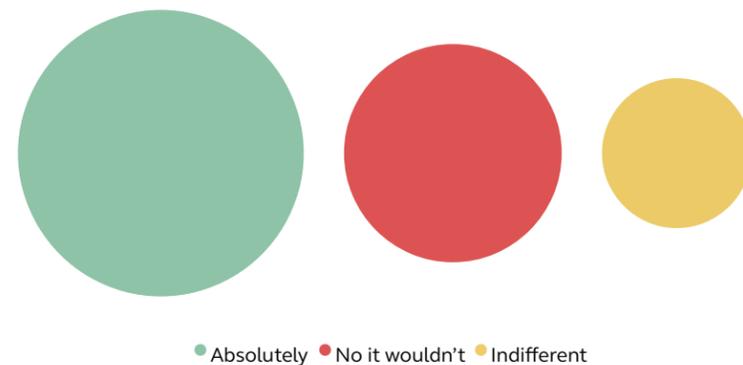


Figure 23: Survey results - likeliness of people using outdoor spaces as a criterion to choose an employer

CONCLUSIONS

The pandemic resulted a shift in employees' working styles and preferences. This study focused on the design and research trends occluding across the globe. The result of this study shows that providing an outdoor workspace for employees have multiple benefits for employees and the employer. Some of the findings of this study are:

1. The pandemic has made people more conscious about spending more time outdoors for physical and mental benefits.
2. People have used their outdoor facilities for work-related tasks during the work-from-home period of the pandemic.
3. Most employees prefer working in a low-rise building with access to the outdoors as opposed to a tall skyscraper with views as the primary selling point.
4. Although there are certain obstacles with an outdoor office – such as noise, distraction and thermal comfort – there are several benefits associated with outdoor workspace includes increase in productivity, wellbeing, mental health, flexibility, creativity, and engagement, and decrease in stress and tiredness.

5. As employees move back to their offices, they would like to see improvements in wellness spaces, outdoor workspaces, social spaces, collaboration and meeting spaces.
6. An outdoor working space would be highly attractive to potential employees and would attract top talent.

IMPLICATIONS FOR PRACTICE AND NEXT STEPS

Although the climate is an important factor in using or not using outdoor workspaces and cause damage to the outdoor office facilities (i.e., desks, chairs, cables, plug points), this research has purposely not considered climate as a factor in the analysis for the sake of time. As a next step, this paper suggests considering climate as a factor in studying feasibility of outdoor workspace in future studies. Another suggestion for future research is to study the possibility of utilizing public squares and plazas to accommodate the employees' work need. It opens opportunities to cross-collaborate with other designers to create multi-faceted dynamic design solutions and provides more exciting and diversify public spaces.

However, these solutions may create inequity and confusion for the public and private ownerships. Thus, another aspect that may be explored is how work activities may occur in public context by considering the culture of both sectors while not encourage classicism and division.

In summary,

- Provide outdoor spaces in workplaces to:
 - Improve employees' productivity, wellbeing, mental health, creativity
 - Decrease stress and tiredness
 - Attract potential employees and top talents
- In return-to-the-office phase, employees would like to see more wellness spaces, outdoor workshops, collaboration and meeting spaces.
- Consider providing shades, outlets, reliable internet connection, TV screens and any other facility to provide a comfortable and productive environment for employees in outdoor workspaces.

REFERENCES

Al-Shammari, S.A., 2015, *The Effect of Work Environment on Employees' Productivity*, International Journal of Science and Research (IJSR), vol 4, issue 5, 1554 – 1558.

Anderer, J., 2020, *Work Productivity Improves After 30 Minutes of Fresh Air Outdoors*, Research Shows, <https://www.studyfinds.org/work-productivity-30-minutes-fresh-air/>

Atmaja, N.P.C.D. and Puspitawati, N.M.D., 2018, *Effect of Physical Work Environment Through Productivity Employees Job Satisfaction as an Intervening Variable*, International Journal of Business, Economics and Law, vol 17, issue 5.

Davis, D., 2021, *The Evolving Office: 2021 Workplace Futures Survey*, <https://www.hassellstudio.com/research/the-evolving-office-2021-workplace-futures-survey#0>

Dezeen, 2015, *Pop-up Office Created Around a Tree Trunk in London's Hoxton Square*, <https://www.dezeen.com/2015/06/11/pop-up-temporary-office-pilot-hoxton-square-shoreditch-hackney-parks-east-london-rooted-to-tree-trunk-translucent-pod/>

Gensler, 2021, *Stretching the New Hybrid Workplace*, <https://www.gensler.com/blog/sketching-the-new-hybrid-workplace>

Luck, M., 2021, *Developers Devote Top Dollar to Meet Office Tenant Demand for Outdoor Spaces*, <https://www.costar.com/article/144983652/developers-devote-top-dollar-to-meet-office-tenant-demand-for-outdoor-spaces>

Morgan Lovell, NA, *The Evolution of Office Design*, <https://www.morganlovell.co.uk/the-evolution-of-office-design>

Veitch, J.A., 2011, *Workplace Design Contributions to Mental Health and Well-being*, NRC Publications Archive (NPArc).

Williams, J., NA, *A Brief History of the Workplace of the Future*, <https://www.workdesign.com/2017/01/brief-history-workplace-future/>

Zhai, D., 2021, *Seven Outdoor Spaces Designed for Productivity in Fresh Air*, WeWork, <https://www.wework.com/ideas/workspace-solutions/flexible-products/seven-outdoor-spaces-designed-for-productivity-in-fresh-air>



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THE 15-MINUTE CITY

Can we go beyond the narrative to apply metrics to the concept?

ABSTRACT

The pandemic has caused us to re-think the way we work, consume and commute. More importantly, it has taught us that it is possible to envision a new way of living that is more engaged with our community – creating more meaningful social links. COVID-19 has rapidly kick-started a trend toward localization, putting the 15-minute city on the agenda of metropolitan areas around the world. The 15-minute city is a new model for urban planning that believes all city residents should be able to meet most of their needs within a short walk or bicycle ride (in approximately 15 minutes) from their homes. New Urbanism, an urban design movement promoting walkable cities, swept across the US in the 1980s, creating an aesthetic of walkability to drive real estate values.

CRTKL was on the forefront of planning walkable developments such as State Thomas, Addison Circle and Legacy Town Center. The 15-minute city concept represents a departure from the past, responding to climate change, social equity, COVID-19 and globalization. This investigation seeks to better understand the theory of the concept and explore a metric-based approach as a means of better understanding how American cities can adapt and strive to become “a city of proximities,” not only between uses and amenities, but between people, too.

CONTEXT

What is a 15-minute city?

The 15-minute city concept embraced by Paris mayor Anne Hidalgo (Guardian News and Media 2020), was developed by Carlos Moreno (TEDtalksDirector 2021), a professor at Sorbonne, who believes that daily necessities of life should all be accessible by a short trip on foot, bike,] or public transit. His research, which originally focused on reducing greenhouse gas emissions from the transportation sector, led him to a vision of modern cities as mosaics of walkable neighborhoods that meet the domestic, professional and entertainment needs of residents.

His vision is of a city where everything you need can be found within a fifteen-minute walk or bike ride from your home – including fresh food, healthcare, schools, offices, shops, parks, gyms, banks and diverse entertainment. The paths to get there are safe, tree-shaded, car-free neighborhoods where people can get to know each other. When interconnected, neighborhoods revitalize and strengthen community, lower greenhouse gas emissions and improve livability with clean air and proficient public transit systems.

Some core elements of the 15-minute city (Hawken 2021):

- It gives residents of all neighborhoods access to essential goods and services, particularly fresh food and healthcare.
- It encourages every neighborhood to include housing of varied sizes and levels of affordability and accommodates many types of households, enabling people to live closer to where they work.
- It advances mixed-use retail and office space, co-working opportunities and digitalization of certain services – all of which limit the need for travel.
- It encourages the flexible use of buildings and public space, including buildings designed to be easily converted to different uses.

While the 15-minute city emphasizes the need for walkable neighborhoods as a way of promoting a healthy lifestyle, a 15-minute city is equally focused on other dimensions, like resilience, sustainability and inclusivity. The concept envisions that each neighborhood should fulfill six social functions: living, working, caring, learning and enjoying. And they should be based on four major principles: Density, Proximity, Diversity and Digitalization. (Moreno 2021)

Density

Density is a crucial dimension of the city and its built environment as having a direct link to travel and diversity. The emphasis is on the optimal density that ultimately allows sustainability pursuits to be achieved on the economic, social and environmental frontiers. With the optimal density, it is possible to effectively plan the available space such that all the essentials could be accessible to residents without the need for time- and-energy consuming automobiles. Density is a key component favoring the social sustainability dimension of cities, and when integrated with the dimension of proximity and diversity, the 15-minute city model would help in improving service delivery and livability.

Proximity

Within the 15-minute quickly accessible radial nodes, residents in each neighborhood can readily access basic services. It allows residents to transition from residential areas, work, commercial areas, education centers, health facilities and other basic institutions in a reduced timespan. This closeness of essential services allows residents to enjoy better service provision both in commercial and public establishments, as the planning model allows for multimodal use of basic infrastructures.

Diversity

Diversity in the context of the 15-minute city concept is the need for mixed use neighborhoods which are primary in providing a healthy mix of residential, commercial and entertainment components and diversity in culture and people.

Having mixed-use neighborhoods is key in sustaining economically vibrant urban fabrics, ensuring sufficient housing for all the urban residents, promoting inclusivity and promoting sustainable practices. In the pursuit of a 15-minute city model, the adoption of mixed-use neighborhoods is paramount in ensuring that an optimal density and proximity of essential amenities are achieved, while also providing for development of walkable streets and bicycle lanes. This approach ensures that residents can benefit from essentials within their residential areas, thus reducing the need for them to travel to access them.

Diversity in a neighborhood is particularly important in promoting social cohesion and social capital. Having a multicultural dimension in a city has positive bearings on the economic front, as locals would also enjoy a wide variety of products such as cultural products and cultural heritage, promoting economic vibrancy, leading to the creation of increased employment opportunities.

Digitalization

This dimension is relevant to the 15-Minute City concept as it ensures the deployment of digital solutions and technologies to the three other pillars. For example, through digital tools and solutions, it would be possible to ensure that biking experiences are enhanced by emphasizing solutions such as bike sharing. Similarly, availability of online shopping and virtual communication would reduce the need for commuting as some services could be delivered within the comfort of homes or offices.

Why is it relevant?

In pursuit of transforming urban areas to improve their livability status and resilience, promote sustainability and their social and economic aspects, many planning models were proposed and have evolved because of their application in varying contexts and geographies. The importance of the 15-minute city is its emphasis on proximity-based planning -- where an urban neighborhood is planned to accommodate an optimal density that would have access to basic essential services within a 15-minute walking or cycling distance. Residents will manage to experience a higher quality of life as they will be required to travel less to access basic facilities, with increased time and opportunities to interact with other members of the community and accomplish other social functions, which are increasingly important, but which

have been lacking as a core function of contemporary urban planning models.

The emphasis on accessibility and proximity advanced in the 15-minute city concept, especially through walking or cycling, has been showcased as having numerous benefits on social, economic and environmental scales. Cities benefit from reduced congestion, reduced pollution (noise, emissions, and others). The resident's benefit from increased time and opportunities to exercise and gain social interactions. On the economic front, this model has the potential to unlock numerous potential positive outcomes such as employment, new innovations as well as helping to reduce overheads incurred from fuels costs, road maintenance, pollution, and other associated costs.

The 15-minute city could be a planning concept that would reorient urban development into paths that support both environmental and equitable paths. A model as an alternative planning approach highlighting dimensions of resilience and livability that has now been seen to be replicated in different cities across the globe and aroused the interests of international organizations, which, among others included the C40 Cities, the World Health organization (WHO), UN-Habitat to improve quality of life in the context of COVID-19 and beyond.

The impact of the pandemic has created an opportunity to observe how people's lives are impacted when they are forced to rely on their immediate community for many of their day-to-day needs, from entertainment to access to green space. The pandemic will see long-term changes in cities, prompt the emergence of new socio-economic structures and force new urban planning models that need to adapt to such trends to ensure a safe and sustainable urban future.

Can the 15-minute city be measured?
Can we go beyond the narrative and apply metrics to the concept?



The 15-minute city could be a planning concept that would reorient urban development into paths that support both environmental and equitable paths.

APPROACH

Since the concept is considered an ideal and no city or neighborhood yet fulfills all the parameters of a 15-minute city, our original goal was to choose elements from neighborhoods around the world to determine a means of defining appropriate standards. Our plan was to use a mosaic of data, cherry-picked from the best examples around the world to paint a picture of the defining metrics of the concept (which to-date has only been defined as an ideal in narrative). Finally, we would use those standards to compare to Downtown Dallas as a “baseline” neighborhood. Dallas was chosen as a test case because its characteristics are reflective of many fast-growing urban areas in the south and western United States.

Identifying the Metrics

Our research effort began by first identifying the metrics that define the 15-minute city concept. This was accomplished with a literature review of articles and books that focus on the categorization and study of elements of successful, vibrant, or ideal urban places and a review and categorization of metrics based on our experience. From this effort, we follow the four main pillars of data as described above:

- **Density** – metrics that focus on the amount of people, places, services or uses within a given area

- **Proximity** – connectivity to and between the various elements with a given area.
- **Diversification** – the range of uses and people: who and when people are in each area.
- **Digitalization** – access to technology and digital tools to improve quality of life or functionality.

Through the course of our research, we determined 68 metrics that could be used to define the elements of a 15-minute city. At this stage of the process, the team focused upon the categorization of these metrics and casting a wide net of standards that would define a “complete picture” of urban conditions without limiting ourselves to metrics that *could* be measured within the scope, budget and timeline of this effort.

The identified metrics are described in more detail in our Findings and Appendix sections but include a range of parameters to describe not only the amount of use, people or amenity but also the typologies, diversity of users and connectivity of said uses.

Data Gathering

Our next step was to determine which of the defined metrics we could realistically measure based on the tools at our disposal, timing of the research effort and budget. Using Downtown Dallas as the test case, the team explored methods

to create clear data sets that fit within our prescribed categories and outlined the methodologies required to acquire data in the categories that we could not measure within the parameter of this exercise.

Early on, it became clear that many of the data sets pertaining to density, use, connectivity and diversity had a straightforward methodology that yielded an array of information about the makeup of the physical and demographic conditions of Downtown Dallas, while other data proved to be challenging (if not impossible) to adequately gather. Quantitative data that included district-wide summaries (such as number of residents, employees, densities, typologies or demographic data) within a defined study area were easily attainable. Other quantitative data that required the collation of information from individual parcels, buildings, or streets (parking ratios, mix of use within individual buildings or sub-districts, where employees live, etc.) would require much more time and resources to attain.

The classifications of quantitative data generally had a clear methodology – obtaining them within our research parameters was another matter. Qualitative data, on the other hand, proved to be a significant challenge to the research team. We quickly realized that creating metrics that assess the “quality” of elements, uses or spaces

within a district rather than classifying data (quantitative) would fall well outside the scope of this research effort. Firstly, qualitative data is more subjective than classification, one’s definition of quality can vary greatly. Without significant polling, interviews or analysis of desires, needs or goals of psychographic segments, there would be no meaningful way of bracketing quality outside the opinion of the research team. Secondly, there was no way to successfully determine the quality of the quantitative data without visual inspection of the entire district. For example, a convenience store counts toward providing access to food in a district, but its impact compared to a full-service grocery store is much different. In the quantitative data sets the convenience store and grocery are treated as equals. In the real world the grocery store is much more impactful to the quality, diversity and “richness” of a neighborhood. To fully understand the qualitative aspects of each data set, an inventory of each use, typology and/or building would be required.

The Wheels Come Off

Our team reluctantly set the qualitative metrics aside as categories that could not be measured within the scope of this effort. Our reluctance was because quantitative metrics inherently tell only part of the story and miss the emotional, psychological and perceptual aspects of a given place. Setting those issues aside,

we quickly ran into another set of fatal flaws in the research process: availability of data and benchmarking.

As we shifted to focus our efforts on the quantitative metrics established and measured in Downtown Dallas, the next step was to benchmark these data sets against best practices from around the world. Through open data platforms most cities in the United States offer a rich array of data but the same data is not always available for cities elsewhere in the world. If we were to successfully benchmark Downtown Dallas with a variety of other cities, we would need the same data selected from similarly sized study areas. Where we could find data, we could never be entirely sure if the data were really giving us an “apples to apples” comparison, or if the quality of the data were comparable. These inconsistencies, while not insurmountable, created concerns about the quality of the information and our findings.

The more concerning limitations in our process was developing a methodology for benchmarking best practices. What we did not consider while developing our initial hypothesis was that for many of the categories there is not a defined standard and any determinations we make regarding “best practices” would be purely subjective. For example, should the benchmark for residential density be taken from neighborhoods in London or

Hong Kong? Both cities include vibrant, world-renowned neighborhoods that exhibit elements of the 15-minute city, but the densities are vastly different. Additional examples highlight the scope of our dilemma: What is the ideal mix of uses in a neighborhood? What is the ideal aspiration for diversity, is it benchmarked against an ideal or against the larger demographic and economic diversity of the rest of the city? In short, the more we looked for an ideal, the more we understood that communities are too diverse to categorize. One size fit all does not apply to active, vibrant neighborhoods.

Putting the Pieces Back Together: How We Learned to Stop Worrying and Love the Process

Part One: The Ethical Quandary

The road to Scientific Enlightenment is riddled with the debris of attempts to post-rationalize broken hypotheses. Faced with a failure in achieving the goals we originally set out on, the research team was at a crossroads: we could have relied on less-than-ideal data, allow subjectivity to creep into our benchmarking standards or otherwise changed our parameters to better suit our original theory. Or, we could choose to recognize the importance of the process we designed and the relevance of the vast amounts of data we had already collected. Rather than accepting that our research had led us to disprove our

original hypothesis, we chose to assess our options to develop another strategy to determine how we could use the data in another way.

Part Two: The Other Way

In assessing our process to-date, we focused on five key take-aways: 1) developing the blend of qualitative and quantitative metrics to define something as complex as a vibrant urban district is impossible given how diverse and sensitive to context neighborhoods are. 2) The diversity and variety of communities makes it impossible to determine what is “best.” 3) While quantitative metrics do not present the whole picture, there is value in the data, and comparing that data across multiple geographies can help to strengthen the understanding that diversity, variety and differentiation that makes individual neighborhood or districts special in the first place. 4) Bracketing, rather than Benchmarking, sheds further light on similarities and difference between geographies, helps to establish ideal ranges rather than hard standards and can help to infer some of the qualitative metrics we originally wanted to determine. 5) Finally, we have a lot of data and can use the same methodology for data gathering for almost any neighborhood in the United States -- producing accurate, definable and (most importantly) easily comparable data sets.

Based on these factors the research team reassessed a strategy for comparing metrics between urban neighborhoods. First, rather than benchmarking against best practices or a single neighborhood or district, we established new criterion for comparing metrics between multiple neighborhoods simultaneously. To do this, we chose to compare Downtown Dallas, not to singular “best practices” from around the world (it’s debatable whether these standards exist in any definitive form, if they could be found they are probably too subjective to provide any real insights), but to three neighborhoods that we felt reflected many of the characteristics of the 15-minute city concept. We chose Williamsburg in Brooklyn, the West Loop in Chicago, and the Mission District in San Francisco as “baseline” neighborhoods. These neighborhoods reflect some of the characteristics of the 15-minute city and represent specific (yet varied) examples of the most well-known walkable urban neighborhoods in the country and are of a similar size. Additionally, their geographic variance (we presumed) would provide further insight into a range of data.

The benefits of this strategy are twofold, first by recognizing that there is not a one-size-fit-all standard for many of the metrics we chose to study, our refined approach gives us the flexibility to understand a range rather than a definitive maximum or minimum

standard. Secondly, our approach creates a useful tool for not only creating ranges for comparison but also to compare the “baseline” geographies to each other as well. Through our research, the most interesting data was not how Downtown Dallas compared to the baseline neighborhoods, it was what the data revealed about Williamsburg, West Loop and Mission District. Understanding how these neighborhoods differ could provide powerful insight into the “mechanics” of successful urban districts. Finally, our approach can be replicated for any neighborhoods of comparable size (given access to data) to allow for further flexibility and adaptability in the research tools.

FINDINGS

3 Pillars

As described in the previous section, our research evolved into development a process and methodology in which to compare data, therefore the findings of this research are really the methodology itself (Figure 1).

Geographic Selection

To keep geographic comparisons similar, we selected census block groups contained within the neighborhood that were within a quarter-mile radius, or a 15-minute walk, of the centroid of the neighborhood for all study areas. Census block groups are the smallest geographic unit for which demographic data is published, and we determined that the fine grain of its boundaries was the most precise way to compare similar sized geographies.

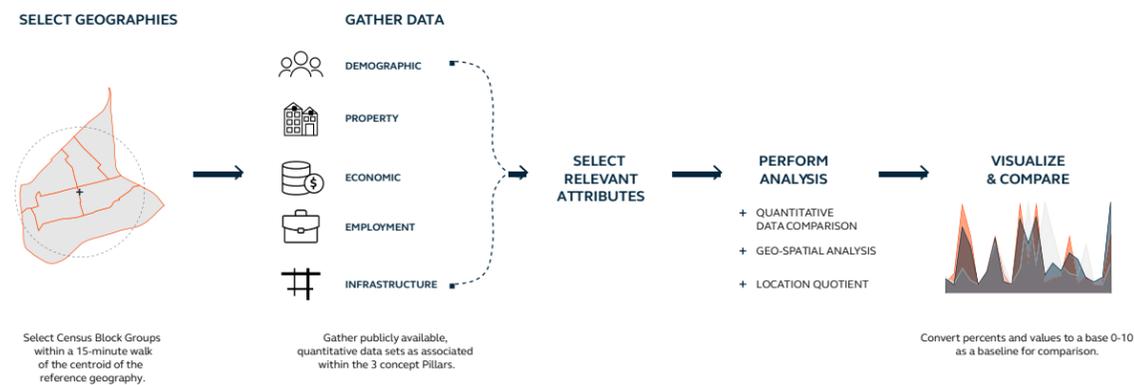


Figure 1: Diagram of the process and methodology developed out of this research effort.

Data Gathering

While all the data gathered is publicly and individually accessible, several main sources were used to collate the necessary information: Social Explorer, OnTheMap, ESRI Business Analyst and UrbanFootprint.

Social Explorer provides easy access to demographic information and creates detailed reports for selected variables and geographies.

- Datasets Used: American Community Survey 2019 5-Year Estimates

OnTheMap is a web-based mapping and reporting application that provides workforce related data for user-defined geographies at census block level detail.

- Datasets Used: US Census Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES) dataset

ESRI Business Analyst provides business, consumer spending, and demographic data.

- Datasets Used: Retail Marketplace, Housing Affordability Index

UrbanFootprint has an extensive library of national parcel-based data sets.

Datasets Used:

- Open Street Map

- Homeland Infrastructure Foundation Level (2019)
- Transitland
- EPA Smart Location Database
- US Department of Housing and Urban Development
- US Census
- National Center for Education Statistics

Additional Datasets Used:

- 2011 National Land Cover Database at 30M resolution
- Walkscore.com

In addition to serving as a clearing house for easily accessible datasets, we also used UrbanFootprint to perform several of the geo-spatial analyses. Again, while these types of analyses can be performed using basic ArcGIS toolsets and joining the tabular demographic data to the geographic blocks, in the context of this research we chose to take advantage of the built-in web-based tool that allows these network graphs to be produced.

Select Relevant Attributes

In the end we studied 68 individual metrics as follows (Table 1):

This is not an exhaustive list of every metric that theoretically is important or could be studied, but represents more of a snapshot of metrics that were publicly available and could be acquired.

| Density | Diversity | Proximity |
|--------------------------------------|---|--------------------------|
| 24 Metrics | 34 Metrics | 10 Metrics |
| Residential Population Density | Median Age | Park Accessibility |
| Household Density | Educational Attainment (LQ) | Retail Accessibility |
| Average Household Size | Ethnicity - White (LQ) | School Accessibility |
| Employment Density | Ethnicity - Black or African American (LQ) | Grocery Accessibility |
| Daytime Population | Ethnicity - American Indian and Alaska Native (LQ) | Employment Accessibility |
| Nighttime Population | Ethnicity - Native Hawaiian and Other Pacific Islander (LQ) | Tree Canopy |
| Day to Night Population Ratio | Ethnicity - Some Other Race (LQ) | Transit Accessibility |
| Building Area: Residential | Ethnicity - Black or African American (LQ) | Walk Score |
| Building Area: Retail | Ethnicity - Two or More Races (LQ) | Bike Score |
| Building Area: Office | Ethnicity - Overall Representation | Transit Score |
| Building Area: Public | Ratio of Average to Median HH Income | |
| Building Area: Industrial | Housing Tenure Owners (LQ) | |
| Dwelling Units/Acre | Housing Tenure Renters (LQ) | |
| Network Density- Auto Miles/SM | Housing Affordability Index | |
| Network Density-Multi-Modal Links/SM | Residential-Large Lot Detached Single-Family Dwelling Units | |
| Network Density- Pedestrian Links/SM | Residential-Small Lot Detached Single-Family Dwelling Units | |
| Average Intersection Density | Residential-Attached Single-Family Dwelling Units (Townhomes) | |
| Car, Truck, Van | Residential-All Multifamily Dwelling Units | |
| Public Transport | Retail-Retail Services | |
| Motorcycle | Retail-Restaurants | |
| Bicycle | Retail-Arts & Entertainment | |
| Walked | Retail-Accommodation | |
| Other | Retail-Other Retail | |
| Worked At Home | Office-Office Services | |
| | Office-Medical Services | |
| | Public-Public Administration | |
| | Public-Education | |
| | Industrial-Transportation/Warehouses | |
| | Industrial-Wholesale | |
| | Retail Employment | |
| | Office Employment | |
| | Public Employment | |
| | Industrial Employment | |
| | Agriculture Employment | |

Methodology of Analysis

To compare the data points across the geographies, there are three main methods of analysis performed:

Quantitative data comparison, e.g: demographic data, building area, commercial data etc. For example: Building Area by Use (Figure 2).

In this example, that Dallas is a CBD clearly explains the high percentage of office and retail uses. Williamsburg appears to be a more residential neighborhood. Both the West Loop and the Mission District appear to be neighborhoods with more balanced uses. This analysis does not indicate what ratio of uses is “best,” but rather provides a means of comparing a range across

| | District | Williamsburg | West Loop | Mission District |
|-----------------------------------|----------|--------------|-----------|------------------|
| Building Area: Residential | 14% | 61% | 30% | 39% |
| Building Area: Retail | 23% | 14% | 23% | 17% |
| Building Area: Office | 49% | 14% | 37% | 9% |
| Building Area: Public | 11% | 5% | 2% | 31% |
| Building Area: Industrial | 2% | 5% | 8% | 4% |
| Dwelling Units/Acre | 6 | 23 | 12 | 19 |

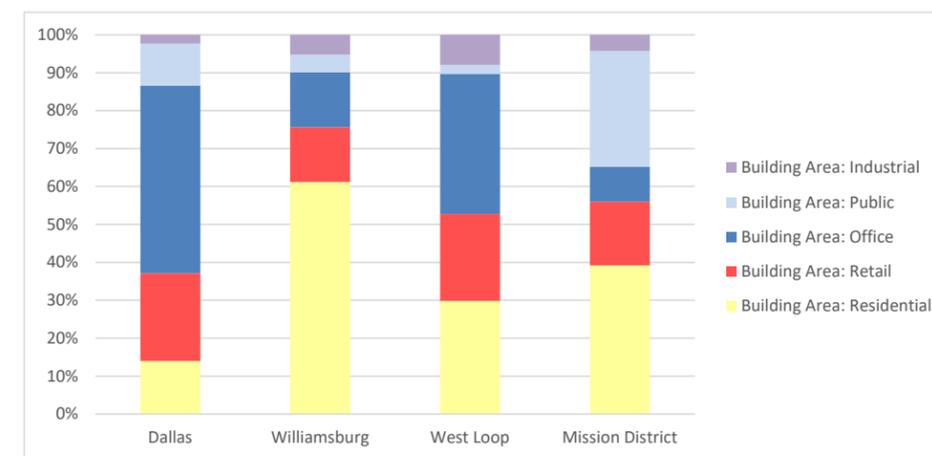


Figure 2: Example of Building Area by Use as a Quantitative Data sample

multiple geographies. It is important to use percentages rather than values to compare these types of data sets. In this example, the square footage of building use is impacted by building typology and density, creating vast differences in total amount of square footage by use between study areas.

Geo-spatial Analysis: For most of the proximity related metrics, a network graph was developed to measure, and then compare across the geographies, the percentage of a neighborhood's population that is within a 5-to-15-

minute walk of a given point, (e.g. a park, retail location, or school etc.) using the existing road and pedestrian network. For example: Park Accessibility (Figure 3)

In this example, it shows that in the compared geographies, a higher percentage of the population within those census block groups are within a 5-minute walk of a park than in Dallas. While this does not evaluate the quality of those parks, it does indicate the distribution of the parks and the proximity and connectivity between parks and the surrounding neighborhood.

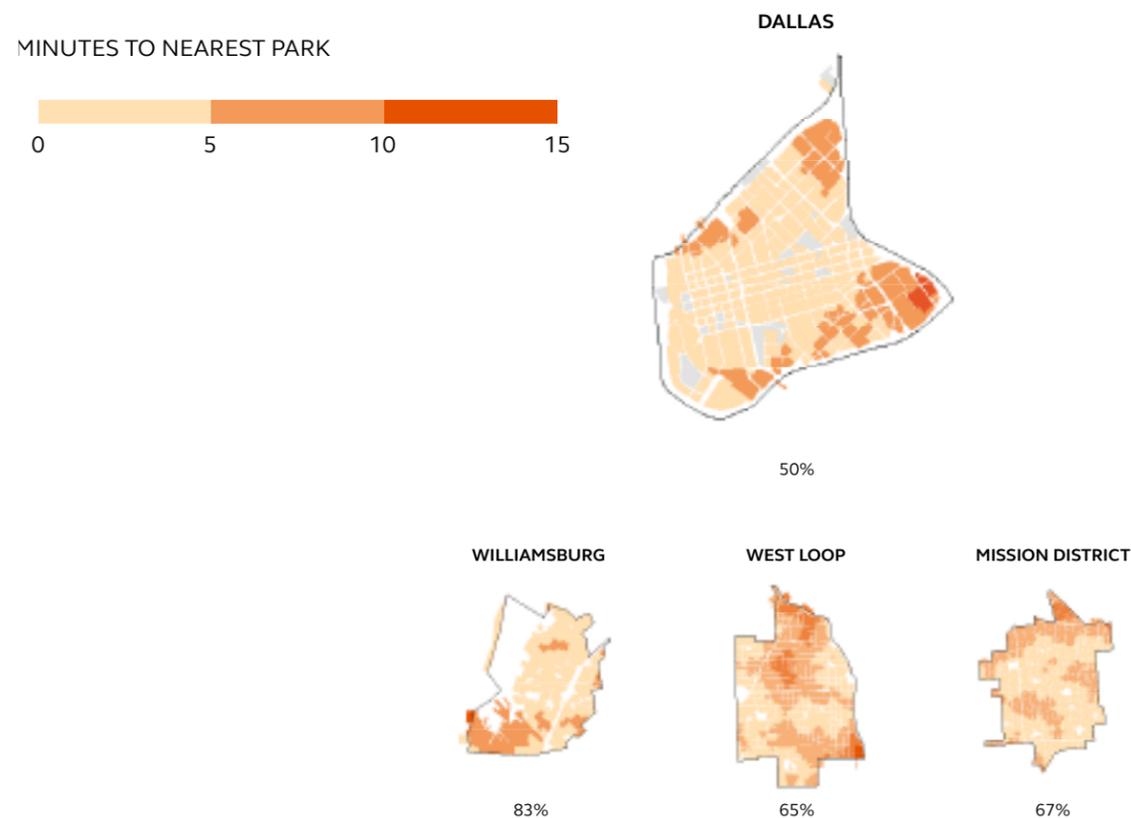


Figure 3: Example of Park Accessibility as a Geo-Spatial sample

Location Quotient Analysis: In some instances, particularly metrics related to diversity and equity, we felt it was not reasonable to compare the 4 selected geographies. Instead, what is more relevant is to understand how those metrics compare to the larger city that they are in. The research team chose this methodology because there is no ideal standard for diversity within a neighborhood and each neighborhood's diversity is specifically tied to geography, history and regional context. For that reason, we chose to compare each study area to the cities in which they are located to determine if the study area is more or less diverse than the city at-large.

Typically used to measure industry concentration, a location quotient (LQ) is an analytical statistic that can also be used to quantify how concentrated a characteristic in an area is relative to a larger geographic unit, in our case the neighborhood versus the city it is in. An LQ is computed as

$$LQ = (e_i/e) / (E_i/E)$$

Where:

- e_i = Local characteristic
- e = Total local characteristic
- E_i = Reference area characteristic
- E = Total Reference area characteristic

If an LQ is equal to 1, this means that characteristic or metric is in balance with

the reference geography. An LQ higher or lower than 1 means the characteristic is relatively more or less concentrated than the reference geography. This helps quantify an area's uniqueness. For example: Ethnicity (Figure 4)

While Downtown Dallas is relatively balanced in "White Alone" and "Two or More Races" as compared to the City of Dallas, there is a much higher concentration of those identified as "Asian Alone" in Downtown Dallas as compared to the City of Dallas. Furthermore, using the Location Quotient Analysis allows us to compare all the study areas and their relationship to the larger geographies to each other.

In this example, it is easy to see that all 4 geographies experience some amount of over and under representation of various ethnic groups. Again, this does not pretend to posit there is an "ideal ethnic mix," but instead is a way to understand if the selected neighborhood is representative of the larger regional demographics.

Weighting

Finally, to easily visualize and digest the numerous data points, many of the metrics were weighted to a base of 0-10 (Figure 5). Those metrics calculated as a "Location Quotient" were omitted from weighting, as the values are calculated differently and do not represent the same thing as a "Quantitative Data Comparison." Where metrics with

percentages were easily converted to their base 10 value (i.e., 100%=10, 10%=1), some metrics were weighted to 10 within the category. For example, Williamsburg has the highest density

of the compared geographies at 58 DU/Acre. In this case, 58 was set to a weight of 10 and the remaining geographies are weighted proportionally.

| SE: A03001. Race | | | | | |
|--|--------|-------|-----------|-------|-----|
| Total Population: | 10,305 | | 1,330,612 | | LQ |
| White Alone | 6,847 | 66.4% | 833,795 | 62.7% | 1.1 |
| Black or African American Alone | 2,281 | 22.1% | 323,051 | 24.3% | 0.9 |
| American Indian & Alaska Native Alone | 27 | 0.3% | 4,077 | 0.3% | 0.9 |
| Asian Alone | 574 | 5.6% | 45,170 | 3.4% | 1.6 |
| Native Hawaiian & Other Pacific Islander Alone | 0 | 0.0% | 393 | 0.0% | 0.0 |
| Some Other Race Alone | 266 | 2.6% | 91,931 | 6.9% | 0.4 |
| Two or More Races | 310 | 3.0% | 32,195 | 2.4% | 1.2 |

| Ethnicity (LQ of Neighborhood vs. City) | | | | | | |
|--|-----|--|-----|--|-----|-----|
| White Alone | 1.1 | | 1.8 | | 1.3 | 1.2 |
| Black or African American Alone | 0.9 | | 0.2 | | 0.3 | 0.6 |
| American Indian and Alaska Native Alone | 0.9 | | 1.4 | | 0.1 | 2.1 |
| Asian Alone | 1.6 | | 0.4 | | 2.9 | 0.4 |
| Native Hawaiian and Other Pacific Islander Alone | 0.0 | | 0.5 | | 0.7 | 0.4 |
| Some Other Race Alone | 0.4 | | 1.0 | | 0.1 | 2.3 |
| Two or More Races | 1.2 | | 1.1 | | 1.3 | 1.2 |

Figure 4: Example of Ethnicity as a Location Quotient Analysis sample

| Pillar | Sub-Pillar | Metric | Downtown Dallas | | Williamsburg | | West Loop | | Mission District | |
|---------|--------------|--------------------------------|-----------------|---------------|--------------|---------------|-----------|---------------|------------------|---------------|
| | | | Value | Weight (0-10) | Value | Weight (0-10) | Value | Weight (0-10) | Value | Weight (0-10) |
| Density | Demographics | Residential Population Density | 9 | 1.55 | 58 | 10.00 | 22 | 3.79 | 42 | 7.24 |

Figure 5: Example pillar metric weighing (0-10)

It is important to clarify that this weighting does not indicate one metric is necessarily weighted as more important than the others in terms of the elements that make up a 15-minute city, or results in saying Geography X is better than Geography Y. This is simply a method to easily compare data sets across the board. The process of weighting was done in preparation of the creation of a Dashboard-type format, which will be further described in the Next Steps section of this journal entry.

CONCLUSIONS

Rather than a conclusive answer to a question, the findings of this research effort is in fact a process that was developed to compare quantitative aspects of communities' attributes that might make up a 15-minute city. There are several clear takeaways from this effort:

- This concept is more than about walkability, and beyond density.
- It is difficult or impossible to measure every element that might make up a 15-minute city.
- There are certain metrics that are in fact more important than others in the core DNA of a 15-minute city.
- A way to compare /contrast, also an opportunity for individuals to find

your own links in the data... means of opening-up others to analyze data for others to draw conclusions to that data.

- Cities/neighborhoods districts are too complex/varied in social, economic, political, context, history, geographic location to create a definitive metric that describes the qualitative aspects of a 15-minute city.
- Methodology has created a means to understand a relationship at a same level. Distill metrics to a point where they all mean the same thing – comparing -- not good or bad.
- Choosing 3 neighborhoods that intuitively have some elements that were important to the 15-minute city concept, choosing 3 instead of 1 builds the range.

IMPLICATIONS FOR PRACTICE AND NEXT STEPS

Based on the approach and methodology described above, we are interested in creating a user-friendly dashboard to help to visualize the data and provide a tool for comparison based on defined metrics. The weighted values of each metric would make it easy to understand, across the board, how the values of each metric stack up against one another. As explained, the weighted values in its current form do not indicate that

Geography X is better than Geography Y, however, as discovered through the process, there are in fact some metrics that are in fact more important than others in the core DNA of a 15-minute city. Therefore, an additional layer of weighting the metrics based on importance of the metric itself will need to be considered. Figure 6 is a mockup of how this dashboard could be visualized.

Beyond the tangible next steps, there are some other important implications of this research:

- How it's relevant to projects/clients- contextualizing references
- Consider how the elements within the “15-minute city” can be shared to educate others.

- Apply the study’s methodology to your neighborhood/district to determine if it is a 15-minute city.
- Potentially a tool for understanding the nuance of the data- what are the fundamental metric that would inform

We are constantly working in mixed-use and urban infill projects. We live and breathe walkability/density etc. but a more nuanced understanding of the reality of what the 15-minute city means is critically important. This could be a new approach for our own redevelopment projects to better serve the communities they are in, as well as in how we weave this story into our daily practice.



Figure 6: Mockup of dashboard that could be used to visualize data

REFERENCES

Hawken, Paul (2021). *Regeneration Ending the Climate Crises in One Generation*. Penguin Books

Moreno, C.; Allam, Z.; Chabaud, D.; Gall, C.; Pralong, F. Introducing the “15-Minute City”: Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. *Smart Cities* 2021, 4, 93–111. <https://doi.org/10.3390/smartcities4010006>

Guardian News and Media. (2020, February 7). *Paris may-or unveils ‘15-Minute City’ plan in re-election campaign*. The Guardian. Retrieved from <https://www.theguardian.com/world/2020/feb/07/paris-may-or-unveils-15-minute-city-plan-in-re-election-campaign>

TEDtalksDirector. (2021, January 25). *The 15-minute city | Carlos Moreno*. YouTube. Retrieved from <https://www.youtube.com/watch?v=TQ2f4sJVXAI>

[com/watch?v=TQ2f4sJVXAI](https://www.youtube.com/watch?v=TQ2f4sJVXAI)

Non-cited references:

15-Minute City. Deloitte. (n.d.). <https://www2.deloitte.com/global/en/pages/public-sector/articles/urban-future-with-a-purpose/15-minute-city.html>

The 15-minute city - catella.com. Catella. (n.d.). https://www.catella.com/globalassets/global/mix-germany-corporate-finance/15minuten_en.pdf

The 15 minutes-city, a sustainable solution for postCOVID19 cities? de Valderrama, N. M. F.; Luque-Valdivia, J.; Asequinolaza-Braga, L. *Ciudad y Territorio Estudios Territoriales*; 52(205):653-664, 2020.



Ibrahim Desooky

MIAMI

MEMORY, EMOTION AND AWE IN THE ALHAMBRA & SAGRADA FAMILIA

Developing a methodology to quantify
cognitive behaviors in architectural space

ABSTRACT

Currently, architectural design practices do not commonly test the emotional, memorable and “awe-factor” behaviors (cognitive factors) of targeted end users. Collecting, quantifying and modeling these data could give designers new meaning for understanding various cognitive behaviors that can be influential during the design process or post occupancy. Two data collection methods of assessing these three distinct cognitive factors were examined to determine which method resulted in more accurate outcomes. The data collection involved conducting *intercept interviews* in the Alhambra and Sagrada Familia – anecdotally, two of the most visited destinations in Spain.

The first method relied solely on memory recall, while the second prompted participants to close their eyes for thirty seconds before verbalizing the element they recall the most – this method is called “memory scanning.” This prompt aimed to push past the limits of short-term memory, enabling users to be more specific about the elements they remember. Both methods evaluated respondents’ sense of “happiness” (the emotion) and “awe” (awe-factor) and asked which areas stood out most for each respondent to assess memory. The second method of prompting participants resulted in an overall more accurate assessment of cognitive

behaviors, hence highlighting an approach that can be of great assistance to designers.

CONTEXT

User experience research in the architectural profession is prominent. However, empirical research on memory, emotion and awe are not frequently visited in the literature. Data-driven research has been pursued focusing on biometrics, like eye-tracking and facial recognition. Cognitive analysis of memory, emotion and awe are less commonly explored due to the difficulty of quantifying and representing them visually. Pulling from the tech and product design industries, understanding the users’ predilections can lead to greater project success and higher value. Don Norman, former vice president at Apple and current professor at UC Berkeley, once said:



“Cognition attempts to make sense of the world; emotion assigns value...Cognition provides understanding; emotion provides value judgements.”

– (Norman 2013: 47)

From the archives of National Geographic, a recent update of a report on memory and how it works quotes:



“Emotions like fear, anger, embarrassment, happiness, and love strengthen our ability to encode and recall events.”

– (Karras 2021:29)

Irene Lok, a senior associate and researcher at CRTKL’s Seattle office, investigated biometrics and neurological nuances for architectural users, specifically eye-tracking and other methods of analysis. In an interview about her work, she mentioned:



“Studying the hard data was powerful, but studying the soft data was a missed opportunity.”

– Irene Lok, CRTKL Seattle

This feedback was a major catalyst and was synergistic with the gaps of knowledge surrounding the intangible concept analysis of architectural spaces, further branding the study to focus on the three concepts of memory, emotion and awe, from users of prominent architecture.

Awe has been defined as an emotional response to perceptually vast stimuli that overwhelm current mental structures, yet facilitate attempts at accommodation (Shiota, Keltner and Mossman, 2007:1) Emotions like fear, anger, embarrassment, happiness and love strengthen our ability to encode and recall events (Karras 2021:29). The most important distinction between awe and happiness is that awe is focused on stimuli that are external to the self, are “self-diminishing” and therefore shift the focus from oneself towards the event or phenomenon they are experiencing. Awe should lessen focus on one-self and increase focus on the vastness of the stimuli being experienced.

We are better at remembering things that engage more than one sense (Karras, 2021: 31). According to a 2018 study from the University of Regensburg, Germany, participants were able to identify objects that they had touched but not seen, at 79% accuracy and those who identified objects based solely on visual memory scored 73% accuracy. Music elicits emotions, ensuring that

we will remember it (Karras, 2021:30). Olfactory (smell) memory, unlike any other sensory input, goes directly to the regions of the brain that process emotions and memory -- the amygdala and hippocampus.

According to ArcGIS (ArcGIS, 2019: Storymaps) the eighth most visited monument in the world is the Alhambra, in Granada, Spain. This building was chosen as an ideal case for study for 3 reasons: central global location with proximity to three different continents, access to a translator and the focus on interior space instead of exterior facades. Previous investigations focus highly on façade research (Sussman et. Al., 2019: 157-158), and this study sought to move past façade-based idiosyncrasies and delve into three-dimensional user experience analysis.

APPROACH

Understanding memory and the type of recall that would be most valuable for analysis helped shape the two methods of questioning and prompting users for their responses.

Working memory functions best when we can tune out signals that are not related to our present task (Karras 2021). Short term memory is the ability to remember a short list of things within a short span of time – usually no longer than thirty seconds or even less (Karras

2021). The study aimed to push past the temporal limits of short-term memory by prompting users to close their eyes for thirty seconds and then mention the element they remember the most. This gave room for their cognition to dig deeper into their working memory to pull the true elements that they remembered the most. This type of mental exercise will be referred to as prompted *memory scanning*.

The approach to gathering the findings involved first doing a pilot test in a local place of high foot traffic, to understand the frequency of scans per geographic location, the proper phrasing for the questions and the method of representation for the results. The place chosen for study was Lincoln Road mall, an outdoor public avenue of high foot traffic. The results yielded no awe responses and further emphasized the need for studying a monumental architecture to capture that behavior in users.

Two methods of questioning (Figure 1) were used for comparative analysis, one being a *prompted*, highly directed method and the other being *unprompted* and open ended.

Method 1 – prompted, (memory scanning) was more effective in yielding specificity of user predilection, regarding the most favorable architectural elements.

Method 2 – unprompted, (memory surveying) yielded lower specificity of responses and faulted by allowing users to comment on their overall experience within their response. The responses showed lower levels of strong happiness in Method 1 (scanning), with higher levels of neutrality towards the most memorable architectural elements. Similarly, Method 1 (scanning) yielded lower levels of awe than Method 2 (surveying), with higher levels of no awe. When comparing the memory scans of the two buildings, the Alhambra yielded higher levels of strong happiness than the Sagrada Familia, with lower levels of neutrality. On the contrary the Sagrada Familia yielded higher percentages of Extreme Awe, while the Alhambra showed higher levels of Awe.

Analysis of the responses involved two methods – conventional data visualization techniques, i.e., charts, graphs and tables, along with 3D modeling of the findings and geographical locations for spatial analysis. This method of data sculpting was constructed by showing every memory in the form of an image, the emotional weight as a colored line surrounding the memory and the awe-factor represented as a colored sphere on top of the memory image. Layering the response data allowed for a rich spatial

understanding of the user experience. This methodology could be used for several cognitive behaviors, however the study aimed to capture the depths of memory, emotion and awe alone.

In the final study, we used two methods of questioning visitors – a prompted method and an unprompted method. Method 1, or the prompted method, involved a deeper and more instructed user analysis, while method 2, the unprompted method, involved a simpler way of questioning and documenting user insight. Method 2 was later used as a comparative dataset to validate the capabilities of method 1. Method 1 will be referred to as “memory scanning” and method 2 will be referred to as “memory surveying” in the report.

To mitigate language barriers and reduce the skewing of data towards English language speakers, Spanish and Italian were used, when necessary, with the aid of a translator, more commonly in the Alhambra Nasrid Palace. The Sagrada Familia had a much higher percentage of international tourists with the highest percentages coming from the UK, US and Spain, while the Alhambra’s highest percentage of visitors were Spanish, constituting 19% of respondents.

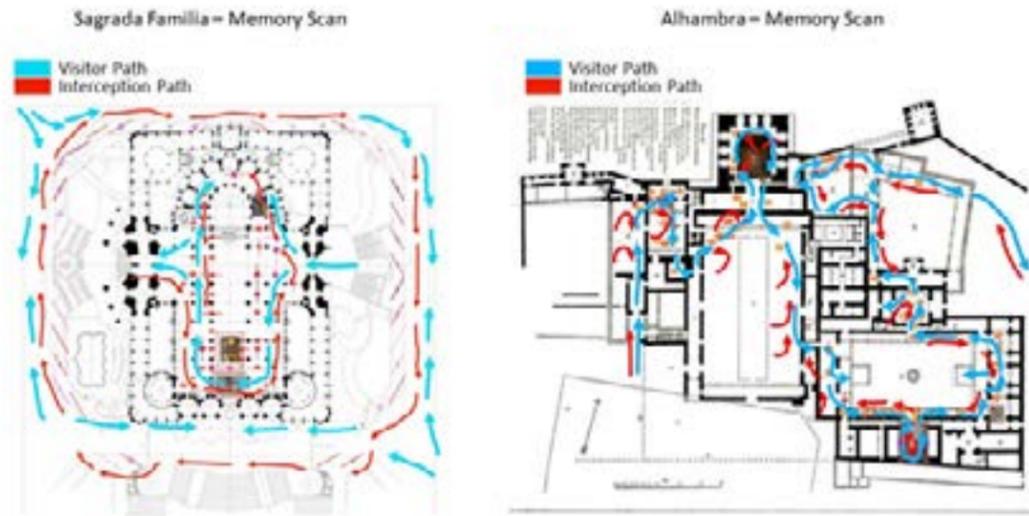


Figure 1: The “against the grain” method of guest flow interception allowed for interspersed collection of responses. This was the method used to conduct the intercept interviews.

Regarding gender and age groups, the goal was to capture balanced frequency distributions of each age group, yet notably the 20-30 age group was more receptive to the memory scan exercise than older age groups. Sampling the 40+ age denominator was more challenging due to their lack of interest in participation. In terms of gender, the aim was to capture a balanced distribution of responses per gender identity, however females were more abundant in all three population samples, and it is evident that they were more inclined to participate in all three studies.

Sample size calculations were done with pre-pandemic visitor numbers in mind, however 2020 yearly, daily and hourly numbers were calculated based on the hourly occupancy limits of each venue during pandemic regulation. The margin of error ranged from 3.5% to 8.1% with a confidence level of 95% for all three studies. See Table 1 for a better understanding of how the calculations were done.

| Venue | 2019-Number of Visitors per YEAR | 2020-Number of Visitors per YEAR | 2019-Number of Visitors per DAY | 2020-Number of Visitors per DAY | 2019-Number of Visitors per HOUR | 2020-Number of Visitors per HOUR | Number of Study Participants | Confidence Level, Margin of Error |
|--|----------------------------------|----------------------------------|---------------------------------|---------------------------------|----------------------------------|----------------------------------|------------------------------|--|
| Sagrada Familia Interior (11-hour access) | 4,700,000 | 600,000 | 12,000 | 1,640 | 1,300 | 182 | 82 | 95% Confidence level, 8.1% Margin of Error |
| Sagrada Familia Exterior (24-hour access) | 20,000,000 | 3,000,000 | 54,790 | 8,220 | 2,280 | 343 | 193+50+243 | 95% Confidence level, 3.5% Margin of Error |
| Alhambra Interior (Nasrid Palace) (11-hour access) | 2,300,000 | 2,190,000 | 7,120 | 6,600 | 790 | 600 | 100 | 95% Confidence level, 6.8% Margin of Error |

Table 1: This table analyzes the yearly, daily, and hourly visitors in the two locations that were studied, with pre-pandemic and post-pandemic changes taken into consideration. The number of study participants yielded high confidence in the data and between 3.5% and 8.1% margins of error.

FINDINGS

In the Sagrada Familia, the responses showed lower levels of “strong happiness” in Method 1 (memory scanning) than Method 2 (memory surveying), with higher levels of neutrality because users focused more on specific elements rather than the memorability of the full experience. Similarly, Method 1 (scanning) yielded lower levels of “awe” than Method 2 (surveying), with higher levels of “no awe”. When comparing the memory scans of the two buildings, the Alhambra yielded higher levels of “strong happiness” than the Sagrada Familia, with lower levels of neutrality. On the contrary, Sagrada Familia yielded higher percentages of “Extreme Awe,” while the Alhambra showed higher levels of “Awe”. Some of the most frequent memories of the Sagrada Familia interior were stained glass (specifically red in color), colored light filtering through the space, tree-like columns, intricate sculptures, impressive size, ceiling intricacy and

the contrast between smoothness and detail throughout, respectively. On the exterior, the most memorable elements were the fruit sculpture tower pinnacles, sculptures in the façade, bone-like structure at the entry, the 4 towers at either entry, angled columns, contrast in materiality and intricacy and stone coloration, respectively. In the Alhambra Nasrid Palace interior, the top memories were the muqarnas archways, wall carvings, garden, “mashrabiya” (lattice) windows, expansive views, turquoise and blue muqarnas, geometric wood ceiling, fountain at the Court of Lions and the red stone in the walls, respectively. The following executive summary coupled with data visualizations help to tell the story of the responses that were collected.

Demographics:

| Visitor Country of Origin: | | |
|--------------------------------|------------------------------|-----------------------|
| Sagrada Familia Memory Survey: | Sagrada Familia Memory Scan: | Alhambra Memory Scan: |
| US – 15% | ESP – 16% | ESP – 19% |
| UK – 13% | UK – 12% | US - 10% |
| ESP – 10% | US - 12% | FRA & GER - 7% |

| Visitor Age: | | |
|--------------------------------|------------------------------|-----------------------|
| Sagrada Familia Memory Survey: | Sagrada Familia Memory Scan: | Alhambra Memory Scan: |
| 20-30 – 28% | 20-30 – 33% | 20-30 – 27% |
| 40-50 – 27% | 30-40 – 27% | 40-50 – 26% |
| 30-40 – 24% | 40-50 – 24% | 30-40 – 24% |

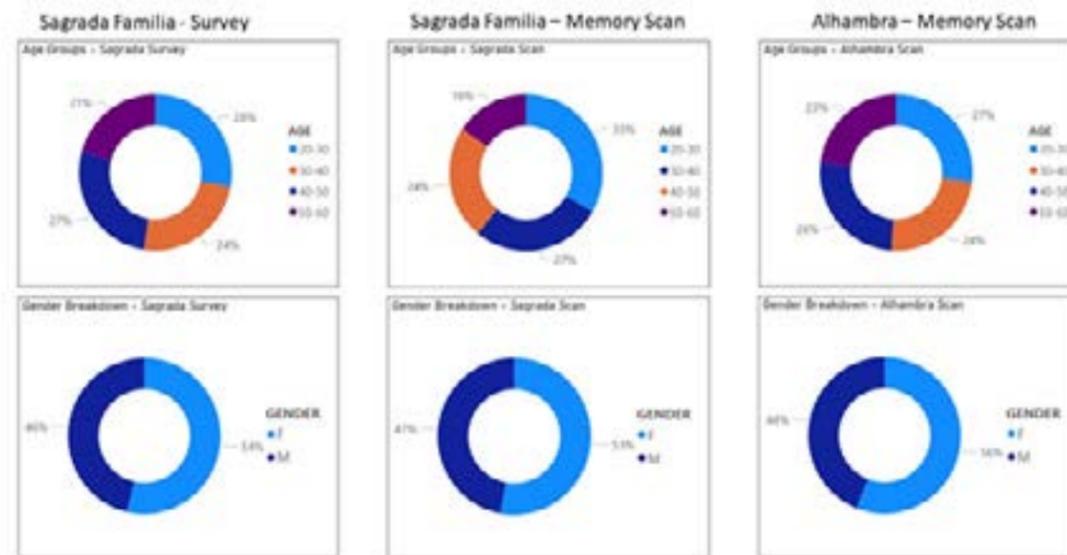


Figure 3: These charts show the age and gender breakdowns for all three studies. There was a balanced representation of age groups and genders across the board. (Desooky, 2022: PowerBI)

Resulting Findings:

| Emotion Percentages: | | |
|--------------------------------|------------------------------|-----------------------|
| Sagrada Familia Memory Survey: | Sagrada Familia Memory Scan: | Alhambra Memory Scan: |
| Strongly Happy - 33% | Strongly Happy – 10% | Strongly Happy - 32% |
| Happy – 35% | Happy – 43% | Happy – 40% |
| Neutral – 27% | Neutral – 41% | Neutral – 27% |
| Unhappy – 5% | Unhappy – 6% | Unhappy – 1% |

| Awe Percentages: | | |
|--------------------------------|------------------------------|-----------------------|
| Sagrada Familia Memory Survey: | Sagrada Familia Memory Scan: | Alhambra Memory Scan: |
| Extreme Awe – 41% | Extreme Awe – 33% | Extreme Awe – 20% |
| Awe – 44% | Awe – 37% | Awe – 50% |
| No Awe – 15% | No Awe – 29% | No Awe – 30% |



Figure 4: These charts show the emotion and awe-factor percentages for all three studies. Method 2 yielded high strong happiness (on the left) while Method 1 yielded the opposite in the Sagrada Familia (middle). This indicates that the method of questioning is important in yielding accurate results and representation of happiness. Method 2 yielded higher Awe values than Method 1. In the Alhambra, the Method 1 analysis yielded “strong happiness” and “happiness” as seen on the right, which compares highly with the emotional results of the Sagrada Familia to the left of it, which uses the same analysis method. (Desooky, 2022: PowerBI)

Awe by Emotion



Figure 5: These charts show the various percentages of awe compared to percentages of happiness, neutrality, and unhappiness. The Alhambra yielded the highest amount of “extreme awe” and “strong happiness”, while Method 1 of the Sagrada Familia yielded the highest “no awe” and “neutrality”. However, in the Method 2 study it yielded the highest percentage of “extreme awe” with “strong happiness”. This is due to the user being prompted to think about the building/experience as a whole, as opposed to specific elements and their reaction to them. This begs the question of what is more valuable to designers – how users feel about the specific architectural elements, or how they feel about the whole experience. Clearly, users have different reactions to either. (Desooky, 2022: PowerBI)



Figure 5: These charts start to itemize and quantify the specific emotions and reactions that appeared most frequently amongst the responders of each study. The most frequent emotions and reactions were Warmth, Curiosity, and Excitement; Staring Up. (Desooky, 2022: PowerBI)

Hierarchy of Memories & their Percentages

| Additional Emotions: | | |
|--------------------------------|------------------------------|-------------------------|
| Sagrada Familia Memory Survey: | Sagrada Familia Memory Scan: | Alhambra Memory Scan: |
| Warmth | Curiosity | Excitement & Staring Up |
| Nostalgia | Amazement | Curiosity |
| Curiosity | Excitement | Impression |
| Impression | Desire to touch | Peace |
| Invitation | Fun | Amazement of detail |
| Surprise | Pleasance | Nostalgia |
| Ambivalence | Memento Mori | Relaxation |
| Majesty | Sadness | Sunlight |
| Overwhelm | Surprise | Warmth |
| Rediscovery | Nostalgia | Absorption |
| Relaxation | | Admiration |
| Curiosity | | Adoration |

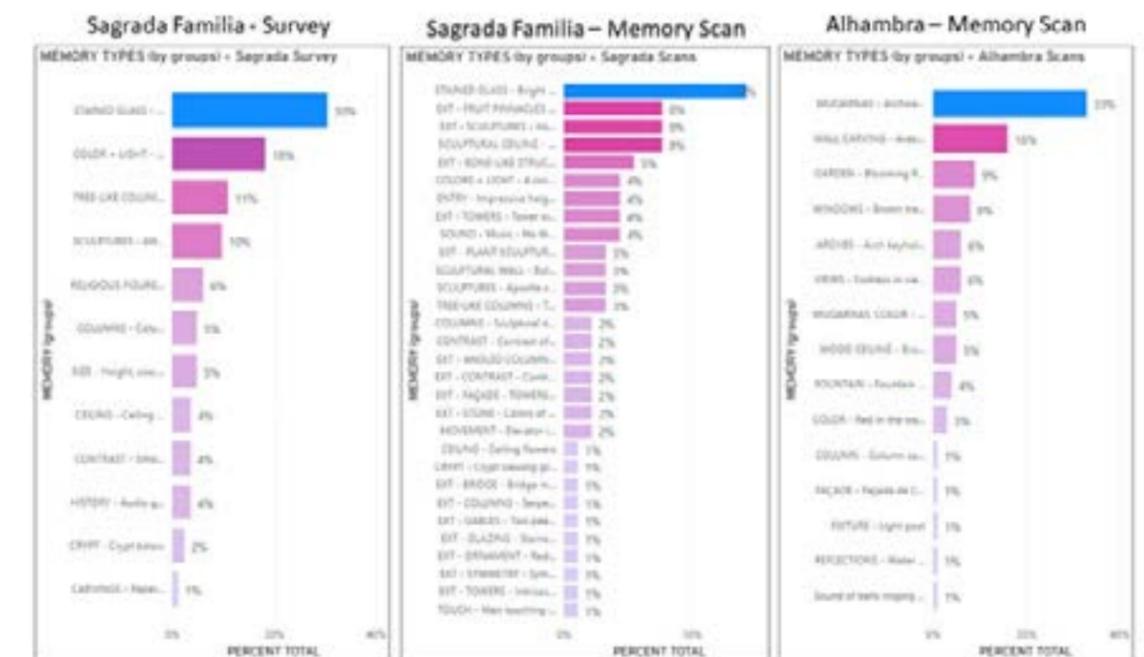


Figure 6: These charts begin to itemize and quantify the specific elements that were most memorable for the responders of each study. The top three elements across the board were stained glass in red, stained glass filtering sunshine, and the highest response at the Alhambra was the Muqarnas Archways. (Desooky, 2022: PowerBI)



Figure 7: These isometric views show the 3D models of the two buildings that were created to showcase the how memories(images), emotions (colored line around the image) and awe (sphere on top of image) could be conglomerated into a data sculpture. The left is the Sagrada Familia, and the right is the Alhambra. (Desooky, 2022: PowerBI)

Alhambra Enscape 3D Model

[Click to play](#)



Sagrada Familia Enscape 3D Model

[Click to play](#)

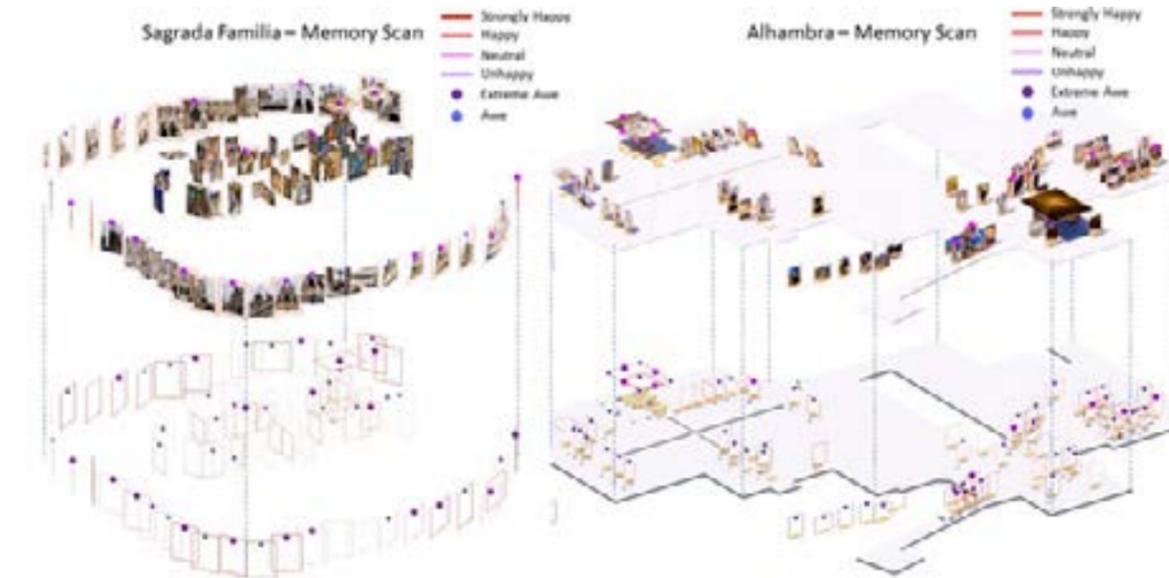


Figure 8: This exploded axonometric shows how the results compare to each memory in the data sculpture. If you look closely, the dark red lines represent strong happiness, while the dark purple represent extreme awe. On the other hand, the light pink areas and memories without a sphere on top represent area of little awe or emotion. Visit the animations below for a closer look. (Desooky, 2022: PowerBI)

CONCLUSIONS, IMPLICATIONS FOR PRACTICE, AND NEXT STEPS

The data sculpture technique is successful in showcasing many layers of intangible information, with the prompted study (memory scan) being more successful in capturing detailed memory, emotion and awe responses by prompting users to extract deeper insight from beyond the limits of short-term memory. It is possible to quantify intangible concepts like memory, emotion and awe, in the context of design. This is useful during the design process through virtual and augmented reality user research, as well as post construction and post occupancy evaluation, as seen in this study. The methodology is customizable as needed, depending on which behavior is meant to be studied. Furthermore, the study aimed to shift designers' focus from the client to the end user. The methodology is already being used by CRTKL design teams to showcase how human centered projects can benefit from interviewing end users, adding value and dimension to concept and schematic design of ambitious human-centered projects.

In summary,

- Memory scanning is the process of directing users-in-space to identify the specific architectural/spatial

elements that induce the strongest behavioral reactions.

- “The most real things in life are the things we can’t see.”
- The data sculpture technique is successful in showcasing many layers of intangible information.
- The prompted study (memory scan) is more successful in capturing detailed memory, emotion and awe responses.
- It is possible to quantify intangible concepts like memory, emotion and awe, in the context of design.
 - During the design process (Predesign, Schematic Design, Concept Design, Design Development)
 - Post construction (Post Occupancy Evaluation, User Experience Analysis)
- The methodology is customizable as needed, depending on which abstract concepts need to be studied – cognitive behaviors, learning, motivation, perception, etc.
- It will help shift the focus of designers from the client to the end user. This is crucial in bolstering the efficacy of our professional services, transforming project delivery from being client driven to being data driven and end user cognitive.
- The study can be useful to these disciplines/groups:

- All architecture – specifically hospitality, civic/public, transportation, workplace
- PLUD – urban planning and high traffic public space
- Interior Design – Highly relevant to our interiors teams
- CX & UX Design Groups
- Academia – Psychology in Architecture

REFERENCES

Karras, T. (2021). *Memory: What It Is, How It Works, and Ways You Can Improve It*. National Geographic.

Shiota, M. N., Keltner, D., & Mossman, A. (2007). The nature of awe: Elicitors, appraisals, and effects on self-concept. *Cognition and Emotion*, 21(5), 944–963. <https://doi.org/10.1080/02699930600923668>

Sussman, Ann & Hollander, Justin. (2021). *Cognitive Architecture: Designing for How We Respond to the Built Environment*. Second Edition. Routledge. 10.4324/9781315856964.

ArcGIS. (2019) *10 Most Visited Monuments in the World*. Esri, HERE, FAO, NOAA. <https://www.arcgis.com/apps/MapTour/index.html?appid=88d5711fdb0849529be3a97624c6a4e0>



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FROM AUTOMOTIVE TO AUTOMATED

How will automated vehicles impact urban outdoor design?

ABSTRACT

What are the implications of self-driving vehicles in urban settings? The purpose of this research is to account or foresee how people will utilize autonomous vehicles, to give us a perspective on what to design for in outdoor urban spaces. Just as smartphones brought a revolution in the way we communicate and interact with each other, autonomous vehicles might change how people interact in the urban environment. Will autonomous vehicles drive people's behavior? Or will people stick to an antiquated use of vehicles? Using a person-driven car in an automated city in 50 years might be like driving a horse carriage in a city now. People's behavior gives us an idea of how automated vehicles will impact urban infrastructure. If people are fully confident in autonomous vehicles, then it is possible that autonomous fleets will dominate the urban setting. Automated traffic might be more efficient, and this will result in having more space for other outdoor activities.

CONTEXT

Electric vehicles can be observed with abundance in urban settings, and they are taking over the roads. But they are not just any car, not even the fact that they are electric is that important. They have the capability of self-driving, which is impressive, but are we fully

understanding the implications of having automated vehicles in a city? Sales of new electric vehicles are increasing annually across the globe (IEA, 2020). The more electric vehicles are manufactured, the cheaper they will become, making it more affordable for the public. The current state of government policies to promote electric vehicles is significantly positive. Governments are pushing policies to reduce the carbon footprint, and the presence of electric vehicles are benefiting from such regulatory changes. That motivated us to research electric vehicles policies from various cities across the US. Below is a summary at the federal scale, as well as select state policies.

Federal:

- Tax credit from \$2,500 up to \$7,500 (IRS, 2022).
- Target of 50% of new vehicles sales to be electric by 2030 (The White House, 2021).

Washington, D.C.:

- Offers excise tax exemption for purchase of electric vehicles.
- Reduced Registration Fee for Alternative Fuel and Fuel-Efficient Vehicles
- Zero Emission Vehicle (ZEV) Deployment Support:
 - Passenger transportation vehicles to be zero emissions by

2045 (Alternative Fuels Data Center, 2021)

New York:

- Electric vehicles take advantage of discounts on toll roads and HOV lane access.
- Zero Emission Vehicle (ZEV) Requirements:
 - Passenger transportation vehicles to be zero emissions by 2035
- Plug-In Electric Vehicle (PEV) and Charging Infrastructure Support:
 - NY program to allocate up to \$250 million to support charging infrastructure throughout the state. (Alternative Fuels Data Center, 2021)

California:

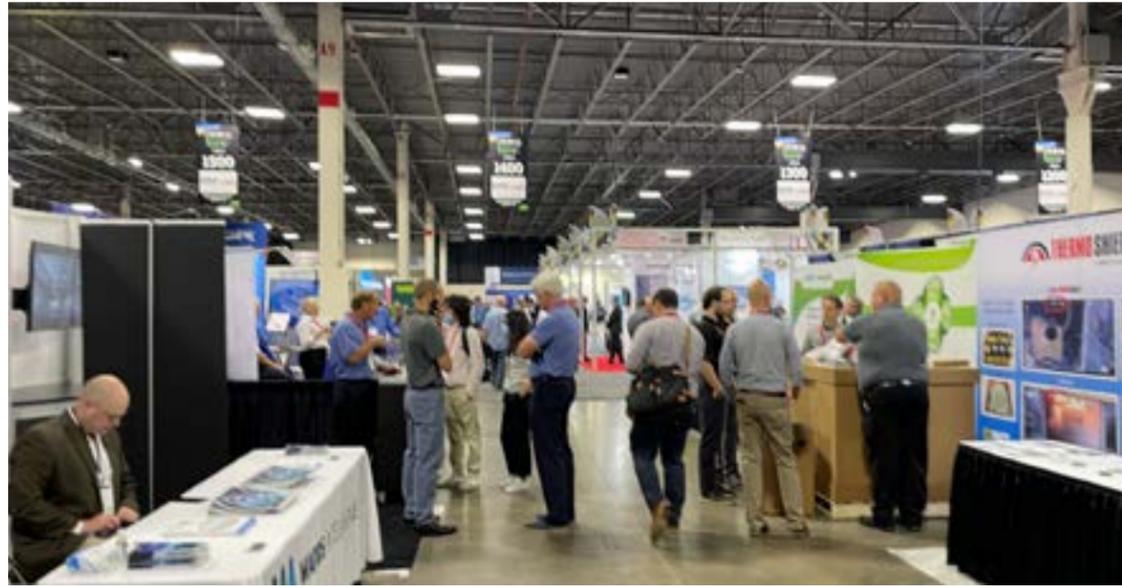
- Electric Vehicle (EV) Rebate Program:
 - Offers sales rebates of up to \$750 for the purchase or lease of a new all electric or plug-in hybrid electric vehicle.
- Zero Emissions Executive Order N-79-20:
 - Bans the sale of new gas-powered vehicles by 2035 (Alternative Fuels Data Center, 2021) (Executive department state of California, 2020)

Various car and tech companies are leading electric self-driving vehicle technology. Tesla has become more familiar in the US, and they currently

have the most self-driving electric vehicles on the roads (Roland Irle, 2021). Another tech company investing in automated vehicle technology is Intel, who are partnering with car manufacturers to provide computer chips for self-driving vehicles (Chris Courtney, 2021). Waymo, originally the Google self-driving car project, is one of the first companies to start testing self-driving vehicles without anyone at the steering wheel (Chris Courtney, 2021). Cruise is a subsidiary of GM that is starting to test self-driving vehicles for an autonomous ride-hailing service. Apple is also getting into the self-driving industry and is scheduled to start production in 2024 (Chris Courtney, 2021).

APPROACH

The goal of this research is to see how people will behave and interact with autonomous vehicles. We started by gaining insights of the industry's focus, by attending North America Electric & Hybrid Vehicle Tech Expo. We heard speakers talk about the vision of the future for their industry. The heavy-duty sector, like trucks/ school buses is more likely to go all electric because mass fleets are more economic (electric is 1/4 cost of gasoline) and manageable (their point-to-point feature). It could push the small car market.



Figures 1 & 2: 2021 North America Electric & Hybrid Vehicle Tech Expo

Venue: North America Electric & Hybrid Vehicle Tech Expo, Novi, MI 48374

- True electrification is happening, faster charging ability will be needed, especially charging at home.
- There are several EV Intenders, who can push the improvement of public infrastructure. Customers do not want to compromise where they can go because of charging ability.
- When EV becomes the mainstream, will user's driving habits be changed or it is the other around – user will change EV design?
- Federal/state level actions are needed to accelerate electrification, private capital also need to be engaged.
- The heavy-duty sector, like trucks/ school buses is more likely to go all electrification because mass fleets are more economic (Electric is ¼ cost of gasoline) and manageable (their point-to-point feature). It could push the small car market.

We also interviewed people, including current EV owners, and prospective EV owners on their thoughts about their attitude to autonomous driving.

Current EV owner: Middle-aged male Architect, Tesla Model 3 owner

- Feels like the way they think about of travelling have been changed dramatically, need to plan for charging.
- Tesla is like an iPhone with four wheels.
- Only used autopilot function during uniform-speed cruise, straight line non-stop driving highway. Never used it in an urban environment because of safety concern.

Prospective EV Owner:

- Mentioned their next car would be an electric car; he mentioned his main reason to get an electric car is because of instant torque/speed. He said the speed of an electric car is instant, as opposed to a gas car where the speed is delivered through more processes. Another reason is to be environmentally conscious. One of his concerns of owning an electric car is the driving range (driving distance on a full battery charge).

We decided to conduct a public survey as well, to see how trusting people are in self-driving vehicles. This is the focus of the research to understand how soon people will adapt to this technology in their everyday lives.



Figure 3: 266 Respondents from different regions of the US

The top 3 concerns on owning a self-driving vehicle are safety followed by price:

- Safety Concern 81%
- Price Concern 72%
- Liability 67%
- Charging Infrastructure 48%
- Driving Range 46%

When asked if they would buy a self-driving vehicle if they became more affordable, 47% responded Yes and 50% responded No.

When asked if they would transport a child or elderly family member in a self-driving vehicle without them:

- Very Likely 7%
- Likely 21%
- Unlikely 30%
- Very Unlikely 40%

When it comes to car sharing, when asked if they would share their self-driving vehicle when they are not using it, 17% said Yes, 57% said No, 24% said maybe.

In summary, most people are still hesitant about using or trusting self-driving vehicles. On a scale from 1 (not safe) to 5 (very safe)

- 1 - 17% - responded self-driving vehicles are not safe.
- 2 - 22%
- 3 - 36%
- 4 - 16%
- 5 - 7% responded self-driving vehicles are very safe.

We also investigated cities that have a strategy to give streets/roads back to pedestrian use and urban public spaces.

CASE STUDY: Streets without cars

City: New York

As a hypothesis, once autonomous driving is accepted by the public, it will benefit urban traffic which might transform certain areas to become pedestrian only zone. After Covid lockdowns, the public's reaction to pedestrian only streets was positive as seen by the following examples:

Hong Kong

- Streets: Sai Yeong Choi Street South, Mong Kok, Kowloon
- The busiest portion of the street was pedestrianized all week long from 2000 to 2013, reduces to weekends only starting from 2014
- Program: Dance & concert parties

- Covid lockdown time.
- Open Streets transforms streets into public space open to all
- Open Restaurants is expanding outdoor seating options for restaurants and bars.
- Open Storefronts assists existing ground-floor businesses who want to use outdoor areas temporarily (Winnie Hu-Nate Schweber, 2020)



Figure 4: Open-street restaurant in NYC during COVID lock down



Figure 5: Amsterdam as a “bike city”



Figure 6: Barcelona “Super Blocks”

AMSTERDAM

- 27-step plan to improve the city for cyclists and pedestrians by 2040. Removing 11,200 parking spots by 2025, and using that space for wider sidewalks and bike lanes, trees, and bike parking.
- Redesign roads for better biking, add bike parking at metro stations. (Sasha Brady, 2019)

BARCELONA

- Neighborhood of Poblenou
- Former intersections becomes playgrounds; Parking & car lanes have been replaced with benches and potted plants
- Superblock idea is introduced in 2016– a concept of carving out islands of car-free space by routing traffic around multi-block areas (Ronika Postaria, 2021)

PARIS

- On the first Sunday of each month, the heart of Paris—the 1st, 2nd, 3rd, and 4th arrondissements—shuts down to most traffic, turning streets over from cars to pedestrians and cyclists

FINDINGS

Based on anecdotal evidence, people are accepting of innovative technology once it becomes mainstream.

Based on our survey, people would be willing to share their autonomous vehicle whenever they are not using it. Over the last few years, car sharing companies have become popular over traditional car rental companies (Table 1). If people can make extra income by sharing their autonomous car, they would be more willing to share their car. Because of

| TECHNOLOGY | YEAR ONE | HISTORY | PERFORMANCE IN EARLY PERIOD | PERFORMANCE NOW | INITIAL REASON OF UNACCEPTANCE |
|------------|----------|---------|--|--|----------------------------------|
| AIRPLANE | 1914 | 107 | 23-minute flight operate between St. Petersburg and Tampa, FL, for four months, with approx 1,200 passengers | 38.9 million flights operated globally in 2019 | Safety, Price |
| IPHONE | 2008 | 13 | 6.1 million 1 st iphone sold | 100 million iphone 12 units sold by 2021 | Price, 2G internet compatibility |
| AIRBNB | 2009 | 12 | \$10,000 for the 2009 yearly revenue | 153% compound growth rate from 2009 to 2019 4.7 billion revenue in 2019 | Trust, Safety |
| UBER | 2009 | 12 | 45 million customers use in 2016 | 103 million customers use in 2019 93 million in 2020 | Trust, Safety |
| TESLA | 2008 | 13 | More than 2,400 Roadsters sold | More than 500,000 units of Tesla's vehicle sold in 2020 | Safety, Infrastructure |

Table 1: Public's acceptance of new technology.

convenience, people will go to work in a self-driving car, and they can do other things such as be in office meetings or immersing themselves in the metaverse. Based on people’s willingness to ride-share, car and tech companies will push the autonomous fleet vehicles.

CONCLUSION

Because of the convenience and seamless experience autonomous vehicles can provide, we envision that people will use more autonomous car sharing fleets or autonomous ride-hailing services. There are certain portions of the population that take benefits of autonomous sharing vehicles and prefer not to own cars. Because of automated vehicles, cities will need to implement infrastructure for 100% automated traffic. The benefits of this will be:

- Seamless/efficient traffic flow.
- Reduced traffic lanes.
- Gas stations will be obsolete.
- Significant reduction in parking spaces in buildings, a conservative estimate would be 60% reduction. Our estimate would be 90% reduction because autonomous cars can park themselves somewhere else.
- People who own automated vehicles can share them while they are working.
- No more additional charging infrastructure in office buildings and homes because autonomous cars can go charge themselves somewhere else.

This will give us design opportunities for the following infrastructure (Table 2).



Figure 7: Impacts on urban infrastructure by autonomous driving

| | | IMPACT ON INFRASTRUCTURE | DESIGN OPPORTUNITY |
|--|-------------------------------|---|--|
| | PARKING GARAGE | <ul style="list-style-type: none"> • Automated smart parking system introduced • Reduced area required • Charging infrastructure installed | <ul style="list-style-type: none"> • Give urban space back to public spaces and green areas |
| | ROAD & STREET | <ul style="list-style-type: none"> • Help traffic congestion • Less traffic light required | <ul style="list-style-type: none"> • Less defined boundary between vehicles and pedestrian |
| | CURBSIDE PARKING | <ul style="list-style-type: none"> • Automated smart parking system introduced • Less number required | <ul style="list-style-type: none"> • Less curbside parking give spaces back to street |
| | GAS STATION | <ul style="list-style-type: none"> • Reduced number, eventually eliminated • Converted to charging stations, battery swapping stations | <ul style="list-style-type: none"> • Give spaces back to city • Transfer to other programmed space, improve quality of high way side service |
| | CHARGING STATION | <ul style="list-style-type: none"> • Large number of charging station required • Integrated with other parking infrastructure | <ul style="list-style-type: none"> • Integrated with other parking infrastructure, solar charging, etc. |
| | BUS & COACH | <ul style="list-style-type: none"> • More economic and environmental friendly | <ul style="list-style-type: none"> • Smaller bus/coach terminal in the city |
| | LOADING & DELIVERY | <ul style="list-style-type: none"> • More economic and environmental friendly | <ul style="list-style-type: none"> • Less loading dock area required for buildings |
| | TRAFFIC LIGHT | <ul style="list-style-type: none"> • Less number needed once vehicles are automated | <ul style="list-style-type: none"> • Traffic light might like telephone booth and be eliminated from the city |

Table 2: Impacts of Autonomous Vehicles on Infrastructure and design opportunities.

NEXT STEPS AND IMPLICATIONS FOR PRACTICE

To test our findings, we used Dupont Circle in Washington DC as a case study to reimagine how the neighborhood will look in an automated city. Dupont Circle, as a popular residential area with restaurants and retails in downtown DC, is planned within the historic L’Enfant urban grid.

In our proposal, based on this idea, traffic is smooth and some streets could be closed to be pedestrian only. We envision

that the neighborhood will be divided and reorganized as several super-blocks. Each super block becomes bike and pedestrian accessible only. That will give the opportunity for streets and street intersections to be public spaces like parks and playgrounds. Each super-block may only need one garage with charging stations. People don’t have to park and charge their car at home but have a shared parking charging station. Bikes, scooters, autonomous AI delivery system may be the new traffic inside the super-block.

The next steps could be taking all the conclusions of our research and producing concepts on a larger city scope. Understanding the impacts of autonomous vehicles on infrastructure and the design opportunities revealed in this study offers insight for designing future cities with flexibility and adaptability in mind.



Figure 8: Dupont Circle is a popular residential neighborhood with lively dining and nightlife in Center Washington, DC.



Figure 9: A future Dupont with superblocks.

REFERENCES

IEA (2020), Global EV Outlook 2020, IEA, Paris <https://www.iea.org/reports/global-ev-outlook-2020>

IRS (2022), Plug-In Electric Drive Vehicle Credit (IRC 30D), <https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d>

The White House (2021), FACT SHEET: President Biden Announces Steps to Drive American Leadership Forward on Clean Cars and Trucks | The White House

Alternative Fuels Data Center (2021), District of Columbia Laws and Incentives, <https://afdc.energy.gov/laws/all?state=DC>

Alternative Fuels Data Center (2021), New York Laws and Incentives, <https://afdc.energy.gov/laws/12700> <https://afdc.energy.gov/laws/12002>

Alternative Fuels Data Center (2021), California Laws and Incentives, <https://afdc.energy.gov/laws/12530>

Executive department state of California (2020), EXECUTIVE ORDER N-79-20, <https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf>

Roland Irlle (2021), Global EV Sales for 2021, <https://www.ev-volumes.com/>

Chris Courtney (2021), Behind the Wheel, Five industry giants leading the self-driving car market, <https://blog.carvana.com/2021/04/five-industry-giants-leading-the-self-driving-car-market/>

Winnie Hu-Nate Schweber (2020), Will Cars Rule the Roads in Post-Pandemic New York?, The New York Times, <https://www.nytimes.com/2020/08/10/nyregion/nyc-streets-parking-dining-busways.html>

Sasha Brady (2019), Amsterdam's 27-step plan to become more bike and pedestrian-friendly, Lonely Planet, <https://www.lonelyplanet.com/articles/amsterdam-car-free-plan>

Ronika Postaria (2021), Superblock (Superilla) Barcelona—a city redefined, Cities Forum, <https://www.citiesforum.org/news/superblock-superilla-barcelona-a-city-redefined/>



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IMPLICATIONS OF LAST-MILE DELIVERY TECHNOLOGY ON RETAIL IN URBAN ENVIRONMENTS

Adapting retail stores and urban infrastructure to recent trends using last-mile delivery technology

ABSTRACT

The goal of this research is to understand recent trends in retail shopping behaviors and explore opportunities to adapt retail design and urban settings to future consumer needs using last-mile technology. Multiple sources show a growing need for faster and cheaper online deliveries and shifting consumer behaviors: those who used to shop in-person at a physical location are now wanting to browse products using online platforms to have their purchases delivered at their front door, or easily picked up from a nearby area. Advances in software engineering for online delivery platforms, as well as in urban infrastructure and logistics, increased the efficiency and speed of deliveries. Technologies of various types and scales, ranging from small circulating droids to flying drones and largely automated distribution centers, have allowed for retailers to produce, organize, and ship products with less time and fewer costs.

In this report, we briefly describe different types of retailer groups and speculate on how retailers may need to adapt their physical store designs and delivery processes to remain competitive in the e-commerce market. We focus on brick and mortar retailers, as these are likely to be most highly impacted by the shifting trend from in-person to online shopping. We also provide an idea on which technologies are likely to

dominate in the next five to ten years based on statistics, and how these are utilized within distribution centers, called “Micro-Fulfillment Centers” or MFCs. We visualize diagrams showing potential changes in retail store design to fulfill e-commerce needs. Then, we summarize impacts of these changes on both retailers and consumers. Finally, we present a few points that are worth exploring as a next step that would enrich this research effort.

CONTEXT

The COVID-19 pandemic has intensified the trend of online shopping. We have witnessed in the past two years, growing numbers in online retail orders in the U.S. with a near spike in e-commerce in 2020, compared to 2019 (Fig. 1) (Digital Commerce 360, Jan. 29, 2021).

Overall, this is a topic that is at the confluence of three realms: the urban environment, retail design and logistics of e-commerce (Fig. 2).

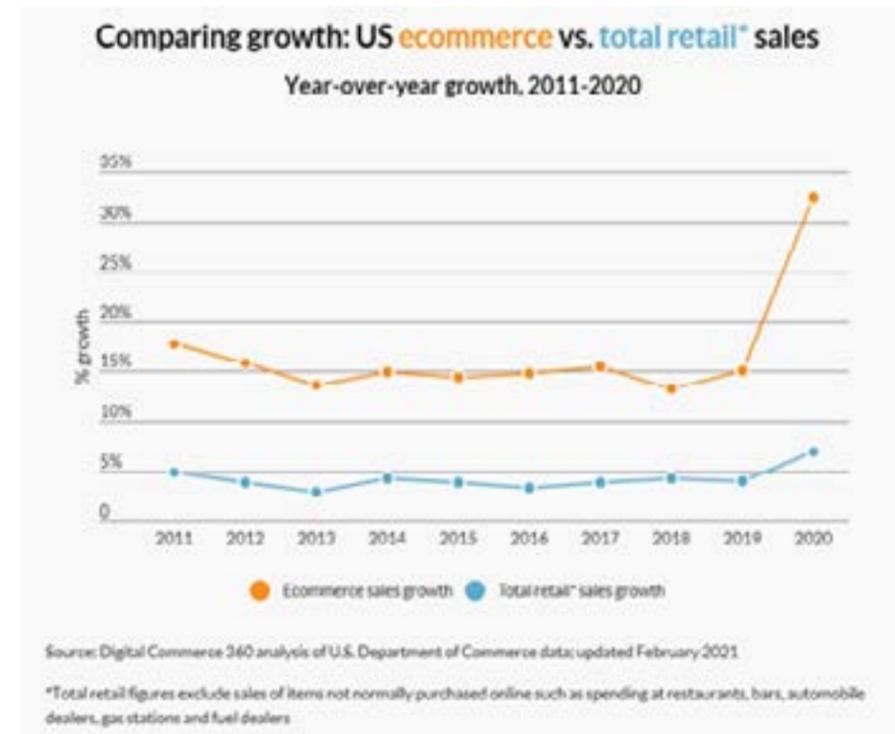


Figure 1: Growing e-commerce trend in the U.S. Image Source: Young, J. (2021, February 19). A decade in review: E-commerce sales vs. total retail sales 2011-2020. Digital Commerce 360.

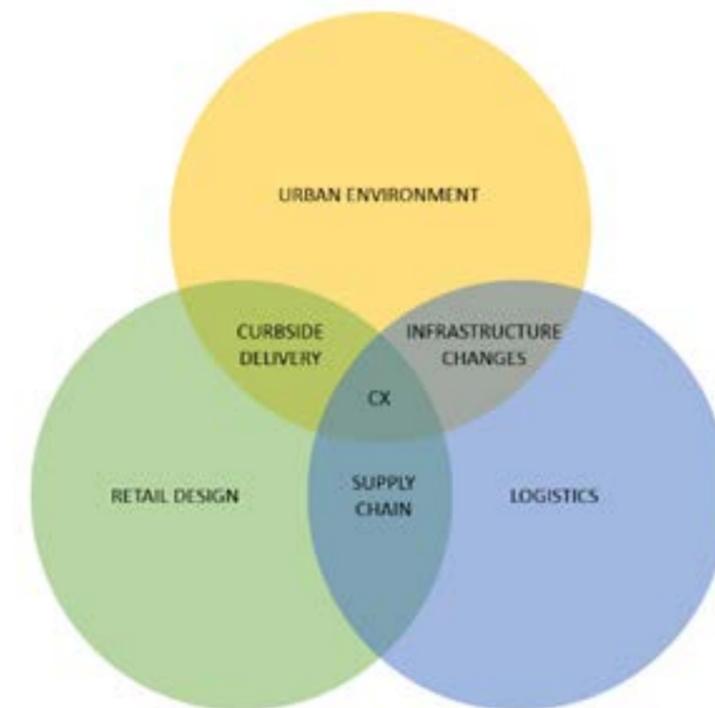


Figure 2: Premise of the research

Growing Urban Population

It is estimated that about one third of the human population is going to reside in urban centers and cities (Pasantez 2018). Along with the influx of people in the cities as seen over the last few decades, there has been an increase in demand and growth in e-commerce and consumer goods. Companies like

Amazon and Alibaba have changed the way we humans consume goods and interact with shopping online. In the past decade, e-commerce sales have almost tripled; and the pandemic has resulted in an aggressive change in the relationship between retail and the average urban consumer.



Figure 3: Project Futures and their use. Courtesy: World Economic Forum (Hillyer, 2020)

There is a growing need for faster and cheaper delivery services or systems, and thus a need to automate last mile delivery as it is the most expensive step of the supply delivery chain, amounting to almost 50% of the overall cost of delivery (Joerss et al. 2016).

What is “last-mile”? The last mile refers to:



“Last-mile delivery is the final stage in the network of courier, express, and parcel companies.”

(Schröder et al. 2018)

It is usually the most complex and costly step in the delivery chain.

What are the existing last-mile delivery options? (Joerss et al. 2016)



Today's Model:

A dedicated delivery person employed by the parcel delivery service provider picks up the parcels at a consolidation point, e.g.: delivery base, and delivers them directly to the recipients. Large vans are typically used as delivery vehicles.” (Joerss et al. 2016)



Bike Couriers:

Couriers employed by the parcel service provider serve a small number of parcels by bike. Today, this is often seen in point-to-point delivery, especially for B2B documents and prepared food.” (Joerss et al. 2016)



Droids:

Small autonomous vehicles, only slightly larger than a regular parcel, deliver parcels to the doorstep. These vehicles are relatively slow at 5 to 10 km/hr and use the sidewalk rather than the street to reach their destination. Such droids also need to be supervised, but due to their size and low speed, developers currently believe that a single supervisor could manage 50 - 100 of them.” (Joeress et al. 2016)



AGVs:

Autonomous Ground Vehicles deliver parcels without any human intervention. Customers are notified of the exact arrival time. Upon their arrival at the door, customers are asked to pick up the parcel from the specified locker mounted on the van or truck – picture a mobile parcel locker. Granted, such vehicles would need to be supervised. We assume

that a central supervisor could manage roughly 8 t- 10 AGVs.” (Joeress et al. 2016)



Drones:

Autonomous aircrafts, eg: copters or vertically starting planes, carry parcels (upto 15 kg) to their destination along the most direct route and at relatively high average speed. Like droids and AGVs, they too need to be supervised. We believe that one supervisor per roughly eight drones is a reasonable assumption.” (Joeress et al. 2016)

Which last-mile technologies are likely to dominate in the future?

According to a study on the future of last mile delivery by McKinsey & Company, the technologies that are likely to dominate in the next decade are drones in low to average density rural areas, AGVs with lockers in average to high density urban areas, and bike couriers or droids in high density urban areas (Joeress et al. 2016) (Fig. 4).



Figure 4: Delivery Models. Courtesy: McKinsey & Company (Joeress et al. 2016)

APPROACH

For this report, we followed a secondary research methodology. We collected data through online articles and interviews with experts in the retail, urban planning, and technology fields. Our data collection and conversations shed the light on existing concepts related to last-mile delivery, current and future e-commerce trends, and assumptions on how these trends may redefine user experience within the retail sector. We focused on synthesizing strategies allowing retailers to adopt and adapt to upcoming technologies and changes in their physical store layouts that aid in the fulfillment of the growing e-commerce trend.

FINDINGS

With the advent of drones, robots, and autonomous ground vehicles, we are going to see an uptrend in faster deliveries and smart tracking. The use of robotics not only makes the deliveries faster, but also allows for more flexibility and reliability in how goods are delivered through smart integrated systems.

We looked at the following types of retailers: E-Commerce only Retailers, Brick and Mortar Retailers, Manufacturers (B2B + B2C) and Manufacturers and Industrial (B2B).

| E-COMMERCE ONLY RETAILERS | BRICK AND MORTAR RETAILERS | MANUFACTURERS (B2B + B2C) | MANUFACTURERS AND INDUSTRIAL (B2B) |
|---|---|--|------------------------------------|
| <p>Fulfilment centers are tailored for filling E-Commerce orders.</p> <p>But they end up using couriers and local post services to fulfill orders.</p> <p>They are less adept with meeting timelines.</p> <p>Usually, the company gets blamed for delays and not the delivery partners.</p> | <p>Growing online retail has become a major threat to brick and mortar stores.</p> <p>Space is their major advantage.</p> <p>With growing online orders, they can convert their spaces to delivery areas and warehouses</p> | <p>Can create their own fleet as they have a varied operative scope.</p> <p>They cater as wholesalers for retailers and can make direct contacts with the end buyer and businesses.</p> <p>Despite being large organizations, they still fall short of delivery capacity, specially in cities.</p> <p>As their fleets depend on the road sizes, traffic rules etc. for delivery can often be a challenge in standardizing processes.</p> | |

Table 1: Retailer Type Analysis.

Existing case studies on the implementation of last-mile delivery in different sectors

We explored different examples of companies in the retail field that have started testing out technologies for last-mile delivery resulting in impacts on urban infrastructure and delivery logistics.

Nuro, a leading self-driving delivery company, has launched self-driving pods (Fig. 5) for delivering Domino's pizzas in Houston (Stock 2021). Kiwibot is a startup using a droid for delivering foods and packages around Berkeley, California, and has invested in a new droid that can operate indoors in places such as airports, malls and hospitals (Stock 2021) (Fig. 6).



Figure 5: Nuro neighborhood mini vehicle (<https://www.nuro.ai/technology>)

Uber Eats is venturing into the food business area and testing out drone technology to cater to rising demands in food pick-ups and deliveries (Fig. 7). Architects may need to adapt future buildings to fit with the requirements of this new delivery model. These requirements may be worth exploring as a next step of this research.



Figure 6: A Kiwibot courier loads a food order into a robot in Berkeley, Calif., in 2019. Photographer: Ulysses Ortega/The New York Times/Redux (<https://www.bloomberg.com/news/articles/2021-04-17/new-deals-for-nuro-and-kiwibot-show-the-power-of-thinking-small>)



Figure 7: Uber Eats technician testing with droid deliveries for 2023 (Robotics Business Review 2019). Canoo's MPDV II fleet for mobile delivery services (www.canoo.com)

Micro-Fulfillment Centers (MFCs):

The uprising e-commerce trend has urged retailers to upkeep with advances in technology that allow for faster and cheaper deliveries to retain their customers. While retail giants, such as Amazon and Walmart, are developing their logistics infrastructure and investing in local and worldwide automated fulfillment centers, smaller retailers are turning to micro-fulfillment strategies.

What is micro-fulfillment?

“Micro-fulfillment involves using small, highly-automated storage facilities near the end customer to bring down the cost and time of delivering goods.”

(CB Insights, 2020)

What are the main components of MFCs?

Main two components: “software management systems, that process online orders, and the physical infrastructure, including robots that pick out items from storage aisles and shuttle them to packing staff” (CB Insights, 2020) (Fig. 8).

Placing MFCs within walkable distances from homes is one approach that allows for quicker and cheaper last-mile delivery. Moreover, retailers can manage deliveries from and to their small distribution centers using online platforms such as Bond, a New York based startup that offers last-mile delivery services and direct-to-consumer brands space at its MFCs. The service can provide

cost-effective and same day delivery using low-emission electric vehicles (Fig. 10). Consumers can schedule the exact delivery time and get real time delivery updates after completing their order while retailers can track all their deliveries through the platform.



Figure 8: Nordstrom; Tompkins Robotics in Newark, California (CNBC 2019)



Figure 9: Bond cargo trike (Peters 2020)

Physical Retail Store Changes

Brick and mortar retailers can build MFCs in two ways: either within existing stores, or as stand-alone facilities to service a group of stores. In the first model, the center is operated directly by the retailer, and in the second model, the center is operated by the company that sets it up. Since MFCs have compact designs, they can be integrated within existing spaces in high-density, urban areas like the back of “existing supermarkets, in garages or parking lots, and in basements.” (CB Insights, 2020) (Fig. 10)

Moreover, retailers can reduce their front-of-house sales area and increase their store’s back-of-house to fit technology that automates services such as counting, organizing, and sorting of inventory, while preserving their overall store footprint (Fig. 11). That would allow them to fulfill a large portion of deliveries from their existing stores without having to utilize additional real estate (CB Insights, 2020).

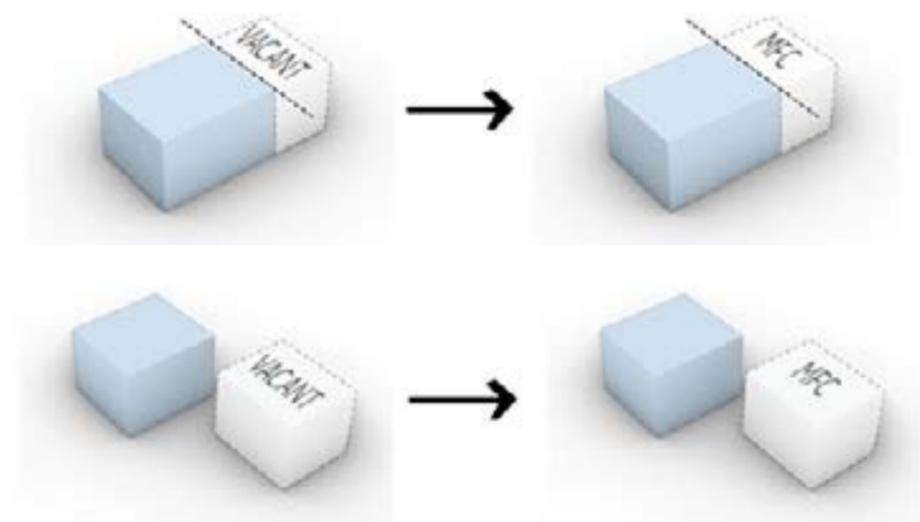


Figure 10: Store/Vacant Space repurposing: a portion of the store or vacant spaces with small footprints in the city would be used as distribution centers.

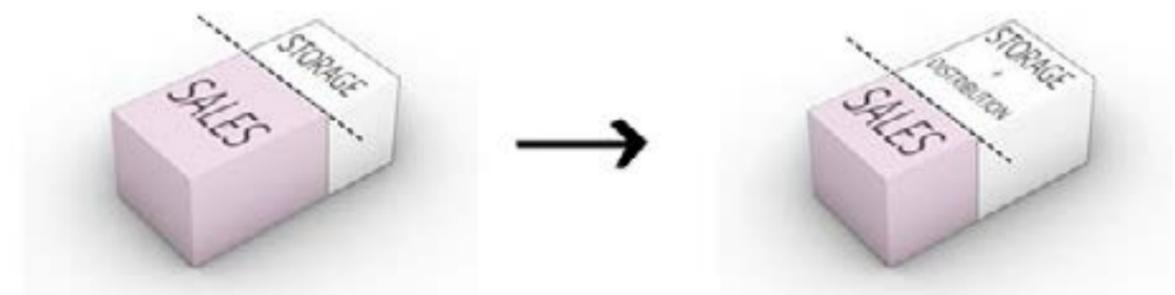


Figure 11: Floor space segmentation: reduced front-of-house and increased back-of-house to fit in the automated process (including last-mile delivery technologies).

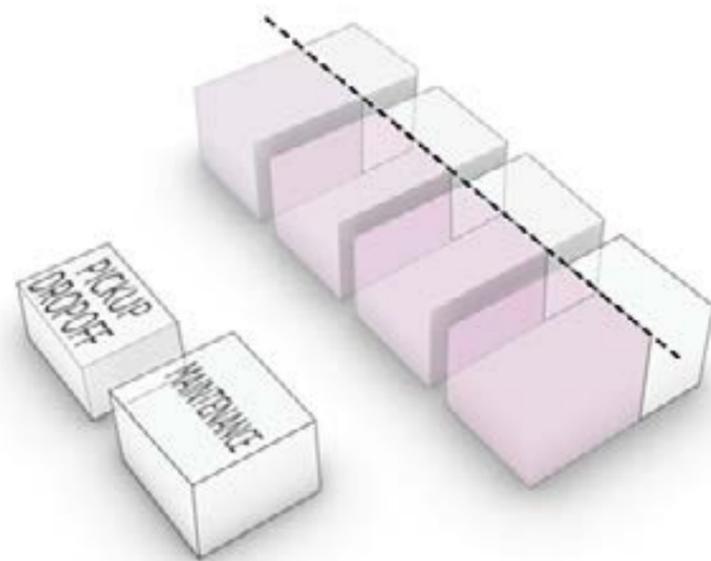


Figure 12: Dedicated facilities for charging, storing, and maintaining last-mile technology either in parking spots located close to retail stores, or in places conveniently distanced from multiple stores.

Retailers might also need to share spaces for maintaining and storing the technology and plan for shared pick-up and drop-off areas that are conveniently distanced from multiple stores when they consider expanding their online delivery infrastructure (Fig. 12).

Impacts on Consumers

Adjustments in retail store designs and delivery systems that support digital demand offer numerous advantages to consumers in the way they experience physical stores.

Firstly, more companies are transforming their front-of-house spaces into “enhanced fitting rooms”, using technology and data from online orders. By incorporating automated systems into their back-of-house area, retailers provide

their salespersons the opportunity to spend more time with customers visiting the store. Secondly, retailers are disposing of a more compacted and customer-tailored inventory based on online shopping trends, and thirdly, pick-ups and drop-offs are becoming easier and faster through micro-fulfillment centers. As mentioned in the earlier “Micro-Fulfillment Centers (MFCs)” section, MFCs are located within cities which reduces the distance between an ordered product and a customer, making last-mile delivery cheaper and quicker (CBS Insights, 2020).

All three of these consumer benefits can be found at Nike’s “House of Innovation 000” in NYC (Fig. 13). The store offers a futuristic shopping experience for

customers through highly immersive and customizable services that combine traditional shopping with the company’s digital app. In the Nike Speed Shop, products that are based on local data are displayed in an entire floor space. Some members can reserve items on their phones and have them held in in-store lockers. Other personal services include one-on-one bookings with Nike experts and scanning a code for items displayed on a mannequin that can be purchased immediately through Instant Checkout (Nike News 2018).

Impacts on Retailers

MFCs allow retailers to save on costs for several reasons. MFCs have a much smaller footprint than traditional fulfillment centers. While normal warehouses can take up to 300,000 sq.ft

of space, MFCs are typically between 3,000 and 10,000 square feet (CB Insights, 2020). This allows retailers to save on leasing and operating costs for large centers that would need to be located at the outskirts of cities due to their space requirements. Retailers also save on transporting goods to customers because of the reduced distance between MFCs and consumers, as well as operational costs due to automation: “Micro-fulfillment is estimated to reduce costs associated with an order by 75% when compared with manual picking of the order, according to an analysis by financial services company Jefferies” (CB Insights, 2020). For example, Nordstrom is the first retailer to bring together both Attabotics’ and Tompkins Robotics’ technology into a single distribution center, in Newark, California (Fig. 14) (CNBC, 2019).



Figure 13: Sneaker Lab; Inside Nike’s House of Innovation in New York; Arena (Sources: Nike; Nicholas Calcott)

About Attabotics:

A 3-D robotics provider that utilizes the structure of “ant colonies” to handle goods more efficiently by storing them vertically, rather than in a horizontal row-and-aisle configuration, in fulfillment centers (CNBC, 2019).

About Tompkins Robotics:

A robotics provider that developed “a parcel-sorting solution it calls t-Sort Plus, which uses autonomous robots that travel the shortest route possible to grab boxes and deliver them to their appropriate destination” (CNBC, 2019).



Figure 14: Nordstrom’s distribution center combining Attabotics’ and Tomkins Robotics’ technology in Newark, California (CNBC 2019)

CONCLUSIONS & IMPLICATIONS FOR PRACTICE

The last few years have shown a rising trend in e-commerce and a desire for faster and cheaper online deliveries. There is an assumption that this trend will keep growing in the next five to ten years. Some technologies, such as drones and AGVs/droids, are being developed and tested in several types of industries (i.e. food, retail, healthcare) to achieve last-mile delivery needs.

Some potential changes to consider in the retail industry, based on this assumption, are the reconfiguration of physical stores to incorporate MFCs and automated processes in an enlarged back-of-house area, and the enhancement and personalization of the customer experience. Newly developed autonomous vehicles and drone technology also call for a revisioning of existing infrastructure and urban elements such as sidewalk design to fit in the technologies, the reconfiguration of roads, and the utilization of curbs or parking spots as areas dedicated for pick-up and drop-offs.

In summary:

- Retailers should consider dedicating a portion of the retail store for the fulfillment of online deliveries (turn the back-of-house area into a micro-fulfillment center is an example)
- Retailers should consider areas, either shared with other stores or as part of their own store, for pick-ups and drop-offs of online products.
- Employing experience-based retail strategies may help to preserve the physical store shopping experience
- Revisit existing infrastructure for roads and sidewalks to incorporate technologies for last-mile delivery (circulating droids, AGVs, bike couriers, or drones)

NEXT STEPS

There are some considerations that may be worthy of further investigation. Introducing new technologies to make deliveries using the streets and sidewalks would require infrastructural changes such as:

- The addition of a road lane dedicated for last-mile delivery technology
- The introduction of loading/unloading zones either as part of the sidewalk or within dedicated facilities

REFERENCES

CB Insights (2020, July 21). *The Next Shipping & Delivery Battleground: Why Amazon, Walmart, & Smaller Retailers Are Betting On Micro-Fulfillment*. <https://www.cbinsights.com/research/micro-fulfillment-tech-shipping-retail/>

Nike News (2018, November 14). *Nike's New NYC Flagship is the Face of Living Retail*. <https://news.nike.com/news/nike-nyc-house-of-innovation-000>

Pesantez, G. (2018, May 16), United Nations Organization. *68% of world population to live in urban areas by 2050*. <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>

Hillyer, M. (2020, January 10) World Economic Forum. *Urban Deliveries expected to add 11 Minutes to Daily commute and increase carbon emissions by 30% until 2030 without effective intervention*. <https://www.weforum.org/press/2020/01/urban-deliveries-expected-to-add-11-minutes-to-daily-commute-and-increase-carbon-emissions-by-30-until-2030-without-effective-intervention-e3141b32fa/>

Young, J. (2021, February 19). A decade in review: Ecommerce sales vs. total retail sales 2011-2020. *Digital Commerce 360*. <https://www.digitalcommerce360.com/2021/02/19/a-decade-in-review-ecommerce-sales-vs-total-retail-sales-2011-2020/>

Joerss, et al. (2016, September) McKinsey&Company. "Parcel delivery. The future of last mile." Travel, Transport and Logistics. https://bdkep.de/files/bdkepdien/pdf/2016_the_future_of_last_mile.pdf

Robotics Business Review (2019, July 30) *Uber Eats drone delivery test touts urban environment flights*. <https://www.roboticsbusinessreview.com/unmanned/unmanned-aerial/uber-eats-drone-delivery-test-touts-urban-environment-flights/>

FutureCar Staff (2021, December 02) FutureCar. *EV Truck maker Rivian Selects Amazon Web Services as its preferred provider*. <https://www.futurecar.com/5034/Electric-Truck-Maker-Rivian-Selects-Amazon-Web-Services-as-its-Preferred-Cloud-Provider>

Deutscher, O. (2019, December 21) Withbond. *The difference between a warehouse and a fulfillment center*. <https://www.withbond.com/blog/>

Peters, A. (2020, January 28) Fast Company. *This startup wants to replace traditional package delivery with hyper-local, electric-trike-driving couriers*. <https://www.fast-company.com/90456321/this-startup-wants-to-replace-traditional-package-delivery-with-hyperlocal-electric-trike-driving-couriers>

Sokolovsky, Daniel. (2021, November 24) Forbes. *How the pandemic accelerated technology advances in last-mile delivery*. <https://www.forbes.com/sites/forbes-techcouncil/2021/11/24/how-the-pandemic-accelerated-technology-advances-in-last-mile-delivery/?sh=3782150142d8>

Schroder, J. et al. (2018, July) McKinsey&Company. *Fast forwarding last-mile delivery - Implications for the ecosystem*. https://www.mckinsey.com/~/_media/mckinsey/industries/travel%20logistics%20and%20infrastructure/our%20insights/technology%20delivered%20implications%20for%20cost%20customers%20and%20competition%20in%20the%20last%20mile%20ecosystem/fast-forwarding-last-mile-delivery-implications-for-the-ecosystem.pdf

Thomas, L. (2019, December 05) CNBC. *How Nordstrom uses robots and shelves inspired by ants to deliver lipstick faster*. <https://www.cnbc.com/2019/12/05/nordstrom-partners-with-attabotics-and-tompkins-robotics-for-faster-delivery.html>

Stock, Kyle. (2021, April 17). Bloomberg. *The (Robot) Pizza Guy Is Here*. <https://www.bloomberg.com/news/articles/2021-04-17/new-deals-for-nuro-and-kiwibot-show-the-power-of-thinking-small>

World Economic Forum (2020, January 10). *The Future of Last-Mile Ecosystem*. <https://www.weforum.org/reports/the-future-of-the-last-mile-ecosystem>

Jones, M., Neyhaus, F., Schroder, J. (2016, October 19) McKinsey&Company. *How customer demands are reshaping last-mile delivery*. <https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/how-customer-demands-are-reshaping-last-mile-delivery>

Interviews and Conversations

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Associate Principal at CRTKL

Mario Sanchez,
Associate Principal at CRTKL

Paul Conder,
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Michelle Decker,
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Lucy Baraquio,
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ADVANCING NURSE WELLBEING

How can we mitigate the risk of burnout for clinical nursing staff for resiliency in their workplace?

ABSTRACT

The pandemic has exposed a direct connection between high-stress environments and their psychological, emotional, and physical demands on personal wellbeing in the clinical frontline. This research takes a human centric approach to understand the current workplace demands for nursing staff, to identify innovations for addressing burnout and to uncover new opportunities aimed at improving staff wellbeing which in turn will increase the quality of patient care. The research methodology began with a data collection effort of relevant case studies, articles, codes, and policies followed by a thorough literature review. It was evident that a shift of current ideologies was in motion and resulted in a research plan that would focus on gathering additional qualitative insights from current healthcare leadership through one-on-one interviews and a digital survey deployed to nursing professionals concerning nurse wellbeing in the US.

The case studies and interviews identified barriers to mitigate burnout and newly implemented trends focused to improve staff fulfillment in the workplace. The survey gathered insights focused on understanding and prioritizing the personal needs of staff, especially related to break patterns and sources of respite. This research confirmed an emerging shift from “patient-centered care” to

“people-centered care,” with the addition of caring for caregivers, and concludes with potential policy and design interventions to improve the future of healthcare delivery and healthcare design.

CONTEXT

Fatigue and Burnout

Fatigue and burnout are not new to the industry but are dramatically impacting the current state of healthcare. A 2018 study reported that over 60% of nurses reported burnout, which was pre-pandemic, and has only increased over the last four years (Cornwall, 2018). Nurses are already at a higher risk of developing burnout, due to occupational stress from workload demands and responsibilities. Burnout can contribute to medical errors, decreased patient satisfaction, and decreased staff productivity all due to the fact that they are not optimally performing (Sweileh, 2020). In addition to burnout, nursing staff are also coping with depression and increased levels of compassion fatigue, where a caregiver manifests the suffering of their patients who are experiencing extreme stress or trauma. Caregivers have been a direct recipient of this secondary stress because of the unprecedented volumes of patients due to COVID.

The Patient Experience: Patients First

The healthcare industry has a mantra of “patients first.” Although a caregiver’s focus is their patients, the needs of staff should be equally as important. The decline of wellbeing and workplace satisfaction is evident in nursing shortages, which impact a health system’s bottom line and ultimately the quality of patient care. The patient experience is highly influenced by the care they receive which is measured through hospital HCAHPS scores and impacts hospital rewards and reimbursables. The industry can no longer support a “patients first” mentality unless needs of nursing staff are prioritized and integrated as part of the patient experience.

Environmental Barriers for Staff

With the mentality of “patients first”, not only are the personal needs of clinical staff not prioritized but nor are their non-clinical environments. Current design and construction codes for healthcare have minimal requirements for non-clinical staff support spaces. Since these spaces do not generate revenue, they can become a lower priority, or reduced and eliminated from a hospital’s capital expenditure. The increased awareness of staff wellbeing and satisfaction in the workplace made the disparity of these spaces and necessity for interventions evident.

APPROACH

The topic of burnout itself is extremely broad and the amount of current research available is vast. A current Google search of the terms “nursing burnout” results in over 34 million resources and over one million scholarly articles as of December 2021. A thoughtful research approach was necessary to narrow down relevant sources. This research focuses on inpatient clinical nurses in the United States and utilizes data that allows for a comparison between pre-pandemic and current states.

The data collection effort compiled a repository of relevant case studies, articles, healthcare policies, and healthcare building and construction codes. Through a literature review, it was evident that there was a critical shift reshaping the healthcare industry. This research plan would first focus on gathering qualitative insights on this shift and trends related to staff wellbeing from healthcare administrators and leadership who are the most informed concerning current operations, processes, and initiatives across their health systems. These insights were gathered through a series of six structured and two non-structured one-on-one virtual interviews.

One-On-One Interviews

The questions for the one-on-one interviews were framed around understanding trending topics and key words that frequently appeared in the data collection process concerning staff wellbeing which included:

- What methods are available to gather feedback from clinical staff regarding their personal wellbeing in the workplace?
- Do you see a shift in healthcare from the focus of “patient-centered care” or “patient’s first” to also include staff wellbeing?
- Is there any research or data available regarding how hospitals are gathering feedback from their staff to effectively track change?
- In the current healthcare guidelines for design and construction, there are limited requirements for non-clinical staff spaces. Are there any areas in your facility that are successfully used or that are needed to better support staff wellbeing?

The participants in the one-on-one interviews included faculty members from large health systems including the assistant dean of faculty wellness, wellness program liaison, assistant vice president of organizational development and training, human resources for staff wellbeing and a project manager with a nursing background focused on design and construction. Additional insights

were gathered from a healthcare journalist as well as a director and clinical assistant focused on human centered design. Their insights were used to understand what health systems are actively doing to address staff wellbeing and to identify opportunities for further improvement and research. It also informed the questions asked in the final part of this research process which was deployed via a digital survey to nursing staff.

Survey Insights from Nursing Professionals

The one-on-one interviews were formatted to understand current trends changing the industry, but this research also wanted to understand more clearly what personal needs should be supported in the workplace from the nurses’ perspectives. The questions focused on three topics including break patterns, methods for respite and current resources available for improved wellbeing.

- What are the current nursing break patterns?
- What methods are staff taking in the workplace and at home to improve their wellbeing?
- What resources do staff have available in their workplace to improve their wellbeing?
- The survey would also include the one-on-one interview questions for additional insight from the staff

perspective to potentially validate the reach and success of current initiatives used to improve wellbeing.

These results would be analyzed against contributors to burnout and used to identify potential innovations in the future of healthcare delivery and healthcare design.

Day In the Life Observations

A “Day in The Life” exercise within a critical care floor was beneficial to better visualize the standard routines and processes of staff within their workplace environment. This was documented over a 12-hour shift of a critical care nurse. The data collected was then used to confirm the insights received from the staff surveys pertaining to break patterns and resources available or utilized for wellbeing.

FINDINGS

The literature review supported a basic understanding of the contributors to burnout and identified the common barriers to prevention. The qualitative insights gathered through the one-on-one interviews and the survey confirmed many of the same barriers but were also successful in gathering real-time trends, more detailed explanations of these issues and examples of action currently taking place in their facilities.

Burnout in Nursing

The data collection effort compiled a repository of relevant case studies, articles, healthcare policies, and healthcare building and construction codes. It was critical to first define burnout, to source current trends of burnout from pre-pandemic to current state, and to identify its key contributors.

Burnout has been referred to as a stress syndrome but was recently updated by the World Health Organization as “a syndrome conceptualized as resulting from chronic workplace stress that has not been successfully managed and results in feelings of energy depletion and exhaustion, increased mental distance from one’s job or feelings of negativism or cynicism related to one’s job; and reduced professional efficacy”. (World Health Organization, 2019). This definition could be applied universally across all professions, but the higher level of responsibility and workload of nurses increases their risk of burnout. In 2018, RNnetwork published a survey that reported that 62% of nurses felt regularly burned out in their jobs and in the following years this increased to almost 90%. (Cornwall, 2018).

Burnout is also linked to higher rates of turnover as nurses seek other job opportunities that are less stressful. It was critical to understand how burnout is being tracked and what new processes are being implemented to mitigate burnout.

Contributors to Burnout (Most frequently expressed terms are bolded):

- **Nursing Shortages**
- Inefficient Scheduling
- **Lack of breaks during shifts**
- Lack of access to break areas
- Staff:Patient Ratios
- **Lack of awareness of available resources**
- **Compassion Fatigue**
- **“Patients First” Mentality**
- **Lack of control of their environment**
- **Insufficient Rewards**
- **Breakdown in Work Community**
- **Lack of Policy Supporting Wellbeing for Staff**
- **Band-Aid Mentality of Addressing Issues Versus Prevention**

Measuring Nurse Wellbeing

This research found that a digital survey is the standard method health systems use to gather feedback from their staff. Specific questions are asked that target health and wellbeing, but all results are anonymous. The survey is distributed every six months from a larger platform that allows the hospital access to a dashboard where they can select specific data that they compare to national benchmarks. The insights received were unclear as to how this information is disseminated to influence change.

In a recent hospital employee survey (Figure 1), one of the questions asked “What is one thing we can do right now to better support you in sustaining your mental health and wellbeing”? The keywords in the responses were aggregated into an easy-to-read diagram (Fig. 1). The results were all associated with the contributors to burnout, including the term burnout itself, focusing on health, time off, wellbeing and staffing issues. Note that “remote working” was eliminated from the data collection since this survey was distributed to a wider audience and not solely to nurses who cannot work from home.

Wellbeing in the Workforce

This priority of self-health is no surprise, especially when considering the future of the workforce. Millennial and Gen Z nurses make up about 50% of the nursing workforce with the remaining consisting of baby boomers (St. Augustine, 2021). The values across generations are very different and this is evident in the current statistics of workplace satisfaction. There is a direct correlation between workplace wellbeing in healthcare and the psychographics by generation. (Psychographics is the study and classification of people according to their attitudes, aspirations, and other psychological research, especially as in market research.) This data provides insight to address workplace satisfaction and burnout prevention in lieu of addressing the current state.

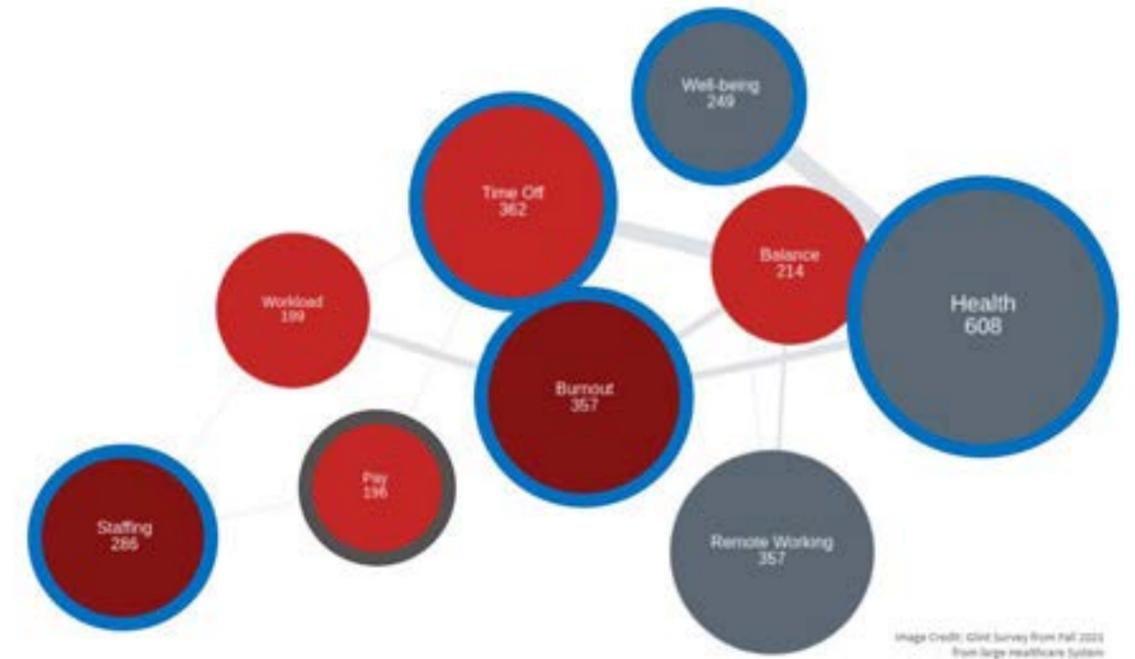


Figure 1: This diagram illustrates how information via a digital survey can be visualized through the survey dashboard by the survey manager. Image Credit: Fall 2021 Survey Results, via Glint Platform, from undisclosed hospital.

According to the Gen Z psychographics, there is a focus on being socially conscious, while their attitude towards work demands flexibility for their personal lives. The 2030 future workforce wants to work to change and be a part of a culture focused on wellness. From the insights gathered, the current healthcare workplace, especially during the pandemic, does not support either generation which is directly reflected in the current survey results of burnout.

In the Fall 2021 employee survey previously referenced, GEN Z scored their current wellbeing the lowest of all generations, with a wellbeing score

of 68% (Figure 2). In a national nursing survey, respondents in the bottom two age groups, ages 18-34, consistently scored themselves much lower in response to their views on meaning in their work, managing work related stress, and self-care (Figure 3) (Nurse Wellbeing at Risk: A 2020 National Survey). This could be contributed to their personal core beliefs about nursing which were disrupted by the pandemic or that compared to other generations, they have less experience with adversity. Ultimately, the current conditions have led many to leave or consider leaving the profession (Figure 4) (Sherman, R. 2021).



Figure 2: Generational breakdown of wellbeing in healthcare. Image Credit: Fall 2021 Survey Results, via Glint Platform, from undisclosed hospital.

| | Millennials (Before 1980/ +71) | Boomers (1946-1964/51 to 71) | Gen X (1965-1979/28 to 51) | Gen Y/ Millennials (1980-1999/20 to 47) | Gen Z/ Zeds/ Gen 2020 (1998 - today/+20) |
|-------------------|---|---|--|--|--|
| Work Ethic | Work hard Thankful Sacrifice/Duty | Work hard Dedicated/loyal Focus on efficiency | Work hard Skeptical Self-reliant Desire structure | Work smart Goal-oriented Multitasker Optimistic | Multitasker Realistic Inquisitive Careful |
| Career | Company man Do the job assigned | Stellar career Likely to stay in one job | Portable career Change jobs to get ahead | Parallel careers Expect substantial job changing | Socially-conscious Realistic |
| Work-Life Balance | Separation | Balance | Balance now | Do what you love | Integrated |
| Education | Cream | Bright | Means to an end | Given | Ongoing |
| Technology | Challenged | Comfortable | Fluent | Dependent | Digital native |
| Communication | Formal | Face-to-Face | Direct, Immediate | Digital Constant | Digital Constant |
| Interaction | Individual | Team-focused | Entrepreneurial | Participative | Networked |

Figure 3: Psychographics by generation. Image Credit: CRTKL “The Future of Work”.

Psychographics of the Future Workforce

| | Workforce in 2020 | Workforce in 2030 |
|----------------------|-------------------------------|----------------------------|
| Field of Work | Information Technology | STEM |
| Commitment | Flexible Full-Time | Contract/Freelance |
| Environment/Location | Workplace | Place to Work |
| Attitudes | Work to Live/Play | Work to Change |
| Technology | Under-Utilized & Still Clunky | Administrative & Invisible |
| Communication | Digital | Personal |
| Benefits | Pay & Flexibility | Culture & Wellness |

Figure 4: Psychographics future workforce. Image Credit: CRTKL “The Future of Work”.

The Shift Within the Culture of Health to Address Staff Wellbeing

The pandemic brought the topic of burnout and mental health in medical professionals to the forefront. The perceived appearance of being unprofessional or the fear of being reported to the medical board prevented clinicians from seeking help to address their burnout, compassion syndrome, depression and other mental health issues. The severe numbers of those affected, high rates of turnover and growing statistics of medical professionals taking their own lives on a daily basis, has created an acceptance for these topics being talked about more openly (Dr.Lorna Breen, 2021). Hospitals are actively changing policies and making resources readily available

to support staff psychologically, socially, physically and environmentally. **There is a shift that is building a culture in medicine that allows staff to speak out and supports their desire for meaning, purpose and community in the workplace.**

Shifts in Policy

- The standard delivery of care model is adapting to support staff wellbeing. This research found revised language that has updated from “patient-centered care” to “people-centered care” and “patient’s first” in addition to “caring for caregivers.”

- Although we are seeing this adapting care model, the focus of what they do will remain focused on the patient. A “Day in the Life” exercise was planned to see patient and staff care firsthand. Due to COVID restrictions, this could not be performed as a part of this research. Instead, a short film created by the NY Times provided similar insights to the day-to-day experiences of an I.C.U. nurse. The video journal illustrated the daily demands in their workplace, the emotions of stress and compassion syndrome as well as their flexibility and adaptability to work in any environment they can to serve their patients. It did document on-one-one and team based interventions. Even amid crisis, patients were their priority (Stockton, S. and King, L. 2021).
- There is a new focus on addressing personal fulfillment and meaning at work, which directly responds to the current and future workplace generations.
- New focus on personal and professional development for staff.
- There has been an increase in new leadership positions dedicated to staff and physician wellbeing. These individuals can collect data from their staff and potentially provide great insight for tracking change.

- To assist with greater staffing flexibility, new opportunities have been created internally. Some health systems are providing the education and necessary experience to cross train specialty care RNs. This enables them to work across multiple campuses and provide clinical support in a wider range of departments. Additional processes are being utilized to provide flexibility from external resources through to shared staffing pools.

Shifts in Programs & Initiatives

- **Prioritizing Wellbeing:** Establishing better methods and procedures to gather insight, measure, track and compare wellbeing against national benchmarks (commonly through digital surveys).
- **Room for Improvement:** Insights gathered through this research revealed that survey responders commonly commented that they did not see any changes as a result of the surveys sent out. Respondents seemed discouraged under their perception that feedback did not result in any change. Improved communication of how this information is used or the influence it has would improve staff perception.

- **Anonymous Outreach for Wellbeing:** Increased numbers of staff are utilizing anonymous methods for mental health outreach. The Employee Assistance Program (EAP) is a well-known government program that provides confidential assessments but also addresses workplace related issues. In addition, the American Foundation for Suicide Prevention has an Interactive Screening Program (ISP) which provides a safe and confidential method for individuals to take a brief screening for stress, depression, and other mental health conditions. In response, they receive personal outreach from a program counselor within the mental health services available to them. Individuals can anonymously communicate with the program counselor to receive recommendations, feedback, and support in connecting with available mental health services.
- **Room for Improvement:** Insights gathered through this research revealed that the EAP at many health facilities, which have a physical office location, had no available appointments for weeks or were located too far away on a campus to be utilized when needed. Convenient accessibility to these resources would most likely result in more frequent use.

- **Empowering Employees:** There has been a focus on encouraging leadership to make more frequent rounds/visits across patient units to personally acknowledge people, build relationships and empower employees. The intent is to build and train future leaders from within. There are also new programs aimed at providing professional and personal growth from a peer-to-peer level, which empowers employees to mentor each other.
- **Room for Improvement:** Insight revealed that there are successful one on one coaching programs occurring but many do not have a dedicated or multipurpose space to accommodate this. One example given mentioned their coaching sessions, which can be emotional, currently occur in personal vehicles. Additional insights raised the concern that there are new programs focused on development and coaching, but no effective way to clearly communicate these resources to staff or to provide flexible time allowances to attend.

- **Group Based Support Intervention:** Compassion syndrome and burnout can develop a sense of being alone. Recently, more group-based initiatives are being implemented to help individuals cope with their emotions together as a method to improve wellbeing.
- One example of support-based intervention is made up of multidisciplinary teams of faculty and staff that provide peer-to-peer support for staff following a traumatic event. These teams offer debriefings, educational presentations, reflection rounds and spiritual care to alleviate the harmful effects of morally distressing clinical situations. This initiative intends to help minimize burnout, increase staff retention, and improve job satisfaction and the quality of patient care. (Rabbi, S. 2018 and UTSW Nomad).
- Another example implemented is the “buddy system”, which provides a variety of methods for staff and physicians to connect with colleagues to talk about their experiences. The model is based on the military’s “battle buddy system” that ensured a check-in at the end of the day with the goal to eliminate the sense of loneliness and build human connections. (Lin, K. 2021).
- **Programs Focused on Work Life Balance:** Insights gathered through this research revealed many unique initiatives that hospitals had implemented during the pandemic were very successful in creating a better work life balance for staff.
 - At healthcare facilities with daycares, children of medical staff could be brought to them during lunch and returned via daycare employees to encourage a better work life balance.
 - Many health systems have established policies to request time off in advance but do not provide as much flexibility for unanticipated leave. With the increased sensitivity for illness because of COVID, many staff with dependents are forced to take unplanned time off or leave during a shift to pick up their children who may just have a mild sickness. To address this issue, one hospital utilized their on-campus free daycare, which was for patients with medical appointments, and extended its services to staff so they could work if needed. Even if this is not an ideal solution, staff felt a sense of relief and support if the need arose.

Shifts in the Built Environment

• Current Support Space Requirements

- Through a review of the current 2018 Facility Guidelines Institute (FGI) Guidelines, which are the foundation for the minimum requirements for the design and construction of healthcare facilities, it was found that required non-clinical staff support spaces are limited. There is a disparity between the code requirements and the necessity of multipurpose spaces for staff wellbeing that the research revealed. Obviously, non-

clinical staff support spaces do not generate revenue, but the metrics being gathered for staff wellbeing and retention should be used to validate the need for these spaces.

- Unfortunately, the FGI Guidelines are updated every four years and the 2022 proposed updates were collected in 2019. The requirement of new staff spaces or proximity to specific areas could be incorporated into the 2026 guidelines but until then, it will be the design and construction industry, alongside their clients, that will need to advocate for staff wellbeing.

2018 FGI Guidelines for Staff Support Spaces

1.2-5: Environment of Care Requirements

- Access to natural light should be available without entering private spaces (patient rooms).
- Separate outdoor respite areas for medical and support staff should be provided.

2.1-2.9 Support Areas for Staff Support

- Areas for staff should be restricted from public access
- Wherever possible, staff lounge facilities should have access to daylight and views of the outdoors
- Staff rest areas should be provided for every unit that has overnight patient care activities. These rest areas should be readily accessible to the work unit and independent from staff on-call rooms (note that staff lounges are typically used to fulfill this requirement)
- Staff Lounge to be located as close to the centralized nurse station and programmatically sized (note there is no minimum size requirement)
- Secure storage for personal belongings near the nurse station or staff lounge

2.1-2.8.5.1 Multi-Purpose Rooms

- At least one multipurpose room shall be provided for staff, patients, and patients' families for patient conferences, reports, education, training sessions, and consultation. (note this is not a staff only space but could be used for respite)

Figure 5: 2018 FGI Non-Clinical Staff Support Requirements (Facilities Guidelines Institute)

- **Adaptive Reuse:** The pandemic exposed the vulnerability of the medical frontline from the psychological distress they confront each day. Many studies showed the need for restorative spaces to decompress or rest without the sounds of medical equipment in the background. Per the 2018 FGI Guidelines, the only dedicated non-clinical staff spaces include the staff lounge or outdoor areas. The lack of needed spaces resulted in the discovery of many adaptive reuse examples of existing healthcare spaces to support staff wellbeing. Some facilities implemented simple improvements such as adding stationary bikes into existing back of house staff spaces to help staff decompress. Most commonly, existing offices or consult rooms were renovated into meditation or respite rooms which provided a quiet area with upholstered seating, soft lighting, and music at a minimum. The Mount Sinai Health System converted an innovation lab space into a multi-sensory immersive experience with projected nature scenes, coordinating music, lighting and sounds that could all be selected by the occupant. Their research showed that restorative spaces promoted stronger immune systems, healthier microbiome, improved mental health, improved heart rates, lower blood pressure and reduced stress and anxiety. One

unexpected outcome was that staff used the space for group intervention with their entire team at the end of a shift in lieu of a solitary experience which builds community (Mount Sinai Recharge Room and Podcast, 2019).

- **Room for Improvement:** Insights gathered from multiple sources exposed that many respite rooms are for physicians only. Some feedback noted that the respite rooms were located too far from a unit, sometimes in a separate building on campus, that made them underutilized. This research did gather insights from a newly completed hospital that included two respite rooms on the med/surg floor. It is exciting to see restorative spaces, which are not code required, being prioritized within the base project scope. These rooms are available to both physicians and staff and do not require reservations. However, the hospital is not currently tracking their use. This could be a great opportunity to gather data on who is using them, purpose, how long and at what times throughout the day to inform future respite spaces.



Figure 6: Private Respite Room Image Credit: Methodist Health System LinkedIn, May 2021.

Survey Insights for Staff Wellbeing

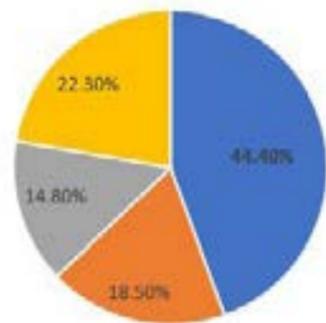
Most of the resources, programs and initiatives explored in this research appear to be a solution to address burnout in their staff, but what can or is being done for prevention? Through a custom survey deployed to a focus group of nurses in the US, this research began to understand how and where staff find respite or recharge in their workplace and personal life.

- The survey found that only about 33% of nurses took their break most of the time (more than 50%). (Fig. 7. Staff Break Patterns in the Workplace)

- Within a standard 12-hour shift, the majority of nurses prefer to take their break at the mid-point of their shift. (Fig 8. Break Location Preference in the Workplace)
- Even with the increase in available programs and initiatives for nursing staff, the top priority during a break is to eat, followed by resting with professional development being the lowest priority. (Fig. 9. Personal Priorities During a Break in the Workplace)
- When asked what activities would have the greatest impact on personal wellbeing outside of work, the priorities matched those of their 30 minute break pattern with sleep and relaxation being the top two. (Fig. 10. Sources for Improved Wellbeing Outside of the Workplace)
- More than 40% of nurses do not return to work from home recharged due to many work related or family obligation barriers. And then while at work, less than 50% take time to consistently recharge. (Fig. 11. Barriers to Improved Wellbeing at Home and in the Workplace).

- The most common spaces for nurses to access within their current facilities align with code requirements including a cafeteria and staff lounge with a respite room being the least common and not code required. Similarly, when given the chance to go anywhere during a break, the staff lounge and cafeteria were prioritized gain. This aligns with their personal priorities to eat and relax. (Fig 12. Current and Preferred Resources in the Workplace to Support Wellbeing)
- The main barriers to utilizing their preferred spaces to recharge were that they were too far away from their unit, which could not be accessed in a 30 minute break so a longer break would be necessary. (Fig. 13. Barriers to Accessing Preferred Resources for Respite in the Workplace)

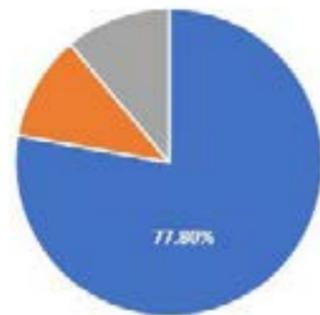
How Often Do You Take a Break?



■ < 50% of the time ■ > 50% of the time ■ Every Shift ■ No Breaks

Figure 7: Staff Break Patterns in the Workplace

If you could take a dedicated 30-minute break in a 12-hour shift, at what point would you prefer to take it?



■ 6 Hours In ■ 9 Hours In ■ Other

Figure 8: Break Location Preference in the Workplace

If you were to take a 30-minute break, what would your priorities be?



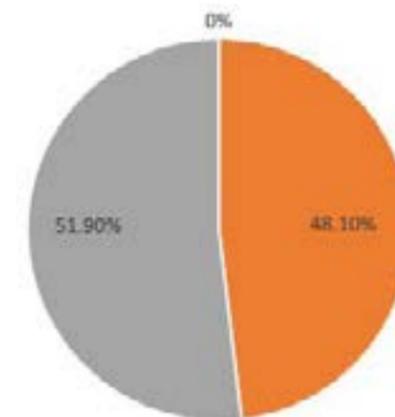
Which of these activities would have the biggest impact on your personal wellbeing and allow you to "recharge" outside of your work environment.



Figure 9: Personal Priorities During a Break in the Workplace)

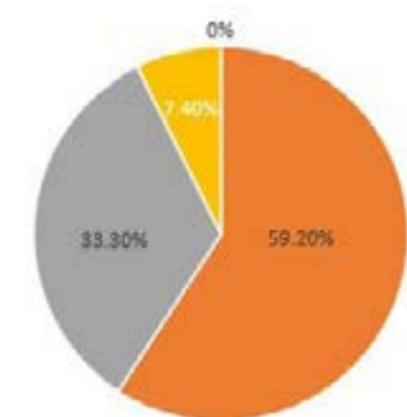
Figure 10: Sources for Improved Wellbeing Outside of the Workplace)

Do you take time to recharge/address your own personal wellbeing AT WORK?



■ Most of the Time ■ Sometimes ■ No

Do you have an effective work life balance where you feel recharged when returning to work from home?



■ Always ■ Sometimes ■ Almost Never ■ Never

Figure 11: Barriers to Improved Wellbeing at Home and in the Workplace



Figure 12: Current and Preferred Resources in the Workplace to Support Wellbeing

Are there any barriers preventing you from using your preferred spaces/methods to recharge during work?

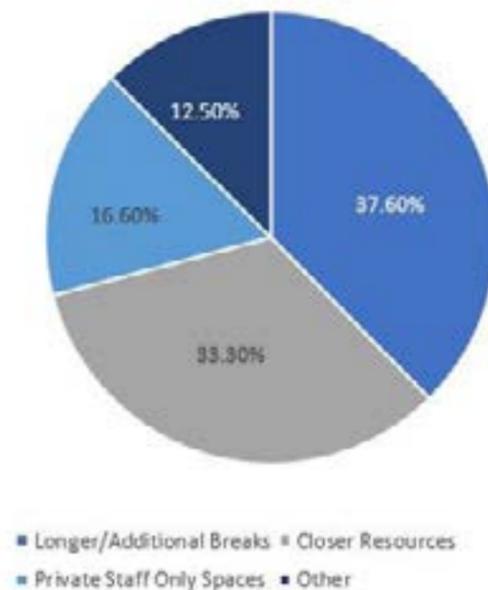


Figure 13: Barriers to Accessing Preferred Resources for Respite in the Workplace

Design and Policy Intervention

The qualitative insights gathered through the one-on-one interviews and a digital survey deployed to frontline workers informed potential design and policy interventions that would improve staff wellbeing in the workplace. The feedback collected aligned with the overall findings of the research, but also provided specific examples from their individual workplace perspectives. These were focused into a series of interventions that are starting to take place or could be adapted to shape the future of healthcare design and delivery.

Design Intervention

- Desire for staff spaces that can support private/solitary activity for staff instead of communal experiences. The design of future staff lounges should be more flexible to accommodate the lunch and relaxation activities prioritized by staff during their breaks.
- Staff respite areas or lounges should include upholstered/soft seating in lieu of plastic furnishings.
- Additional insights exposed the issue that staff toilets and lockers are typically located within the staff lounge for easy access but affect the quality of relaxation due to the loud noises associated with each. Separating the toilet and storage functions from the respite area would be beneficial.

- Lounge or respite areas should also be acoustically sound-proofed or separated as much as possible from the noise of patient monitors.
- Many respondents expressed that they would be more at ease if all staff lounges could include patient tracking boards so they could monitor their patients while on break. This is counter intuitive to the concept of needing to separate from work during breaks but may increase the amount of breaks staff actually take if they can maintain their sense of responsibility for their patients.
- Need for additional multipurpose spaces to support leadership and wellbeing initiatives. The close proximity of these would be ideal for ease of access, but more personal discussions related to mental health are preferred to take place further away from administration or the nursing unit.

Policy Intervention

- Based on these insights, there are few facilities with an effective method to cover patient loads to allow staff to take dedicated breaks. There seems to be a lack of trust to allow others to cover their patient load and/or the discomfort that their patient's may not receive the best care if another nurse is given double the patient load so that they can take a break.

- Even with dedicated breaks, some staff commented that they are unable to make it to the cafeteria and order food within their 30-minute time allowance. More facilities should implement an order ahead system to allow staff quick access to meals, so they have more time for respite.
- The ability to take a shorter wellness break, in addition to their lunch break, was commented on multiple times as a benefit to influence wellbeing.
- Many facilities have existing and new programs, initiatives, and staff support spaces available, but insights revealed that staff didn't know they existed. A published list of resources accessible to staff, spaces, and their availability to be reserved or a map of their locations should be distributed frequently.
- Many insights referenced the night shifts, which have limited access to many of the hospital's resources including the gym or cafeteria that are closed after hours. A better balance of these resources, including just access to coffee, for both staff and faculty should be provided in the evenings.
- The patient experience is highly influenced by the care they receive, which is measured through hospital HCAHPS scores and impacts hospital rewards and reimbursables. Could future policy instead rate health systems on their staff wellbeing or staff satisfaction?

CONCLUSIONS

Collected data and real time insights that identified initiatives and trends in place to address burnout, that when implemented aim to improve wellbeing. It was unclear as to how the data collected from within a hospital is being utilized to efficiently track change. Data confirmed inconsistent break patterns and a lack of restorative spaces or access for staff increases the potential for burnout and impacts wellbeing. Data supported that health and wellbeing would benefit from these resources.

Survey results identified and prioritized the human needs of staff in their workplace. By prioritizing these needs, resources and policies can be developed to better support wellbeing and influence the design of future healthcare environments. Research documented the lack of code required staff support spaces in current healthcare guidelines, but gathered insights that support the need for additional non-clinical staff spaces.

Insights were synthesized into potential design and policy interventions that could improve wellness and mitigate burnout. These new opportunities, aimed to improve staff wellbeing and in turn will increase the quality of patient care.

IMPLICATIONS FOR PRACTICE AND NEXT STEPS

The next steps for this investigation would be to deploy the survey previously sent to a focus group of nurses in the US to a wider audience from a larger variety of health systems to gain further insight on the shifts occurring, especially as the pandemic has become more manageable.

In addition, evaluate how we might develop a specific value or return on investment for restorative spaces to support staff wellbeing and workplace happiness. When considering that the cost of replacing a bedside RN was over \$40,000 and an ICU nurse was \$65,000 in 2020, a considerable amount could be saved with the recent staff nursing turnover rate of 18.7% (NSI National Report 2021).

What metrics might we use to measure the impact of design interventions on wellbeing or happiness in the workplace to support future code modifications for healthcare design and construction? How might the design and construction industry create new standards for wellbeing, even if not code required, to promote human centered design and create positive design outcomes? There are common threads across all of this data gathered related to healthcare burnout in the frontline and the workplace in general. Many of the policy

and design interventions are applicable across the workplace industry. A further study could continue to research which initiatives, policy or design interventions were most successful in workplace and see how they could be achieved in healthcare or visa versa.

In summary,

- This research documented the lack of code required staff support spaces in current healthcare guidelines but gathered insights that supports the need for additional non-clinical staff spaces. These insights can be used to influence future revisions to the FGI guidelines such as providing required staff spaces, specifics on proximity, size requirements and acoustic separation for active versus respite areas for staff.
- Insights gathered provided design interventions that can be implemented to improve staff support spaces. At a minimum, we can be more thoughtful in our design concerning the adjacencies or placement of toilets and lockers (noisy activities) in relation to staff respite space (restorative activities). These spaces typically occur in a singular larger environment but we can challenge that approach to achieve improved workplace happiness.

- Design teams and healthcare leadership should align project scope and vision for improved staff wellbeing during planning phases. With the increase of staff wellbeing initiatives across the U.S., insights gathered showed that hospitals typically do not have adequate space or ability to provide proximity to access these functions.
- This research has developed another initiative to put a return on investment for restorative spaces to support staff wellbeing and workplace happiness using the cost of replacing a bedside RN or ICU nurse and turnover rates as supporting data.

REFERENCES

Sweileh, W.M. Research trends and scientific analysis of publications on burnout and compassion fatigue among healthcare providers. *J Occup Med Toxicol* 15, 23 (2020). <https://doi.org/10.1186/s12995-020-00274-z>

Sherman, R (2021, February 19). *Keeping an Eye on Generation Z Nurses*. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7713635/>

Rabbi, S. (2018, April). *Code Lavender: A tool for Staff Support*. NSG0418_Cover_Puneet.indd (clevelandclinic.org)

Bodenheimer, T. and Sinsky, C. (2014 November 12). *From Triple to Quadruple Aim: Care of the Patient Requires Care of the Provider*. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4226781/>

Nurse Wellbeing at Risk: A 2020 National Survey. <https://www.emergingrnleader.com/wp-content/uploads/2020/10/NurseWellbeingAtRisk-Final2020-web.pdf>

World Health Organization (2019, May 28). *Burn-out an “occupational phenomenon”*: *International Classification of Diseases*. <https://www.who.int/news/item/28-05-2019-burn-out-an-occupational-phenomenon-international-classification-of-diseases>

Cornwall, L. (2018, December 12). *RNnetwork 2018 Portrait of a Modern Nurse Survey*. RNnetwork. <https://rnnetwork.com/blog/rnnetwork-2018-portrait-of-a-modern-nurse-survey/>

NSI Nursing Solutions, Inc. (2021, March). *2021 NSI National Health Care Retention and RN Staffing Report*. https://www.nsinursingsolutions.com/Documents/Library/NSI_National_Health_Care_Retention_Report.pdf

University of St. Augustine for Health Sciences. (2021, May) *The 2021 American Nursing Shortage: A Data Study*. <https://www.usa.edu/blog/nursing-shortage/>

Dr.Lorna Breen Hero’s Foundation (2021), <https://drlornabreen.org/the-issue/>

UT Southwestern, *Navigating our Multifaceted Acute Distress (NOMAD)*. <https://www.utsouthwestern.edu/about-us/faculty-wellness/group-peer-support/>
https://www.nsinursingsolutions.com/Documents/Library/NSI_National_Health_Care_Retention_Report.pdf

Lin, K. (2021, June 21.) *How a new buddy system is helping health workers grapple with Covid’s toll*. <https://www.statnews.com/2021/06/21/how-a-new-buddy-system-is-helping-health-workers-grapple-with-covids-toll/>

Mount Sinai Abilities Research Center, Recharge Rooms. <https://www.mountsinai.org/locations/abilities-research-center/programs-technologies/recharge-rooms>

Stockton, S. and King, L. (2021 February 24). *Death, Through a Nurse’s Eyes*. <https://www.nytimes.com/video/opinion/100000007578176/covid-icu-nurses-arizona.html>

Mount Sinai Road to Resilience Podcast, (2020, May 22). *The Recharge Room*. <https://www.mountsinai.org/about/newsroom/podcasts/road-resilience/recharge-room>

American Association of Critical Care Nurses, (2020 July 1). *Leadership at Its Best: Supporting Staff Nurses in a Pandemic*. <https://www.aacn.org/clinical-resources/covid-19/podcast-series/leadership-at-its-best-supporting-staff-nurses-in-a-pandemic>

Other Resources:

Healthcare Employee Assistance Program (EAP), <https://www.theeap.com/healthcare-eap>
American Foundation for Suicide Prevention, <https://afsp.org/>
Facilities Guidelines Institute, <https://fgiguilines.org/>



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LIGHT & WELL-BEING IN THE HYBRID WORKPLACE

ABSTRACT

Considering recent events from the pandemic and the growing awareness around work-from-home preferences, the Lighting Design Studio at CRTKL set out to answer the following question: If a hybrid work model is the new normal for office workers, how might different lighting conditions at home and in the office vary, and what are the implications to human health and well-being? Our research approach consisted of building general knowledge around the topic of circadian lighting design standards and design practices and conducted two field surveys to examine the disparity between “work-from-home” (WFH) and “return-to-office” (RTO) lighting conditions. These field surveys identified inadequate circadian effective light levels at home and excessive circadian effective light levels in the office, in the evening hours after 5pm. When designing circadian lighting applications for human health and well-being, it is important to consider industry metrics and the whole experience of the occupant(s). Lighting controls and material specification, as well as spatial relationships with sources of light across time, should be integral to any conversation about circadian lighting design outcomes.

CONTEXT

In the twenty years since the National Human Activity Pattern Survey (NHAPS), funded by the Environmental Protection Agency (EPA), determined that Americans spend 86% of their lives indoors and a further 6% in an enclosed vehicle on average (Klepeis et al, 2001), the wellness industry and the science behind circadian lighting has evolved significantly. In 2021, the global wellness market was estimated to total \$1.5 trillion dollars (Callaghan, 2021), of which circadian lighting is expected to be valued at \$1 billion dollars with an estimated 20% annual growth rate through 2028 (Data Bridge Market Research, 2021).

The understanding that our interior spaces have a direct impact on our psychological, biological, and sociological well-being is widely accepted today, as evidenced by the emergence and subsequent exponential growth of the WELL Building Standard since its launch in 2013. Following the World Health Organization’s (WHO) declaration that COVID-19 was a pandemic in 2020 (Cucinotta, 2020), the focus on human well-being in the built environment has dramatically expanded across multiple industries. The “work-from-home” (WFH) transformation that occurred across broad swaths of the economy during the early months of the pandemic brought the seriousness of human health and

well-being home for millions, and laid bare for many, the health concerns that an overconnected “constantly on” 24-hour society and its detachment from the natural world (Figure 1) can have on mental health, disrupted circadian rhythms, and sleep deprivation.

Although the pandemic may have shed light on these issues for the public, by no means are they new concerns. In 2014, the CDC declared sleep deprivation as a “public health epidemic” linked to a wide range of medical issues, including hypertension, diabetes, depression, obesity, and cancer (Pinholster, 2014). More recently, the International Agency for Research on Cancer (IARC), an intergovernmental agency forming part of the WHO of the United Nations (UN), concluded in 2019 that “night shift work” is a probable carcinogen to humans (Erren et al, 2019).

As of January 2022, approximately 23.9 million or 15.4% of the total U.S. workforce still identify as having teleworked due to the pandemic (U.S. Bureau of Labor Statistics, 2022), with management, professional, or other service-related occupations accounting for 75% of this population category. As restrictions are lifted and companies begin their “return-to-office” (RTO), often emphasizing workplace flexibility, these figures underscore the extent of a hybrid workplace model, which is characterized by a work routine split between the

home and the company office. As lighting designers at CRTKL, this emergent “flexible” hybrid workplace for millions raises questions about the human health and well-being consequences that might result from the disparity of lighting conditions between working from home versus at the office.

Light and Circadian Rhythms

Almost all living organisms on Earth exhibit circadian rhythms, which are biological cycles regulated by environmental signals that are adapted to the 24-hour light dark cycle that results from the Earth’s regular rotation (Vitaterna et al, 2001). According to recent studies, a consistent and stable light-dark cycle is necessary for a healthy system (Legates et al, 2014). Predictable daily cycles of light and dark allow for the synchronization of behavioral and biological processes to the external environment with light being one of the most important signals for the circadian system. This process starts at the eyes when light is processed by photoreceptive retinal cells that signal the brain (Figure 3), which regulates rhythmicity throughout the body’s tissues and organs (Figures 4 and 5), affecting hormone levels, gene expression and the sleep-wake cycle (Figure 5).

With the discovery of intrinsically photosensitive retinal ganglion cells (ipRGCs) (Figure 3) in 2002 by David

Berson, came a paradigm shift in how light is measured, manufactured, specified, and put into practice (Figueiro, 2016). Scientific research has demonstrated that ipRGCs are biologically responsive to short wavelengths of light (sky-blue) (Lucas et al, 2014) and form the main conduit for light to signal the central circadian clock that exists in the suprachiasmatic nucleus (SCN) found within our brains (Figure 4) (Buttgereit et al, 2015). ipRGCs produce melanopsin, which is a light sensitive photopigment protein that provides information to the melatonin production system and the sleep regulation system, and modulates cognitive function, alertness, body temperature, mood, and emotion (Cao et al, 2015) (Lucas et al, 2014). Concerning negative health effects, studies have shown, disruption of circadian rhythms has been associated with increased risk of hormone-dependent cancers (Sigurdardottir et al, 2012).

When it comes to measuring light's impact on "well-being," definitions and metrics can vary widely. Likewise, the difference between wellness and well-being are significant and can have a large impact on employee engagement, productivity, and performance (Pendell, 2021). Today, numerous models exist that loosely define well-being as a general framework relating to the psychological, physiological, and socio-economic dimensions that influence a person's

overall state of a well-lived life. One such industry example is the Human Spaces report into the "Global Impact of Biophilic Design in the Workplace," led by renowned organizational psychologist Professor Sir Cary Cooper. This report revealed that employees who work in environments with natural elements report a 15% higher level of well-being, are 6% more productive and 15% more creative overall. Furthermore, the study found that those who reported working in environments that were light and spacious had higher levels of well-being, motivation, productivity, and creativity (Figure 2) (Interface, 2015).

Purpose

With these questions in mind, the lighting design team at CRTKL set out to understand how light plays a contributing factor to one's overall well-being with its ability to influence and regulate the human circadian rhythm. The primary purpose of our research was to fact-find and gain general knowledge on the principles behind human circadian rhythms and its implications on well-being. We also sought to better understand the different industry metrics and recommendations that are still in development to measure design outcomes. Lastly, and most importantly, the purpose of our research was to test the hypothesis that different lighting conditions at home and in the office would vary significantly, and that work from home conditions would likely be inadequate for healthy circadian entrainment.



Figure 1: Earth's black marble composite assembled from data acquired by the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite. Source: NASA Earth Observatory images by Joshua Stevens, using Suomi NPP VIIRS data from Miguel Román, NASA GSFC.



Figure 2: Access to daylight is more important than ever when working from home since electric lighting conditions in residential settings do not provide enough light to promote healthy circadian sleep/wake cycles. Source: Adobe Stock image, 2022.

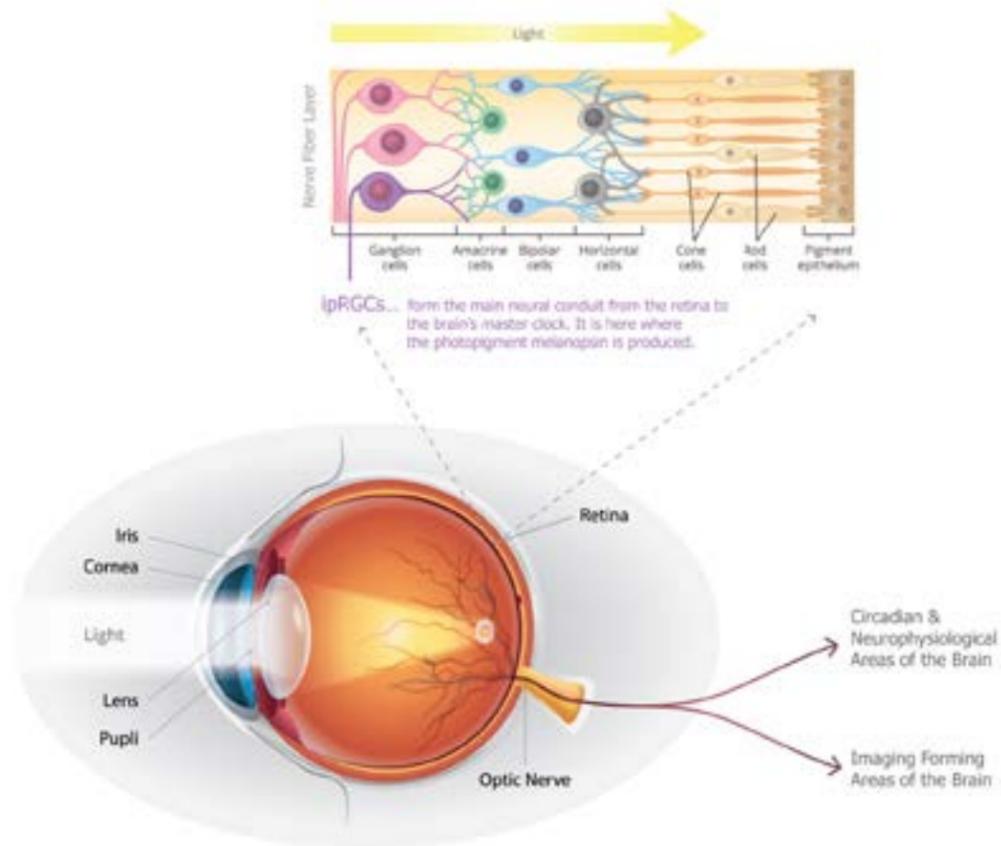


Figure 3: Neuroanatomy of the human eye, retinal fiber layer, optic nerve, and the relative location of intrinsically photosensitive retinal ganglion cells (ipRGCs) within the context of the neural pathways to the brain. Source: Adobe Stock images edited by CallisonRTKL, 2022.

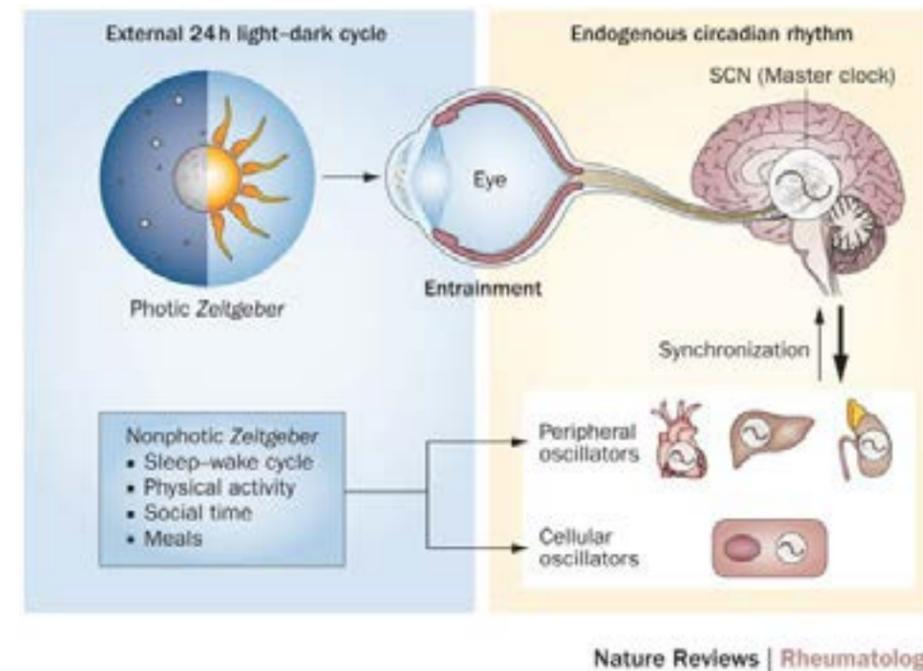


Figure 4: Internal circadian clocks (oscillators) throughout the body and external zeitgebers (also known as time-givers). Source: Buttgerit, F., Smolen, J., Coogan, A. et al. Clocking In: Chronobiology in Rheumatoid Arthritis. Nature Review Rheumatol 11, 349–356 (2015). <https://doi.org/10.1038/nrrheum.2015.31>

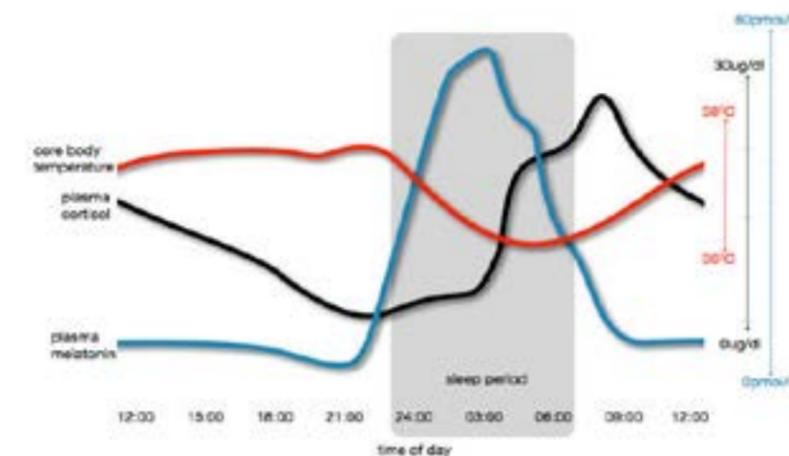


Figure 5: The normal synchronous relationships between sleep and daytime activity and varying levels of cortisol, melatonin and body temperature.

Figure 5: Normal synchronous relationships between sleep and daytime activity and corresponding levels of cortisol, melatonin, and body temperature. Source: Hickie, Ian & Naismith, Sharon & Robillard, Rébecca & Scott, Elizabeth & Hermens, Daniel. (2013). Manipulating the sleep-wake cycle and circadian rhythms to improve clinical management of major depression. BMC medicine. 11. 79. 10.1186/1741-7015-11-79.

Metrics

What Are We Measuring?

The WELL Building Standard set an industry precedent when it became the early adopter and promoter of the theoretical model for Equivalent Melanopic Lux (EML) published by Lucas et al in 2014. Since that time, EML has been revised by the CIE and other models, that challenge this early metric by utilizing human subjects within field studies to determine effective outcomes, have been proposed. Codifying and adopting evolving circadian lighting metrics with consensus persists as a challenge for the industry, which has led to confusion for design practitioners and stakeholders across industries as reliable outcomes are sought.

Equivalent Melanopic Lux (EML)

According to Lucas et al. from 2014, Equivalent Melanopic Lux (EML) is computed as a two-part calculation involving the melanopic to photopic (M/P) ratio and vertical illuminance at the eye (Ev). EML was introduced in 2014 as a metric and methodology that multiplies photopic illuminance (daytime sensitivity) by this ‘melanopic ratio’ (Lucas et al, 2014). This function provides a resultant value for melanopic lux which forms the basis of determining a light source’s potency regarding the melanopic sensitivity curve of the human eye (Figure 6) that is based on the photopigment melanopin as produced by ipRGC’s within the eye (Figure 3).

Melanopic Equivalent Daylight Illuminance (m-EDI)

Current best practice for calculating effective brightness for melanopsin in humans is to employ the method defined by the international standard CIE S026 (CIE, 2018), which proposes Melanopic Equivalent Daylight Illuminance. Also known as melanopic EDI, or “m-EDI” for short, this metric represents the illuminance of standard daylight (D65). For example, m-EDI of 100 lux means that the light source under evaluation produces the same amount of melanopsin-activating radiation as 100 lux of daylight at 6,500K.

A limitation of the Lucas et al. and CIE methods is that they are based solely on one photopigment signal, melanopsin, yet it can be argued that it is unknown how photopigment signals are combined by photoreceptors and processed by the brain (Figueiro, 2017). Understanding of how EML and m-EDI relate to non-visual outcomes in real-world settings is limited due to their theoretical basis for measurement and limited predictive outcomes.

Circadian Stimulus (CS)

Circadian Stimulus (CS) allows one to predict how different spectral power distributions and light levels will suppress the hormone melatonin at night. (Figure 7). This metric is a non-linear model of human nocturnal melatonin suppression that is based

on the quantity and spectrum of light when assuming 1-hour of exposure time. Accordingly, Circadian Stimulus (CS) is based on the measured characteristics of retinal phototransduction – the process by which the retina converts light into neural signals for the circadian system – from response threshold (CS = 0.0) to saturation (CS = 0.7) and is directly proportional to nocturnal melatonin suppression after one hour of light exposure. (Rea et al, 2016).

Current Recommendations

What Are We Designing For?

Chief among the advice offered by the WELL Building Standard is the simple recognition that buildings act as an intermediary between the material world around us and the amount and quality of light that reaches the eyes of people who inhabit the built environment. With this awareness, together with evolving and nascent circadian lighting metrics, consensus for a single set of authoritative recommendations remains a challenge for the industry. Design guidelines for circadian effective projects have largely coalesced around two distinct organizations as follows:

WELL Building Standard v2

Widely referenced and perhaps the most prevalent industry adopted model for building design and circadian lighting, the WELL Building Standard outlines several recommendations and minimum requirements over nine unique design

“features” (IWBI, 2022) for light.

To comply with the “Circadian Lighting Design Feature,” designers must provide a minimum of 150 EML [135 m-EDI] for 1-point or provide 275 EML [250 m-EDI] for 3-points. In either case, these light levels must be maintained for a minimum of four hours, beginning by noon at the latest (IWBI, 2022). These light levels must be achieved on the vertical plane at eye level to simulate light entering the eye of the occupant. These values are based on recommendations established by the 2nd International Workshop on Circadian and Neurophysiological Photometry convened in 2019 (Brown et al, 2020).

UL Design Guidelines 24480

Published in 2019, the UL design guide is based on the circadian stimulus (CS) method for designing and specifying circadian-effective light. These recommendations have been tested in field studies demonstrating that light that promotes circadian entrainment will lead to better sleep, mood, and behavior (Rea & Figueiro, 2016). This publication was the result of a diverse task group assembled by UL, which included two rounds of public comment during which lighting design professionals, facility owners, lighting manufacturers, sleep scientists and others provided constructive input.

In addition to establishing recommended thresholds for CS, the design guide also outlines design criteria for occupant considerations, intensity, duration, timing, spectrum, spatial distribution and measurement (Brown et al, 2019). It is recommended that a CS of 0.3 or higher be achieved during morning into daytime conditions, decreasing the amount of CS as the day progresses reaching 0.2 by 5pm and < 0.1 by 8pm (Figure 7).

The 2nd International Workshop on Circadian and Neurophysiological Photometry

This conference brought together eighteen scientists in lighting, neurophysiological photometry, sleep, and circadian research. Together, this group of scientists agreed on recommendations for daytime light and evening light in indoor environments (Brown et al, 2020), expressed in accordance with the new CIE measurement standard codifying m-EDI (CIE, 2018), as follows:

Daytime recommendations for indoor environments:

- Throughout the daytime, the recommended minimum m-EDI value should be 250 lux measured at the eye.
- If available, daylight should be used in the first instance to meet these levels. If additional electrical lighting is required, the light source should have

a spectrum that, like natural daylight, is enriched in shorter wavelengths close to the melanopic action spectrum – 480 nm.

Evening light recommendations for residential and other indoor environments:

- Starting at least three hours before bedtime, the recommended maximum m-EDI value should be no more than 10 lux measured at the eye.
- To help achieve this, where possible, the light source should have a spectrum depleted in short wavelengths close to the melanopic action spectrum – 480 nm.

These recommendations are intended to apply to adults with regular daytime schedules. Special considerations may apply to specific populations (e.g., children, the elderly, shift workers) as discussed in the publication.

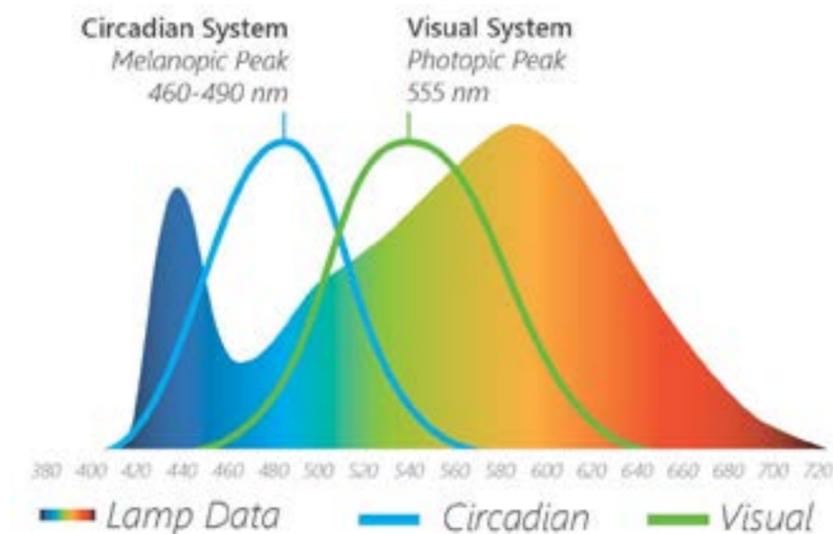


Figure 6: Peak sensitivity curves for Melanopic (circadian) and Photopic (visual) systems compared to the typical spectral power distribution of a 3500K LED light source. Source: International Well Building Institute, WELL Building Standard v2 Melanopic Ratio Toolkit, 2022.

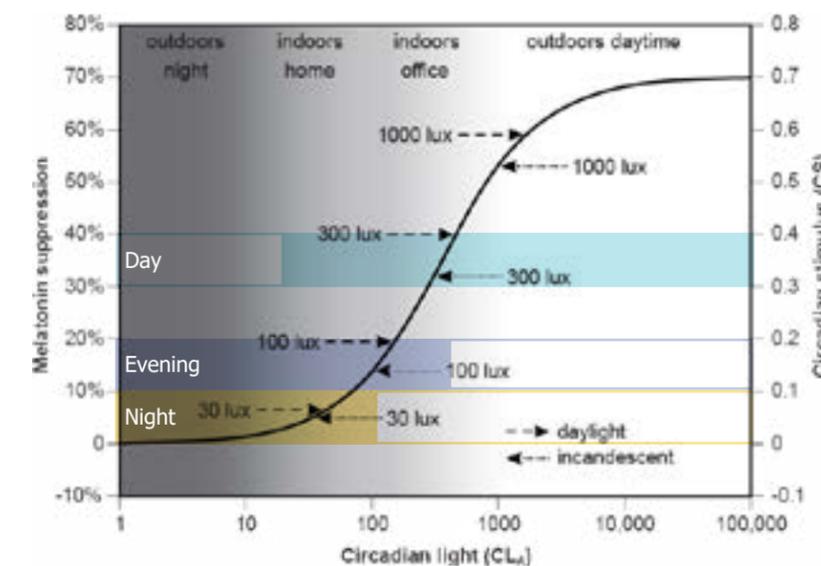


Figure 7: Synchronization of the circadian system is best achieved by providing a robust pattern of light and dark that delivers: 1. High amounts of CS (0.3 minimum, preferably ≥ 0.4) during the morning. 2. Decreasing the amount of CS as the day progresses, reaching a CS of 0.2 by 5:00 pm and < 0.1 by 8:00 pm. The circadian stimulus (CS) metric was developed by the Lighting Research Center (LRC) and is used to assess how effective a light source (amount and spectrum) is in stimulating the circadian system. CS calculations use circadian light (“CLA”) based on the spectral sensitivity of the circadian system response. CS is calculated by transforming CLA into a relative scale, from approximately 0.1 ($\approx 10\%$, the threshold for circadian system activation), to approximately 0.7 ($\approx 70\%$, response saturation). CS is equivalent to nocturnal melatonin suppression (in percent) after a 1-hour exposure to light. Source: Lighting Research Center, Rensselaer Polytechnic Institute, <https://www.lrc.rpi.edu/healthyliving>

APPROACH

While decades of important scientific research and industry precedent on the topic of circadian light and its metrics for analysis and design exist today, the primary goal for this research initiative was to educate ourselves and build general knowledge on the subject, so as to gain better insight into the implications of evolving circadian lighting design metrics being proposed and put into practice by the WELL Building Standard as related to the hybrid workplace and the return-to-office (RTO) transition. To that end, the team was interested to understand how conditions working from home would compare to those in the CRTKL New York office.

With this potential in mind, our research set out to examine a simple question; to what degree does a disparity exist between circadian lighting conditions at the home and in the office? We hypothesized that a disparity in circadian lighting quality would not only exist between these different environments, but such a disparity would be substantial and indicative of the highly personalized spaces that have become emblematic of the WFH revolution for a significant portion of the professional services workforce.

Our investigation began as a mixed method approach to collect primary quantitative data in the form of field

measurements, both at home and in the office, alongside the collection of qualitative insights in the form of a general population survey. These efforts eventually narrowed in scope to focus solely on field measurements and the review of existing secondary research in the form of articles, journals, and other works cited.

Data Collection

Direct observations took on the form of two different field surveys measuring circadian effective lighting exposure utilizing two different metrics. Both field surveys involved four members of the CallisonRTKL Lighting Design Studio.

Point-In-Time Circadian Stimulus (CS) In-Situ Samples

Measurement Method

The measurement method for this study followed the WELL Building Standard v2 Performance Verification Guidebook requirements for Feature L03 Part 1 for Circadian Lighting (IWBI, 2021).

- Measurements were conducted in-situ at the home of each participant at the following intervals: 9am, 12pm, 5pm and 8pm.
- All measurements were recorded on the vertical plane approximately 1 meter above the finished floor and perpendicular to the workstation to simulate the light entering the eye of the occupant (Figure 8).

- The measuring instrument was mounted on a tripod and placed on a stable surface for each measurement.
- Care was taken to ensure the shadow of the testing volunteer was not obstructing the measurement instrument.

Measurement Equipment

All measurements were conducted with a spectrometer according to the following specifications:

- Wavelength range: 380-780 nm
- Maximum acceptable overall error: +/-5%
- Optical Resolution: 10nm or less
- Range: 5-50,000 lux
- Resolution: 1 lux (at values up to 2000 lux)
- Meter calibration in accordance with an ISO/IES 17025:2017 accredited calibration lab or traceable to a National Metrological Institute, such as NIST, NPL, or PTB.

Continuous Melanopic Equivalent Daylight Illuminance (m-EDI) Interval Sampling

Measurement Method

The measurement method for this study was largely self-determined by the group of participants. A trial period was conducted to proper equipment operation and data synchronization between devices.

- Participants were asked to wear their sensors daily for a period of 7-days while working from their homes.
- The measuring instrument was attached to the collar or lapel of clothing (Figure 8).
- Care was taken to ensure that clothing was not obstructing the measurement instrument.

Measurement Equipment

All measurements were conducted with a wireless wearable spectrometer according to the following specifications:

- Wavelength range: 350-750 nm
- Range: 0-100,000 lux
- Resolution: 1 lux (at values up to 2000 lux)
- m-EDI: melanopic lux, α -opic equivalent daylight (D65) illuminance with spectral age correction
- Calibration from the manufacturer could not be determined.

Analysis

The point-in-time field data collected reporting CS was analyzed using the “CS Calculator 2.0” published by the Light and Health Research Center (LHRC, 2021) with the Icahn School of Medicine at Mount Sinai and was further formatted with the “Melanopic Ratio Calculator” published by the International Well Building Institute (IWBI, 2018). The continuous m-EDI interval sampling field data captured over seven days was

provided by LYS Technologies and made accessible via their proprietary cloud-based data platform. All data post-processing, final analysis and formatting was generously provided by data scientist Eduard Nilaj of the Jain Family Institute.

Factors and Limitations

Care was taken to make sure the field research was as rigorous as possible. Unlike computer modeled simulations which can easily employ a multitude of data capture points in an artificially controlled environment, our field research dealt with real world conditions observed in-situ.

The primary aim of each field survey was intended to gain knowledge on the topic at hand, test our hypothesis against known limitations, and identify variables for future study. We recognize that several factors exist which limit the data collected and impacts the conclusions one might draw from the result of the findings depicted. Due to limited cost, time and variance within environmental conditions at the time of observation, the data collected and summarized should be a preliminary assessment of the hypothesis only.

Data Sample

The data captured through our field studies should be compared to a broader data set via means of re-testing to ensure consistency of the measurements and results reported. Single point in time

observations and standalone interval sampling should be observed more than once to mitigate deviations that might occur.

Participant Sample

Since the number of participants was limited to four individuals, future studies will benefit from a larger sample group. Increasing the number of participants by ten-fold or more will help to account for standard deviation within data captured.

Environmental Variables

Environmental factors such as daylight access, time of day, season, weather conditions, as well as social and behavioral circumstances all influence the overall human experience with light. This research and future studies could benefit from a more detailed accounting of these variables to determine the extent of their impact on the data collected.

Behavioral & Qualitative Outcomes

The scope of this research initiative did not endeavor to correlate findings with specific behavioral or medical health outcomes. Our goal was to identify disparities between work from home (WFH) and return to office (RTO) conditions within the current context of circadian lighting design practices and industry recommendations.

FINDINGS

Point-in-Time Circadian Stimulus (CS) In-Situ Samples

Measurement Method Considerations

Although the following point-in-time field measurements were conducted in accordance with the methods established by UL Design Guidelines 24480 and the WELL Building Standards Performance Verification Guidebook Q4 2021 (Figure 8), it should be acknowledged that these methods do not properly account for overall visual experience since human vision is always on the move (Figure 9).

With this mind, the data captured in this study only represents one orientation that is normal to the work surface, which cannot accurately depict the overall behavior of the occupant at their workstation. This realization highlights the limitation that these types of field measurements encounter since multiple recordings from the same point in time would be labor intensive therefore requiring a rigorous system of reporting.

Software simulations can make up for this limitation by providing more readily available granular results over multiple iterations for less time, however, their data outcomes remain byproducts of a simulated environment, which is dictated by the accuracy of its construction. This research initiative is surely not the only that suggests the value of comparison between field results with those of computer modeled simulations to validate results between the two data sets.

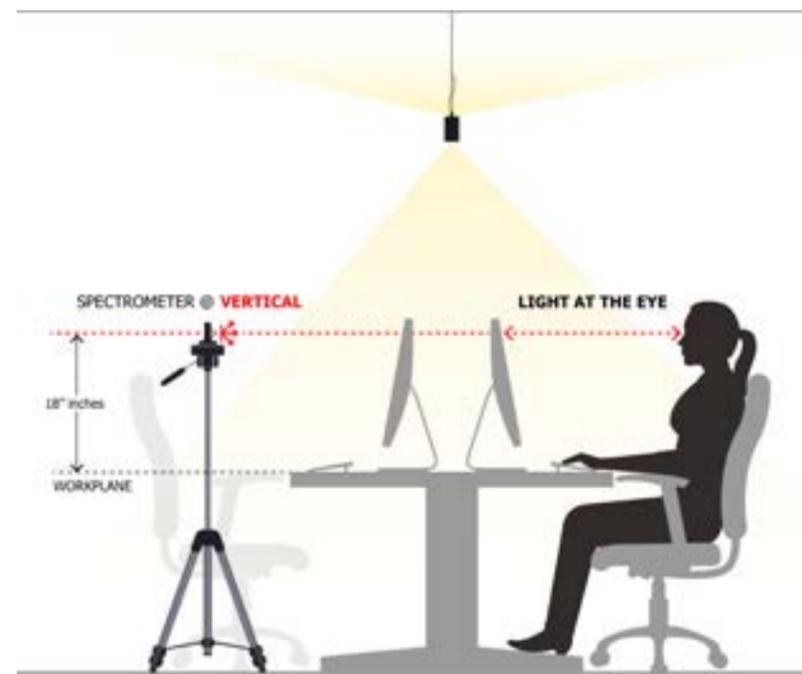


Figure 8: Method for field measurement of CS data according to UL Design Guide 24480, and m-EDI according to the WELL Building Standard. This method presupposes a static relationship between the viewer and the overall luminous environment. Source: CallisonRTKL, 2022.

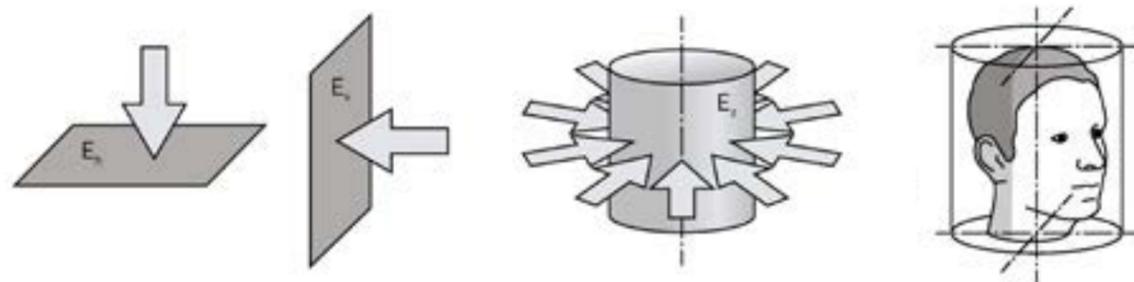
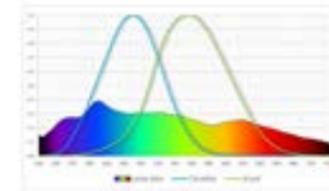


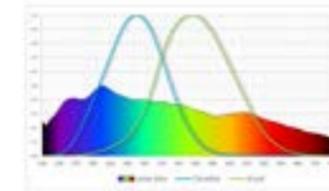
Figure 9: Comparison of the Horizontal illuminance E_h , Vertical illuminance E_v , and Cylindrical illuminance E_z modeling methods. Cylindrical illuminance (E_z) is the average of the vertical illuminance computed in the four cardinal directions (N,S,E,W). Source: TRILUX GmbH & Co. KG

WFH - AGB

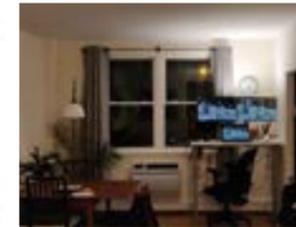
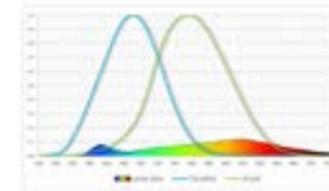
9AM - 0.32 CS



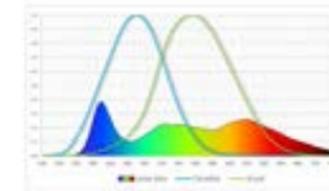
12PM - 0.38 CS



5PM - 0.07 CS



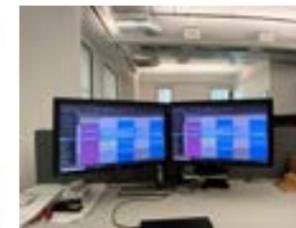
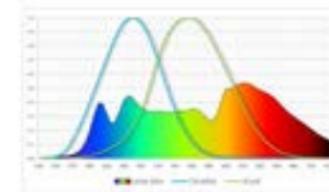
8PM - 0.22 CS



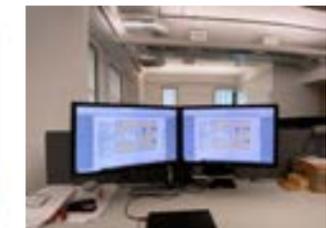
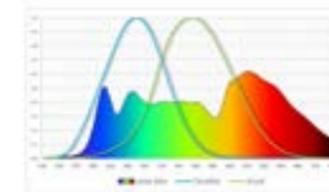
Recorded on December 4th, 2021 under partially cloudy sky conditions. The daylight aperture is North facing with moderate urban obstructions. Results indicate CS values that consistently meet minimum recommended values during daytime hours, where evening and nighttime exposures vary. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

RTO - AGB

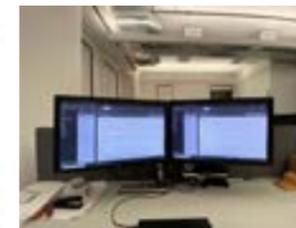
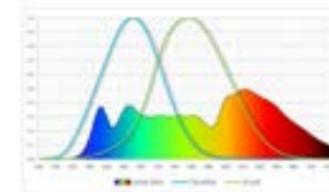
9AM - 0.31 CS



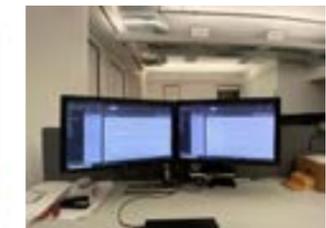
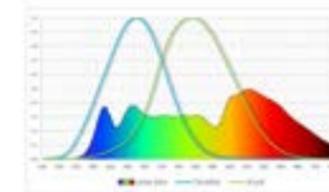
12PM - 0.34 CS



5PM - 0.29 CS



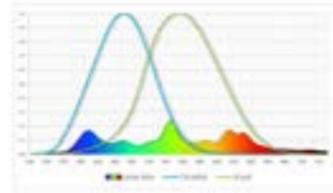
8PM - 0.29 CS



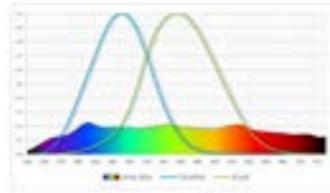
Recorded on January 18th, 2022 under clear sky conditions. Adjacent daylight apertures are South and West facing with significant urban obstructions. Additionally, the majority of windows shades were drawn throughout the measurement period. Results indicate CS values that consistently meet minimum recommended values during daytime hours, whereas evening and nighttime values exceed recommended maximum thresholds. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

WFH - CC

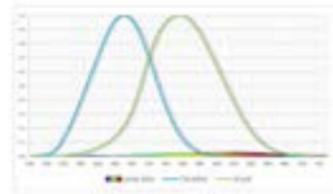
9AM - 0.13 CS



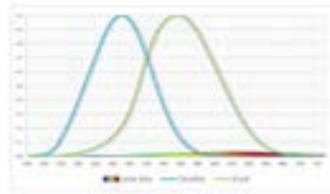
12PM - 0.23 CS



5PM - 0.02 CS



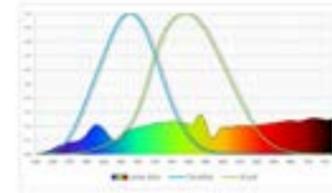
8PM - 0.02 CS



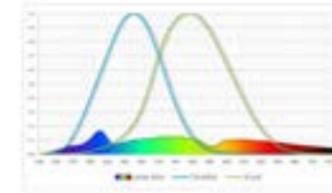
Recorded on December 10th, 2021 under partially cloudy sky conditions. The daylight aperture is East facing with minimal suburban obstructions. Results indicate CS values consistently fail to meet minimum recommended values during daytime hours. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

WFH - KM

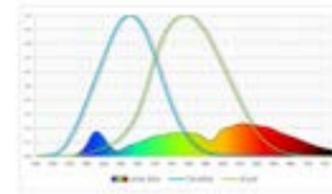
9AM - 0.19 CS



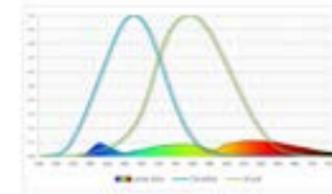
12PM - 0.14 CS



5PM - 0.12 CS



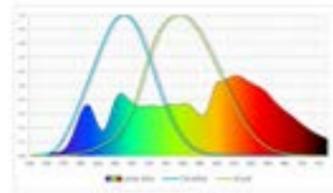
8PM - 0.07 CS



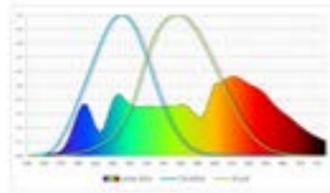
Recorded on December 12th, 2021 under partially cloudy sky conditions. The daylight aperture is North facing with moderate urban obstructions. Results indicate CS values are consistently below minimum recommended values throughout the day. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

RTO - CC

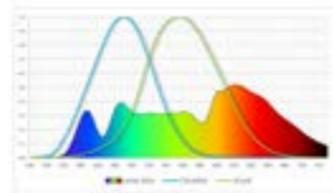
9AM - 0.31 CS



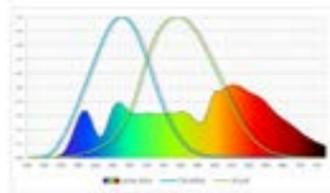
12PM - 0.31 CS



5PM - 0.29 CS



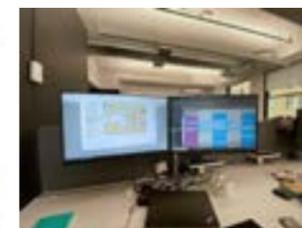
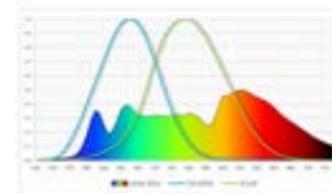
8PM - 0.29 CS



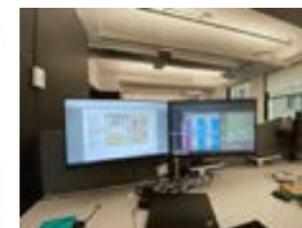
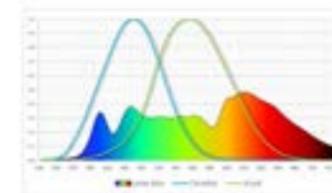
Recorded on January 18th, 2022 under clear sky conditions. Adjacent daylight apertures are South facing with significant urban obstructions. Results indicate CS values that consistently meet minimum recommended values during daytime hours, whereas evening and nighttime values exceed recommended maximum thresholds. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

RTO - KM

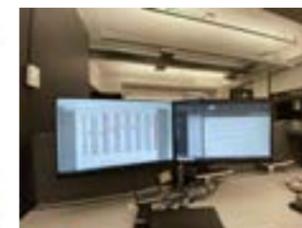
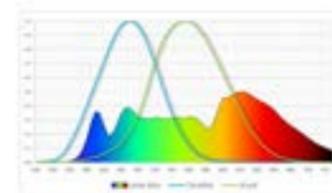
9AM - 0.28 CS



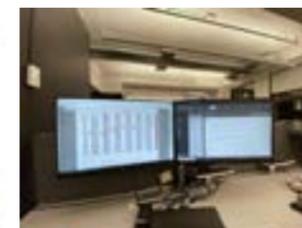
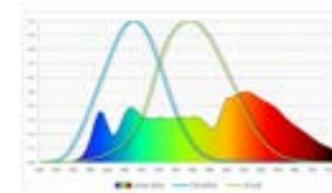
12PM - 0.28 CS



5PM - 0.28 CS



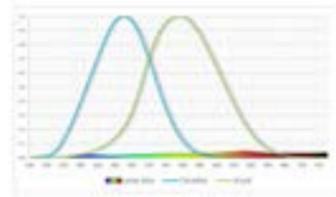
8PM - 0.28 CS



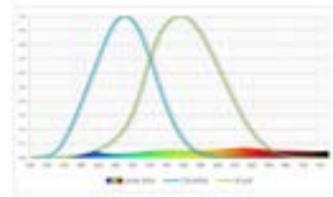
Recorded on January 18th, 2022 under clear sky conditions. Adjacent daylight apertures are South and West facing with significant urban obstructions. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

WFH - MV

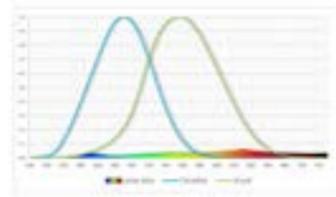
9AM - 0.03 CS



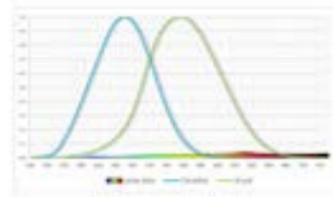
12PM - 0.04 CS



5PM - 0.03 CS



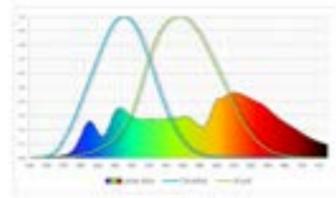
8PM - 0.02 CS



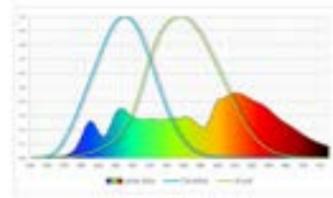
Recorded on December 8th, 2021 under cloudy sky conditions. Adjacent daylight aperture is Northeast facing with significant urban obstructions. Results indicate CS values consistently fail to meet minimum recommended values during daytime hours. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

RTO - MV

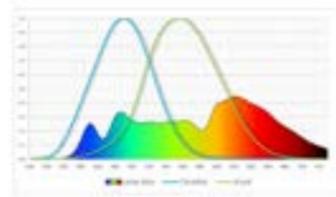
9AM - 0.26 CS



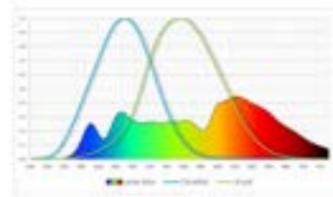
12PM - 0.25 CS



5PM - 0.24 CS



8PM - 0.24 CS



Recorded on January 18th, 2022 under clear sky conditions. Adjacent daylight apertures are South and West facing with significant urban obstructions. Additionally, the majority of windows shades were drawn throughout the measurement period. Source: CS values calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. SPD charts generated with the WELL Building Standard Melanopic Ratio Calculator.

Work From Home - Spectral Power Distribution

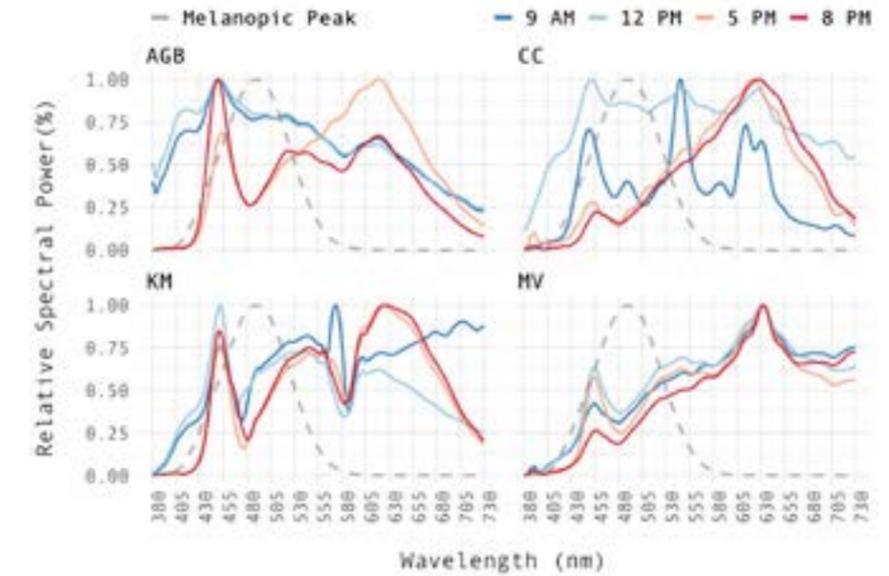


Figure 9: Spectral power distribution of the light sources under Work from home (WFH) conditions vary greatly between participants. Source: Calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

Return To Office - Spectral Power Distribution

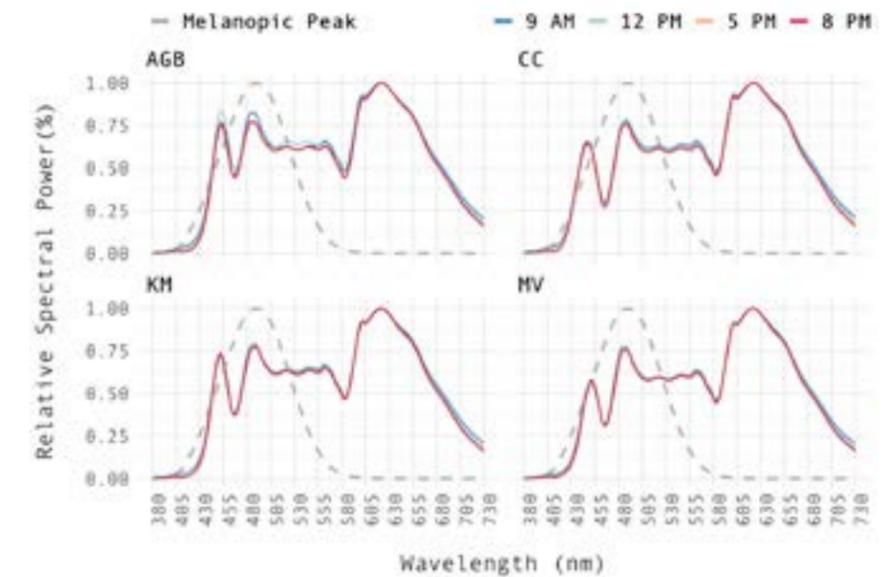


Figure 10: Data recorded on January 18th, 2021 under clear sky conditions on the 16th floor of the Woolworth Building. Return to office (RTO) conditions in New York indicate minimal deviation and consistency in spectral composition across location and time of day. Based on the data, it is apparent that the spectral composition of the office lighting has been optimized for melanopic peak sensitivity. Source: Calculated with the Light and Health Research Center CS Calculator (2.0), <https://cscalc.light-health.org>. Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

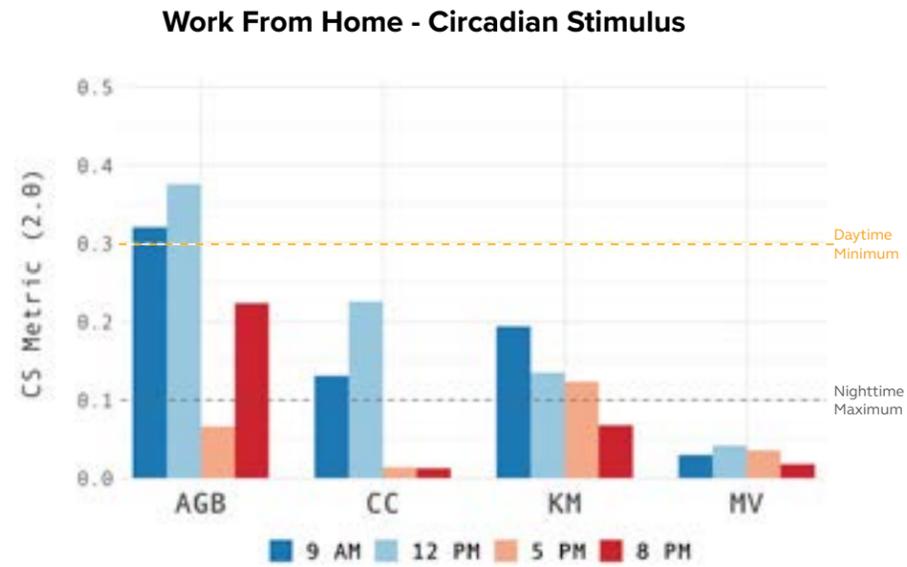


Figure 11: Data recorded from December 4th to 12th, 2021 under partially cloudy sky conditions within the home of each participant. Work from home (WFH) conditions for each participant vary greatly. From the data, Circadian Stimulus (CS) values consistently fall short of recommended minimum values for daytime exposure (as determined by the UL Design Guideline 24480). Source: CS values calculated with the Light and Health Research Center. CS Calculator (2.0), <https://cscalc.light-health.org>. Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

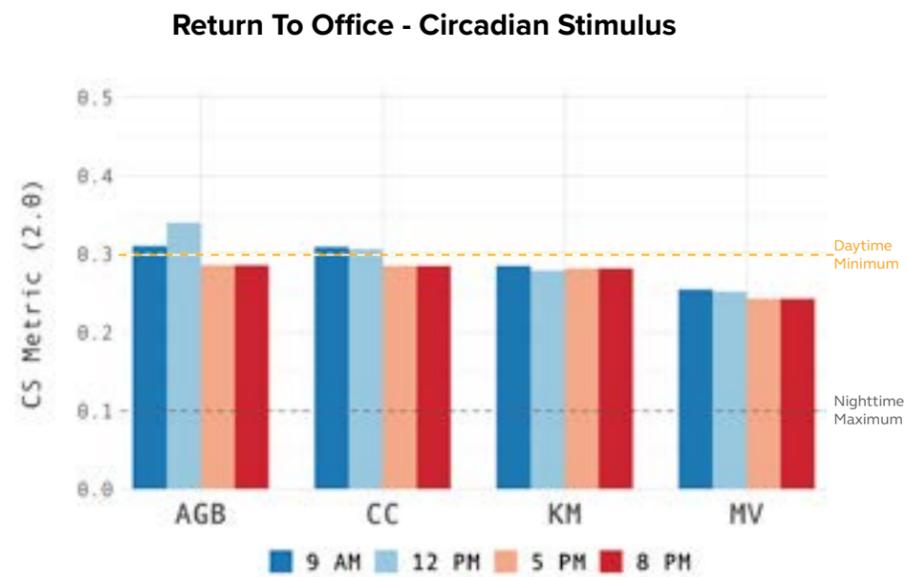


Figure 12: Data recorded on January 18th, 2021 under clear sky conditions on the 16th floor of the Woolworth Building. Return to office (RTO) conditions in New York indicate minimal deviation and consistency between location and time of day. From the data we can clearly see that the nighttime hours of 8pm or later exceed maximum recommended values (as determined by the UL Design Guideline 24480). Source: CS values calculated with the Light and Health Research Center. CS Calculator (2.0), <https://cscalc.light-health.org>. Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

Continuous m-EDI Interval Sampling

Measurement Method Considerations

Each participant involved in the field study voluntarily wore a wireless wearable sensor during waking hours over the course of seven days while working from home. The data recorded was synchronized to a local smart phone and uploaded to a cloud-based data platform. Although this setup was easy to initialize, the field study required trials to inculcate participant behavior

toward a consistent use of the wearable device. Data synchronization was also prone to error as is evidenced by the abbreviated four-day summary from one of our participants. Rigorous testing and retesting of the equipment as well as consistent usage by each participant is recommended to ensure accuracy in the data capture process.



Figure 13: Wireless wearable spectrometer and accelerometer continuously measuring circadian light exposure values at 15-second intervals throughout the day. Source: LYS Technologies LTD™, 2022.

Andres - Observed m-EDI Values Over One Week WFH

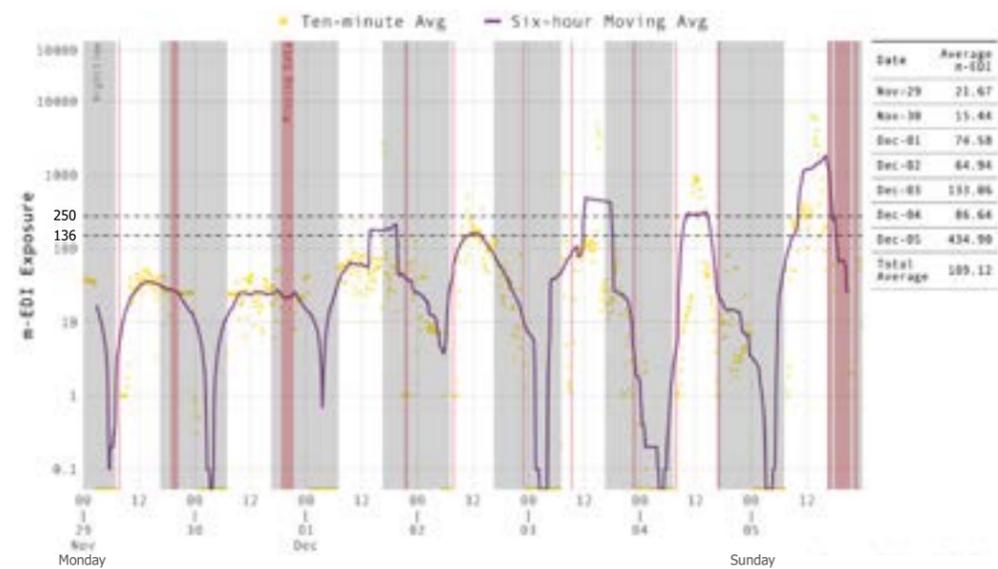


Figure 14: Observed m-EDI exposure with reference to recommended minimum values (as required by the WELL Building Standard v2) during a 7-day WFH period indicates an inappropriate and consistently dim environment throughout the work week daylight hours from 7am to 4:30pm. Friday, Saturday and Sunday stand as outliers to the rest of the week underscoring the importance of leaving the home to increase access to daylight and higher levels of light. Data recorded at 15-second intervals were averaged to 10-minute intervals. Source: Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

Kyle - Observed m-EDI Values Over One Week WFH

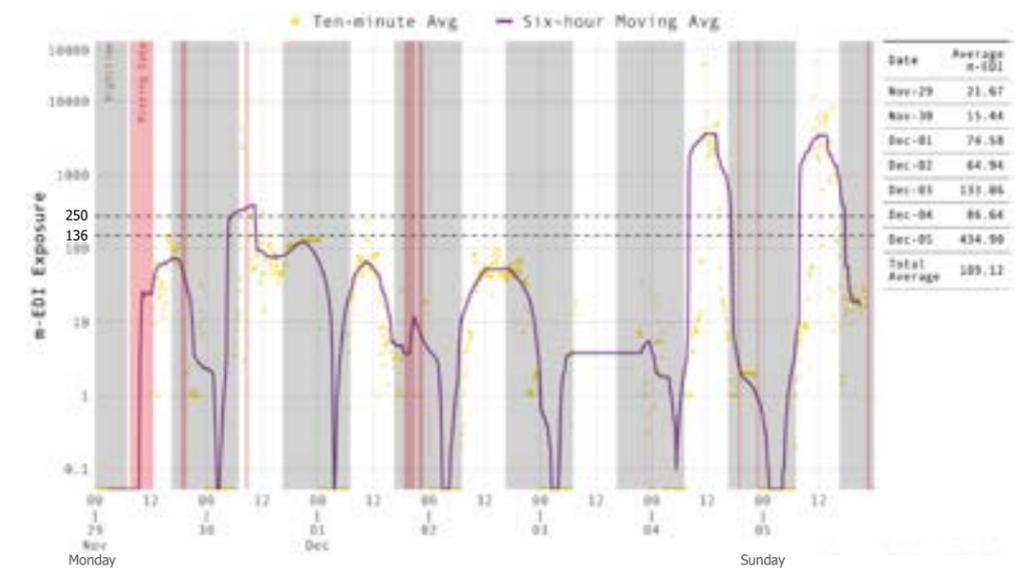


Figure 16: Observed m-EDI exposure with reference to recommended minimum values (as required by the WELL Building Standard v2) during a 7-day WFH period indicates an inadequate and consistently dim environment throughout the work week during daylight hours recorded from 7am to 4:30pm. This stands in stark contrast to the weekend underscoring the importance of leaving home to increase access to daylight and higher levels of light. Data recorded at 15-second intervals were averaged to 10-minute intervals. Source: Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

Carol - Observed m-EDI Values Over One Week WFH

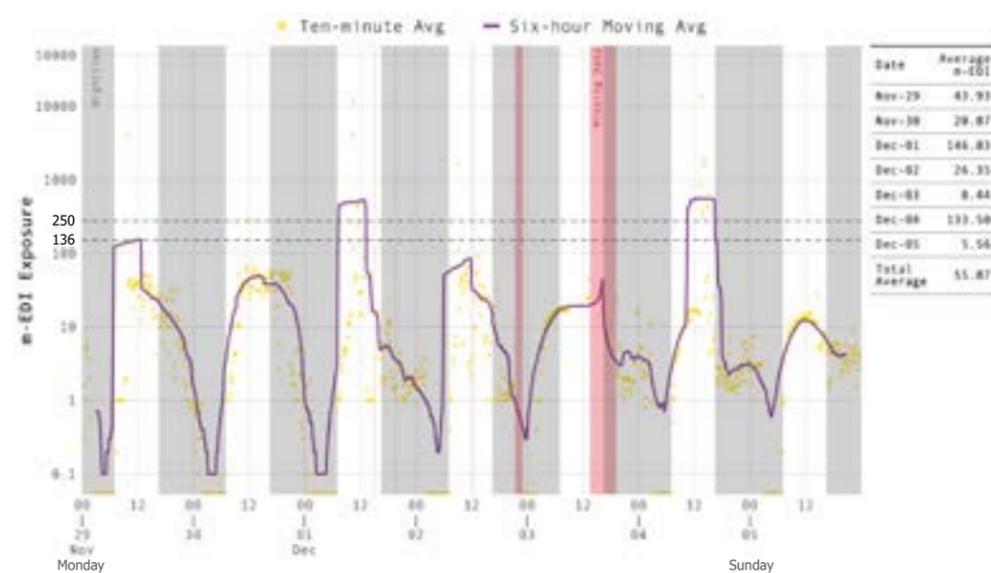


Figure 15: Observed m-EDI exposure with reference to recommended minimum values (as required by the WELL Building Standard v2) during a 7-day WFH period indicates an inadequate and consistently dim environment throughout the daylight hours recorded from 7am to 4:30pm. Wednesday and Saturday stand as outliers to the rest of the week underscoring the importance of leaving the home to increase access to daylight and higher levels of light. Data recorded at 15-second intervals were averaged to 10-minute intervals. Source: Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

Manisha - Observed m-EDI Values Over Four Days WFH

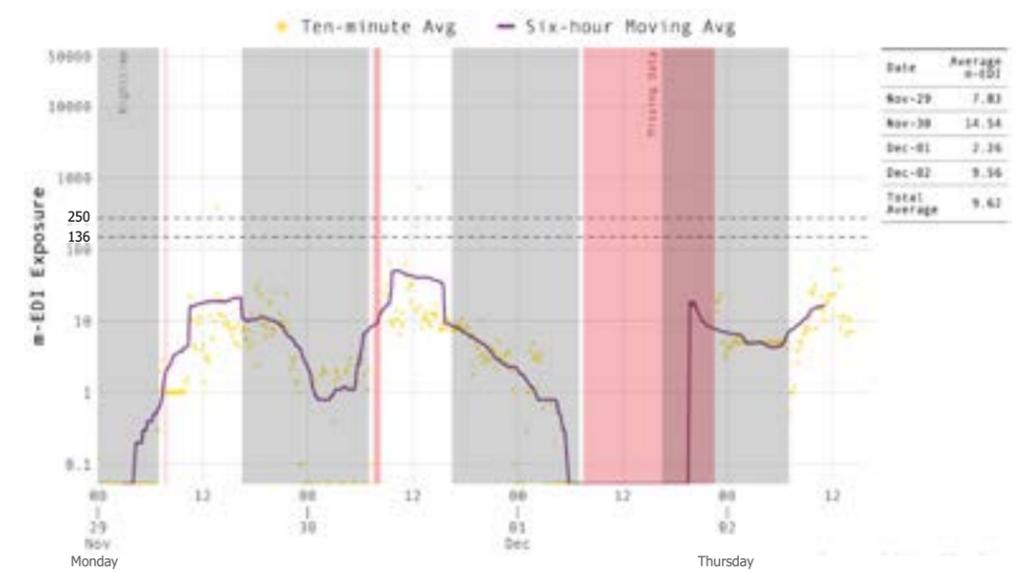


Figure 17: Observed m-EDI exposure with reference to recommended minimum values (as required by the WELL Building Standard v2) during a 4-day WFH period indicates an inadequate and consistently dim environment throughout the daylight hours recorded from 7am to 4:30pm, underscoring the importance of leaving home to increase access to daylight and higher levels of light. Data recorded at 15-second intervals were averaged to 10-minute intervals. Source: Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

m-EDI Six-Hour Moving Average Over One Week

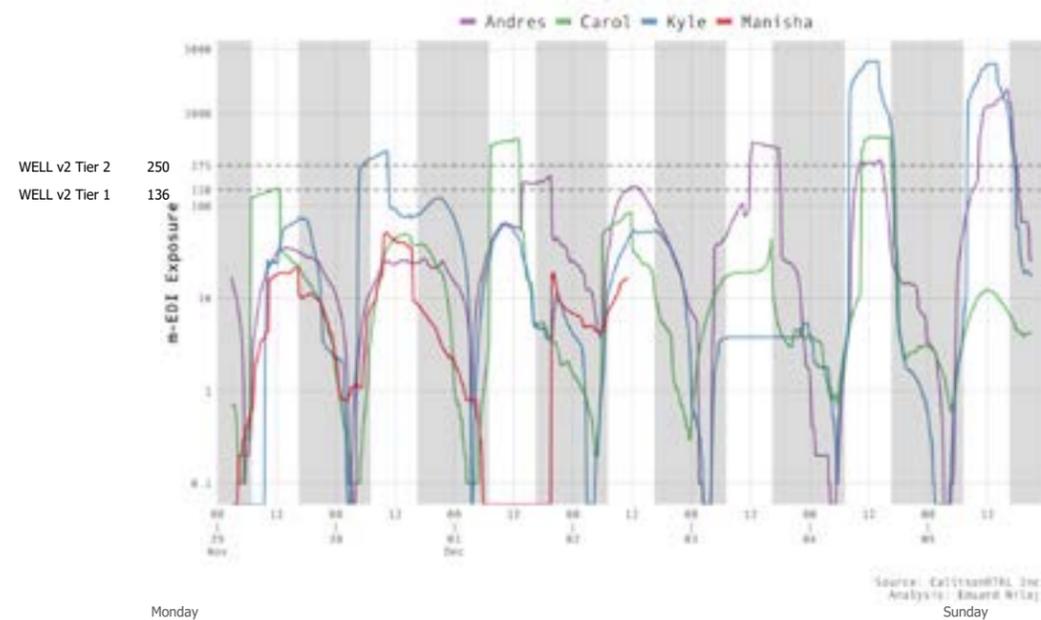


Figure 18: Six-hour moving average m-EDI exposure with reference to recommended minimum values (as required by the WELL Building Standard v2) during a 7-day WFH period suggests a significant variation from person-to-person day-to-day. Source: Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

m-EDI Daily Average Over One Week

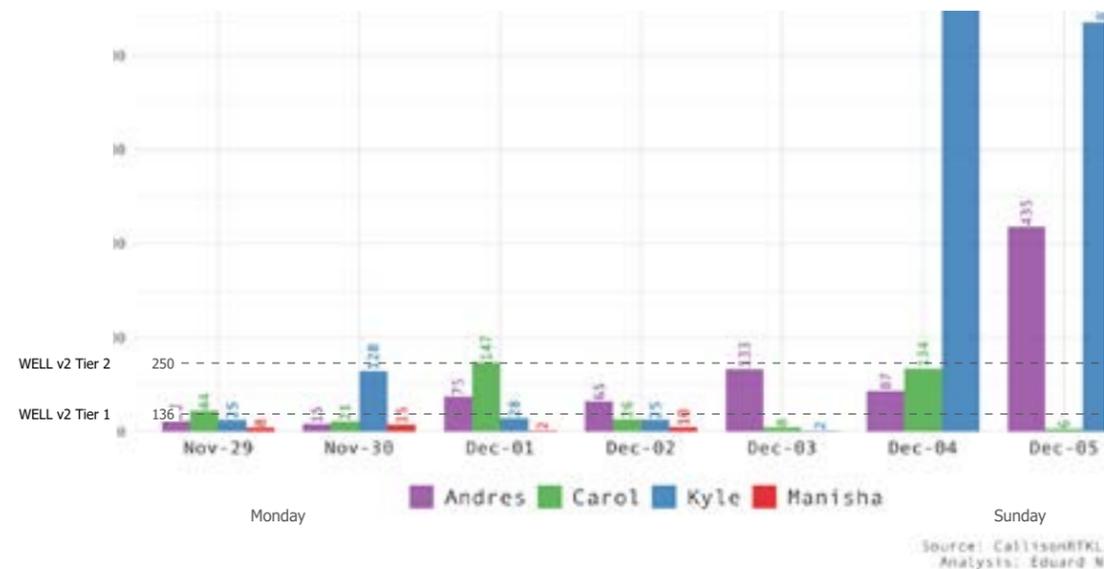


Figure 19: Daily average m-EDI exposure with reference to recommended minimum values (as required by the WELL Building Standard v2) during a 7-day WFH period suggests a significant disparity between the work week and the weekend. Source: Data analysis and formatting by Eduard Nilaj for CallisonRTKL, 2022.

CONCLUSIONS

This study has revealed how varied people’s lighting conditions are when working from home.

Findings & Observations

- Work from home (WFH) conditions indicate a high degree of variation in both spectrum and intensity of light exposure.
- Spectral power distribution of the light sources under Work from home (WFH) conditions vary greatly between participants.
- Based on the WFH data, Circadian Stimulus (CS) values consistently fall short of recommended minimum values for daytime exposure (as determined by the UL Design Guideline 24480).
- Return to office (RTO) conditions in New York indicate consistency and minimal deviation across the four test locations over the course of a prototypical in January.
- Light sources with enhanced spectral power were discovered throughout the open office work areas within the New York office.
- Based on the RTO data, during nighttime hours of 8pm and later, the observed Circadian Stimulus (CS) level of ~0.3 exceeds the maximum recommended CS value of 0.1 for that time of day (as determined by the UL Design Guideline 24480).

- The excess circadian stimuli during the evening hours are directly correlated to the absence of lighting controls throughout the New York office.

Final Thoughts

- Given everything that we have learned from “Working from Home,” user preference and comfort is key to any design solution.
- Task lights will be the most effective in either WFH or RTO scenarios given their proximity to the occupant and flexibility to accommodate individual preference for intensity, duration of use, and spectral composition.
- At a minimum, ensure a circadian stimulus >0.3 is provided for at least 2-hours during the morning hours of one’s day.
- Design considerations for workplace environments need to incorporate greater strategies to create more vertically illuminated surfaces, improve views to daylight and implement finishes that are conducive for a bright and luminous appearance.
- Workplace design proposals should consider integrated lighting controls with scene changes throughout the time-of-day as integral to any holistic design.

Psychological and neurophysiological health profiles are incredibly complicated and subject to countless relationships between external inputs and biological

processes, along with other environment and social factors. Measuring, analyzing, and determining behavioral or medical health outcomes because of circadian lighting requires a great deal of expertise, time, funding and a rigorous peer review process.

In a departure from the past, today's lighting design is more than just a collection of luminaires enabling vision

and aesthetics (Figure 20). As the world and our profession continue to evolve, the luminous environment around us will continue to have a biological impact on our collective health and well-being, and therefore must be considered with the changing priorities that are demanded of the built environment and the industry at large.

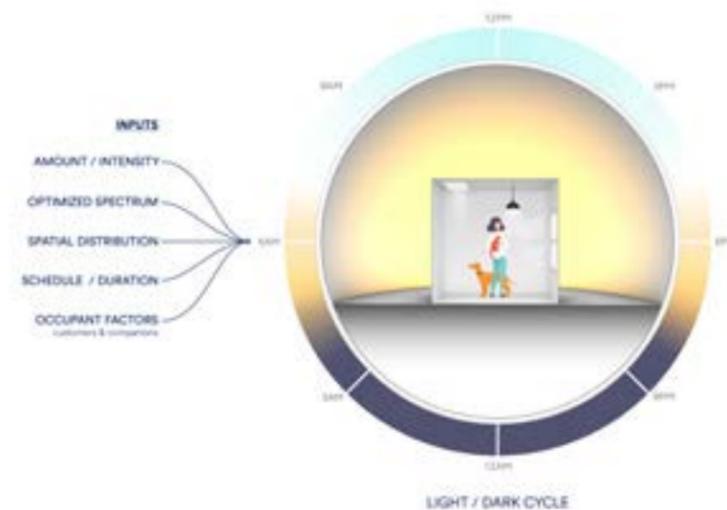


Figure 20: Illustration of the luminous environment that we inhabit, and the input variables that influence our visual and non-visual response to the world around us. Source: CallisonRTKL, 2022.

IMPLICATIONS

Exemplified by the WELL Building Standard, the design community must take care to understand the environmental and biological implications of their designs. As the emerging practice of circadian lighting design continues to evolve, the same level of rigor applied to the scientific process must also be applied to the evaluation and application of designs being implemented in the pursuit of human health and well-being. To that end, designers must not to confuse the metrics as a minimum prescriptive solution since there is no one-size-fits-all model that can be applied to all human environments or situations (Houser & Esposito, 2021).

Just as no environment is static, nor are the buildings we inhabit. It has long been recognized that the design choices we make for the built environment impact the health and well-being of the public with legal frameworks for policy and liability being implicated (Purdue et al, 2011). In keeping with the American Institute of Architects (AIA) Ethical Standards, we must recognize our obligation to public welfare by upholding environmental equity and justice when designing for spaces that support human health and well-being (AIA, 2020). As this study advocates, light is a fundamental part of one's environment, and the discourse and design for "human-centric

lighting" must expand the conversation beyond what we can readily see as a product feature or equipment application (Figure 21).

To guide future lighting designs, a framework was recently proposed which prioritizes occupant needs within the context of current guidance by outlining the following (Houser & Esposito, 2021):

1. Characterize the lighting application
2. Determine the likely sleep-wake cycle(s) of occupants
3. Determine the sleep needs of the occupants
4. Review published guidance to develop goals and design criteria that support visual and non-visual outcomes
5. Deploy this information to establish design criteria that will guide decisions in the latter stages of the design process.

Though research-based recommendations are available, a key challenge to designing with circadian light to promote human health and well-being continues to be the lack of an accepted framework from which the design community can analyze and quantify desired outcomes. As witnessed by the competing metrics found within the WELL Building Standard, which stands in contrast to those found in the peer reviewed UL Design Guidelines for Promoting Circadian Entrainment with Light for Day-Active People, metrics and

recommended practices are still evolving, and explicit recommendations have not yet been adopted by national and international standards organizations (ANSI, CIE, IES, and ISO). As a result, the differences between Circadian Stimulus (CS), Equivalent Melanopic Lux (EML), and Melanopic Equivalent Daylight Illuminance (m-EDI) have led to healthy debate within the lighting industry (Figueiro & Rea, 2017) (Ashdown, 2019). As of this writing, the Illuminating Engineering Society's (IES) Light and Human Health Committee still maintains their policy position that caution should be exercised when considering

a non-consensus document for design, application, product qualification or regulatory purposes (IES, 2020). At the end of the day, designers must conduct their due diligence with the metrics being put forth for consideration. Lighting design practitioners should continue to participate in and add to these discussions, evaluate scientific implications, review expert recommendations, proceed with a commonly accepted standard of care, co-author consensus driven best-practices, engage industry adopted standards and apply the science where and when appropriate.

Market Opportunities

Building upon industry precedent, expert recommendations, current research and advancing technologies the following market areas stand to benefit from the rigorous design and implementation of circadian lighting principles that prioritize human health and well-being:

- Healthcare: Providers and Patients
- Senior Living
- Learning Environments
- Workplace
- Residential
- Transportation

Wearable Technologies

The market for, and the technology behind, personal wearable sensor accessories will only continue to grow and advance with time. As designs continue to become more performance driven, they can begin to think about how the design process might incorporate a data-driven feedback loop to advance the conversation on health-related client solutions. The emergence of neuro-aesthetics as a field of study for the design industry continues to show potential in how the design process can change for measured outcomes. Just as a doctor may diagnose a patient, so too could a design professional diagnose an existing or newly built set of conditions to better understand the “health” implications underpinning a given environment.

In summary,

- Designers should begin to think about how the design process might incorporate a data-driven feedback loop, by way of personal wearable sensor accessories, to advance the conversation on health-related client solutions.
- Lighting design practitioners should continue to participate in and add to these discussions, evaluate scientific implications, review expert recommendations, proceed with a commonly accepted standard of care, co-author consensus driven best-practices, engage industry adopted standards and apply the science where and when appropriate.

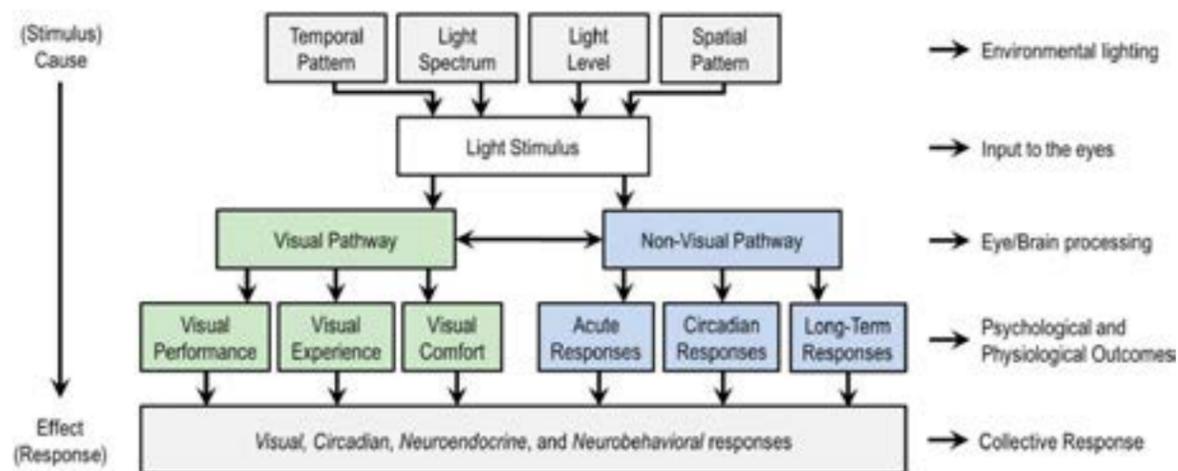


Figure 21: An overview of the stimulus (top) response (bottom) relationship between light and human responses, with a schematic subdivision of the visual and non-visual responses. At the top level, the temporal pattern relates the timing and duration of exposure to a light stimulus, spatial pattern refers to the spatial distribution of light in the three-dimensional light field, light spectrum refers to the spectral power distribution (SPD) that governs color qualities, and light level refers to the quantity of light in radiometric or photometric units. These four factors contribute to the biological potency of the light stimulus. Non-lighting factors not shown such as age and chronotype moderate the effects of light on people and are important in practice. Source: Houser, K. W., & Esposito, T. (2021). Human-Centric Lighting: Foundational Considerations and a Five-Step Design Process. *Frontiers in Neurology*, 12.

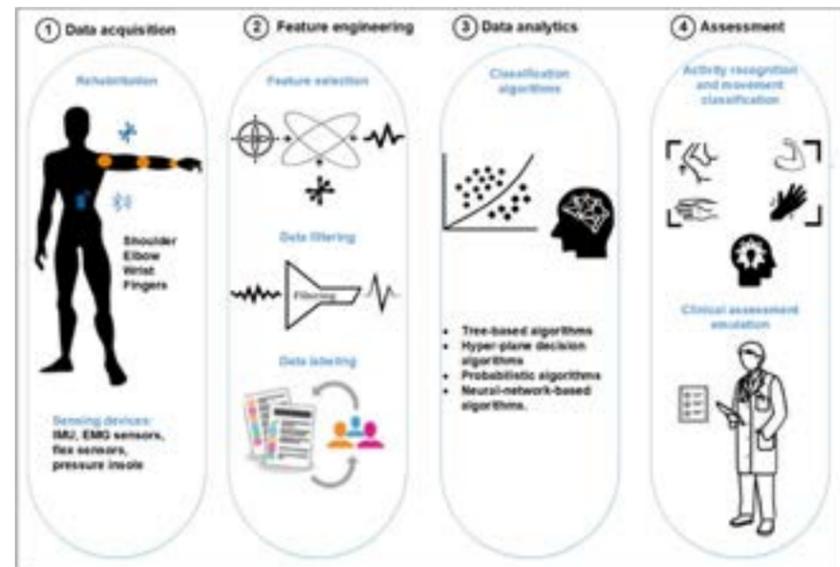


Figure 22: Depiction of a wearable sensor based and data-driven rehabilitation assessment. Source: Boukhennoufa et al, 2022.

NEXT STEPS

As our Team moves into the future with this research, we will endeavor to pursue the following opportunities:

1. Distribute survey to company employees and a segment of the general population to gain insight on individual lighting preferences within the home and in the office.
2. Conduct daylight analysis of the office accounting for urban context, weather conditions, and annual variation.
3. Identify locations and conditions within the office that under-perform current recommendations for circadian effective designs.
4. Create and test interventions at home and in the office.
5. Study opportunities with task lighting to optimize the office for user comfort and increase individual agency while also reducing energy use.
6. Continue to explore wearable technologies emerging in this field and develop methodologies for further field research.
7. Create design recommendations for the home and office that account for varying user preferences.

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Jain Family Institute: Eduard Nilaj

University of Tennessee: Milagros Zingoni Phielipp

BIOS Lighting: Robert Soler

REFERENCES

- AIA Code of Ethics and Professional Conduct. (2020, December 10). AIA Code of Ethics. Retrieved February 4, 2022, from <https://www.aia.org/pages/3296-code-of-ethics-and-professional-conduct>
- Ashdown, I. (2019, May 9). *Circadian Lighting: An Engineer's Perspective – Illuminating Engineering Society*. Fires Forum. Retrieved February 4, 2022, from <https://www.ies.org/fires/circadian-lighting-an-engineers-perspective/>
- Boukhenoufa, I., Zhai, X., Utti, V., Jackson, J., & McDonald-Maier, K. D. (2022). Wearable sensors and machine learning in post-stroke rehabilitation assessment: A systematic review. *Biomedical Signal Processing and Control*, 71. <https://doi.org/10.1016/j.bspc.2021.103197>
- Brown, T., Brainard, G., Cajochen, C., Czeisler, C., Hanifin, J., Lockley, S., Lucas, R., Munch, M., O'Hagan, J., Peirson, S., Price, L., Roenneberg, T., Schlangen, L., Skene, D., Spitschan, M., Vetter, C., Zee, P., & Wright Jr., K. (2020). Recommendations for Healthy Daytime, Evening, and Night-Time Indoor Light Exposure. *Preprints*. <https://doi.org/10.20944/preprints202012.0037.v1>
- Buttgereit, F., Smolen, J. S., Coogan, A. N., & Cajochen, C. (2015). Clocking in: chronobiology in rheumatoid arthritis. *Nature Reviews Rheumatology*, 11(6), 349–356. <https://doi.org/10.1038/nrrheum.2015.31>
- Callaghan, S., Lösch, M., Pione, A., & Teichner, W. (2022, January 27). *Feeling good: The future of the \$1.5 trillion wellness market*. McKinsey & Company. <https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/feeling-good-the-future-of-the-1-5-trillion-wellness-market>
- Cao, D., & Barrionuevo, P. A. (2015). The importance of intrinsically photosensitive retinal ganglion cells and implications for lighting design. *Journal of Solid State Lighting*, 2(1). <https://doi.org/10.1186/s40539-015-0030-0>
- CIE. (2018). CIE S 026/E:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light. *CIE*. <https://doi.org/10.25039/s026.2018>
- Circadian Rhythm Lighting Market – Global Industry Trends and Forecast to 2028 | Data Bridge Market Research*. (2021). Data Bridge Market Research, <https://www.databridgemarketresearch.com>, All Right Reserved 2022. Retrieved April 2, 2022, from <https://www.databridgemarketresearch.com/reports/global-circadian-rhythm-lighting-market>
- Cucinotta, D., & Vanelli, M. (Eds.). (2020). WHO Declares COVID-19 a Pandemic. *National Library of Medicine*, 157–160. <https://pubmed.ncbi.nlm.nih.gov/32191675/>
- Effects of the coronavirus COVID-19 pandemic (CPS)*. (2022, January 24). Bureau of Labor Statistics. Retrieved April 4, 2022, from <https://www.bls.gov/cps/effects-of-the-coronavirus-covid-19-pandemic.htm#table3>
- Erren, T. C., Morfeld, P., Groß, J. V., Wild, U., & Lewis, P. (2019). IARC 2019: “Night shift work” is probably carcinogenic: What about disturbed chronobiology in all walks of life? *Journal of Occupational Medicine and Toxicology*, 14(1). <https://doi.org/10.1186/s12995-019-0249-6>
- Figueiro, M. (2016, December 6). *Discovery of the Photosensitive Retinal Ganglion Cell*. Architect Magazine. Retrieved February 2022, from https://www.architectmagazine.com/technology/lighting/discovery-of-the-photosensitive-retinal-ganglion-cell_o
- Figueiro, M., & Rea, M. (2017, February 13). *Quantifying Circadian Light and Its Impact*. Architect Magazine. Retrieved February 4, 2022, from https://www.architectmagazine.com/technology/lighting/quantifying-circadian-light-and-its-impact_o
- Houser, K. W., & Esposito, T. (2021). Human-Centric Lighting: Foundational Considerations and a Five-Step Design Process. *Frontiers in Neurology*, 12.
- Interface. (2015, March). *Human Space: The Global Impact of Biophilic Design in the Workplace*. https://www.interface.com/APAC/en-AU/about/press-room/Human-Spaces-Report-Press-Release-en_AU
- International WELL Building Institute. (2021). WELLTM Performance Verification Guidebook, Q4 2021</i>. Resources.Wellcertified.Com. Retrieved March 2, 2021, from <https://resources.wellcertified.com/tools/performance-verification-guidebook/>
- KLEPEIS, N. E., NELSON, W. C., OTT, W. R., ROBINSON, J. P., TSANG, A. M., SWITZER, P., BEHAR, J. V., HERN, S. C., & ENGELMANN, W. H. (2001). The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *Journal of Exposure Science & Environmental Epidemiology*, 11(3), 231–252. <https://doi.org/10.1038/sj.jea.7500165>
- Lucas, R. J., Peirson, S. N., Berson, D. M., Brown, T. M., Cooper, H. M., Czeisler, C. A., Figueiro, M. G., Gamlin, P. D., Lockley, S. W., O'Hagan, J. B., Price, L. L., Provencio, I., Skene, D. J., & Brainard, G. C. (2014). Measuring and using light in the melatonin age. *Trends in Neurosciences*, 37(1), 1–9. <https://doi.org/10.1016/j.tins.2013.10.004>
- Pendell, B. R. (2021, November 20). *Wellness vs. Wellbeing: What's the Difference?* Gallup. Com. Retrieved February 2022, from <https://www.gallup.com/workplace/340202/wellness-wellbeing-difference.aspx>
- Perdue, W. C., Stone, L. A., & Gostin, L. O. (2011). The Built Environment and Its Relationship to the Public's Health: The Legal Framework. *American Journal of Public Health*, 93(9), 1390–1394. <https://doi.org/10.2105/ajph.93.9.1390>
- Pinholster, G. (2014, March 14). *Sleep Deprivation Described as a Serious Public Health Problem*. American Association for the Advancement of Science. <https://www.aaas.org/news/sleep-deprivation-described-serious-public-health-problem#:~:text=The%20U.S.%20Centers%20for%20Disease,%20depression%20obesity%20and%20cancer.>
- PS-12-19: IES Position On UL RP 24480 Regarding Light and Circadian Entrainment – Illuminating Engineering Society*. (2020, August 10). Ies.Org/about-Reach/Position-Statements. Retrieved February 8, 2022, from <https://www.ies.org/about-outreach/position-statements/ps-12-19-ies-position-on-ul-rp-24480-regarding-light-and-circadian-entrainment/>
- Rea, M., & Figueiro, M. (2016). Light as a circadian stimulus for architectural lighting. *Sage Journals: Lighting Research & Technology*, 50(4), 497–510. <https://doi.org/10.1177/1477153516682368>
- U.S. Bureau Of Labor Statistics. (2022, January 24). *Effects of the coronavirus COVID-19 pandemic (CPS)*. Bureau of Labor Statistics. <https://www.bls.gov/cps/effects-of-the-coronavirus-covid-19-pandemic.htm#table3>
- Vitaterna, M., Takahashi, J., & Turek, F. (2001). *Overview of Circadian Rhythms*. National Center for Biotechnology Information, U.S. National Library of Medicine. Retrieved 2022, from <https://pubs.niaaa.nih.gov/publications/arh25-2/85-93.htm>
- IWBI. (2022). *WELL Building Standard v2*. <https://v2.wellcertified.com/en/wellv2/concepts>
- Brown, C., Deng, L., Figueiro, M., Lewis, A., Lilien, A., McGowan, T., Panda, S., Rao, G., Rea, M., Steele, C., Severson, B., Walker, A., Willis, K., & Yandek, E. (2019, December). *Design Guideline for Promoting Circadian Entrainment with Light for Day-Active People*. Underwriters Laboratory.
- Legates TA, Fernandez DC, Hattar S. Light as a central modulator of circadian rhythms, sleep and affect. *Nature Reviews Neuroscience*. 2014;15(7):443-454.
- Sigurdardottir L, Valdimarsdottir U, Fall K, et al. Circadian disruption, sleep loss, and prostate cancer risk: a systematic review of epidemiologic studies. *Cancer Epidemiology Biomarkers & Prevention*. 2012;21(7):1002-1011.

THE JURY

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