# Creating the perfect meeting environment

# Introduction

Christopher Parker
Sharp Europe

## How IoT sensors and smart building management will improve collaboration and wellness in meetings

Why do we need to be concerned about the temperature of our meeting spaces? Or the lighting?

Put simply, we spend a lot of time and money on meetings, so we need to get them right. We assign a lot of expensive floor space to meetings—and we spend a lot of time attending them. Sharp's research put this conservatively at 25 hours per person per month for office workers.

Many things affect the success of a meeting space and the productivity of the people who use it, but environmental factors, such as temperature and air quality, are the foundations. There is a wealth of academic research that shows the significant impact of these conditions on our performance at work.

In this report, workplace psychologist Dr. Oseland summarizes these findings for us, findings which add up to a strong business case to create the right conditions for meetings if we want to boost productivity.

What is exciting, is that now, for the first time, via the Windows collaboration display from Sharp, you can start to monitor your meeting environment quickly and easily.

As well as including a host of features to improve teamwork, the Windows collaboration display is the first to include smart sensors that measure temperature and humidity, ambient light, air quality levels and even potentially the number of occupants in a meeting. The display and Sharp's Synappx Workspaces Intelligence platform provide you with a dashboard of environmental data that hasn't been possible before within such a technically straightforward and cost effective solution.

It paves the way to smarter cloud-based building management systems without the need to invest in physically changing your building. As well as increasing productivity, better management of environmental conditions also cuts out waste and saves money.

It's a huge waste of resources for example, to keep meeting rooms lit and air-conditioned when not in use, or to keep them too hot or too cold, a common complaint. How much could be saved if a building "knew" when to turn the lights on and off, when to cool a room in readiness for a meeting?

A building where all systems are integrated and optimized—a "high performance building"—can deliver a 40 percent reduction in energy costs according to the Institute for Market Transformation (2017). However, applying smart technology and artificial intelligence to any office building will reduce costs.

The Windows collaboration display and Sharp Synappx™ Workspaces, together with cloud platforms such as Microsoft Azure, provide the starting point for applying smart systems. For example, when you know the temperature of a meeting room and you can send that data to the cloud, and from the cloud, communicate this to your heating and cooling system to take an action, you have a system that adapts to how your meeting spaces are used.

We believe this is the start of a revolution in smart spaces.

We look forward to our customers automating their meeting environments to make the perfect conditions for productivity and wellness.

Many thanks for reading our report. We welcome your feedback, to get in touch with us contact **@Sharp_Business** on Twitter or visit us at **www.sharpusa.com/windows-collaboration-display**

# Summary

## Impact of environmental conditions on performance

Dr. Nigel Oseland

There is extensive research on the impact of indoor environmental conditions on office worker performance. Studies have shown that indoor climate has physiological and psychological effects, impacting concentration, attention span, alertness, cognitive functioning, accuracy, data processing, creativity, mood and motivation[1-6].

Strangely, no research has been published that has specifically examined the impact of meeting room conditions on meeting success. This is surprising, as data from Herman Miller[7] and Ecophon[8] reveals that office workers spend a significant amount of time in meetings—approximately 19 percent depending on their role and business sector[i].

Nevertheless, the learnings from studies of general office space can be applied to meeting rooms. Research exploring concentration, communication and creativity are all relevant to meeting rooms and meeting success.

Large databases of post occupancy evaluations[9,10] consistently show that the design factors that office workers are most dissatisfied with but consider of key importance are: temperature, noise and air quality—lighting fares better but can still be a source of dissatisfaction.

This report focuses on air quality, temperature and lighting, as they can be controlled through the building management system, whereas noise is more affected by psychophysical factors and behaviour than design alone.

In their review of 75 studies, Oseland & Burton[11] compared studies that showed a direct effect of the various environmental factors, including temperature, air quality and light etc. on performance. They predicted that the average gain for air quality was 1.4 percent, temperature 1.2 percent and lighting 1.1 percent. Based on the Law of Diminishing Returns, providing a combination of adequate air quality, temperature and lighting could enhance overall worker performance by approximately 2.5 percent.

The combined impact based on this research is conservative compared to that reported in some individual studies, which are discussed as we look at temperature, air quality and lighting in detail.

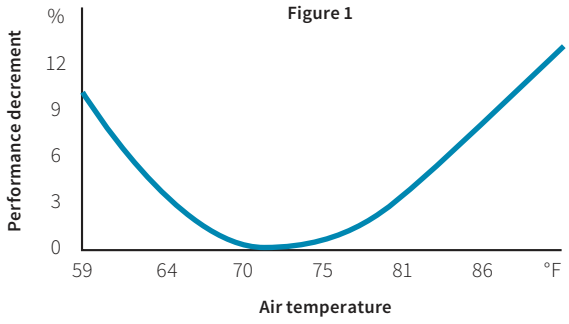
# The perfect temperature for productivity?

## Takeaways:

- Performance declines by 2 percent for each degree above 25°C/77°F and by 4.7 percent for each degree below 21°C/70°F.
- Ideal meeting temperature: from 20°C/68°F to 25°C/77°F depending on participants.

Temperature, and other related environmental variables, affect thermal comfort which in turn affect performance. Human physiology and cognitive functioning is less effective outside of normal core body temperature levels.

Thermal comfort is affected by a person's activity, meaning more seated activities have a lower metabolic rate (body heat production) than standing or more vigorous work activities. Thermal comfort is also affected by the clothing worn. So, comparing situational extremes, lengthy seated meetings require higher room temperatures than short standing meetings or workshops or group activities. In contrast, formal meetings (wearing suits) require lower temperatures than informal meetings (with casual clothing).




The relationship between temperature and the typical office work performance was plotted by Helsinki University of Technology[12] after an extensive review of the literature including 24 studies (see Figure 1). Additional research from the Lawrence Berkeley National Laboratory[5] indicates that performance declines by 2 percent for each degree above 25°C/77°F and by 4.7 percent for each degree below 21°C/70°F.

However, based on thermal comfort standards[13] and depending on (seated) activity and clothing, a comfortable effective temperature in meeting rooms could be anything from 20°C/68°F to 25°C/77°F.

Therefore, offering the room occupants control of the temperature to meet their circumstances and requirements is vital for comfort. Indeed, a seminal study of the West Bends Mutual Insurance Company found a 2.8 percent increase in claims processor performance if the subjects were provided with control over desk temperature (plus air supply and task lighting).[1,4]

Valančius & Jurelionis[14] found that a short-term temperature drop from 22°C/71.6°F to 18°C/64.4°F increased general employee performance by 4.1 percent. Furthermore, tasks specifically requiring concentration and focus showed a 10 percent increase in performance. They suggest gradually decreasing temperature to 18°C/64.4°F one hour before the end of the working day could create boosted productivity. While this is a contentious and unique finding, if verified it may mean that a short-term drop in temperature would help improve productivity in lengthy meetings.

Various studies of thermal comfort carried out by Wyon and colleagues[1,4,5,] found that typing (now more common in meetings with the uptake of mobile devices), comprehension and memory recall (all critical to meetings) are adversely affected when the temperature is 4°C/39.2°F or higher than that considered optimal for comfort.

Memory was also found to be affected by temperatures below that required for comfort. Wyon et al[15] found that "moderate heat stress, only a few degrees centigrade above the optimum, has a marked effect on mental performance when temperatures rise slowly" whereas "memory and creative thinking, are improved by exposure to a few degrees above thermal neutrality, but they too are impaired at higher temperatures."

# Air quality and indoor air pollution

## Takeaways:

- Improved ventilation can result in up to 11 percent gains in productivity.
- Ideal meeting air quality: 350 to 1,000 ppm $CO_2$ (as low as possible)

Air quality refers to the level of pollutants in the air, including Volatile Organic Compounds (VOCs) released by some furniture and building materials, and Carbon Dioxide ($CO_2$) exhaled by people and created during the burning of fossil fuels. Combatting the build-up of indoor air pollutants requires a regular supply of fresh air through a ventilation system or from natural ventilation (windows) in clean air locations.

As $CO_2$ is a primary pollutant, it is often used as a proxy measure of poor air quality, and by maintaining low $CO_2$ levels, other pollutants are likely to be reduced. High levels of $CO_2$ can displace oxygen in the air, and in turn, the blood stream and brain, resulting in symptoms such as hyper-ventilation, rapid heart rate, clumsiness, emotional upset and drowsiness.

Typical outdoor $CO_2$ levels are 250 to 350 parts per million (ppm) with the recommendation for offices is at 350 to 1,000 ppm[13], which is typically produced using fresh air supply rates of 10 liters per second (l/s) per person or more. Researchers tend to expose their experimental subjects to around 600 ppm, which may be considered the optimal $CO_2$ level for desk-based tasks.

The WGBC[5] refers to a review of 15 studies linking improved ventilation with up to 11 percent gains in productivity, as a result of increased delivery of fresh air to the workstation and reduced levels of pollutants.

Maula et al[20] compared experimental subjects under two conditions: high ventilation rate, with a corresponding 540 ppm $CO_2$ and low ventilation rate with 2,260 ppm. The raised $CO_2$ level was found to have a more negative effect on information retrieval, subjective workload, perceived fatigue and lack of motivation.

Similarly, Satish et al[21] found a notable decrease in the decision-making performance of test subjects with $CO_2$ levels of 1,000 ppm and 2,500 ppm compared to 600 ppm. Likewise, Katjár & Herczeg[22] observed a significant decrease in reading performance under conditions of 4,000 ppm of $CO_2$ compared to 600 ppm.

Allen et al[23] compared experimental subjects in a controlled office building in the United States with air quality conditions representing "conventional" (high concentrations of VOCs), and "green" (low VOCs); $CO_2$ was also manipulated in the two spaces. On average, cognitive scores were doubled in the green office building compared to the conventional one. Both the VOCs and $CO_2$ affected the scores independently.

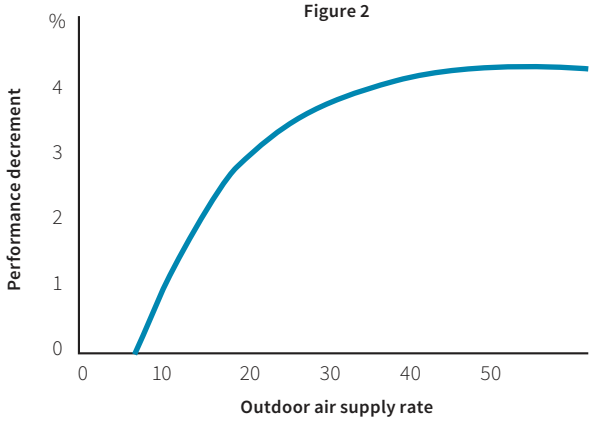
Others have found a high impact of air quality on performance. Woods et al re-analyzed the data collected during a survey of 600 office workers and found that performance could be increased by 20 percent for most of the workforce simply by improving the air quality[4].

In contrast, in an Australian study, poor indoor air quality was found in an office, i.e. high levels of formaldehyde and volatile organic compounds, so the fresh air intake was increased to 100 percent. As a result, the observed productivity loss was reduced from 29 to 16 minutes per day, per person; a 45 percent increase equivalent to a 3 percent increase across the working day[4].

Wargocki, Wyon and colleagues have conducted and reviewed many studies of air quality. They conducted a series of studies exploring how subjects performed on a typing task when exposed to a pollution source (a hidden, old office carpet) at a 10 litres per person fresh air supply rate. The participants typed 6.5 percent slower, made 18 percent more typing errors and experienced more headaches under the polluted condition.

The relationship between the outdoor air supply rate per person and the performance of office work was derived by Seppänen & Fisk[12] based on their review of relevant literature, see Figure 2. Their reviewed studies showed a clear improvement in performance for tasks requiring cognitive activity when ventilation rates increased. Their consolidated results indicate that an increase of 3 litres per person results in an approximate 1% improvement in performance, but the affect starts to plateau at around 30 l/s per person.

**Figure 2**




The above studies indicate that increasing the fresh air supply rate in offices, and undoubtedly in meeting rooms, which often become stuffy in lengthy and crowded meetings, will reduce $CO_2$, VOC and other pollutant levels, therefore improving performance. Such a strategy requires a well-designed and maintained ventilation system (or access to openable windows in suitable locations) and needs to be balanced against energy costs and sustainability targets.

# Lighting and alertness

## Takeaways:

- Good lighting can improve performance by 15 percent.
- Ideal meeting light level: 500 to 1,000 lux task illumination is appropriate in most cases, lowering to 300 to 500 lux with screen usage.

Clearly, lighting is required to enable work activities to be carried out. The more paper-based activities, such as reading or drawing (on boards), require more lighting than those which are more screen based, such as software development and air traffic control. Access to daylight is also important as it directly affects human physiology, health, performance and mood.

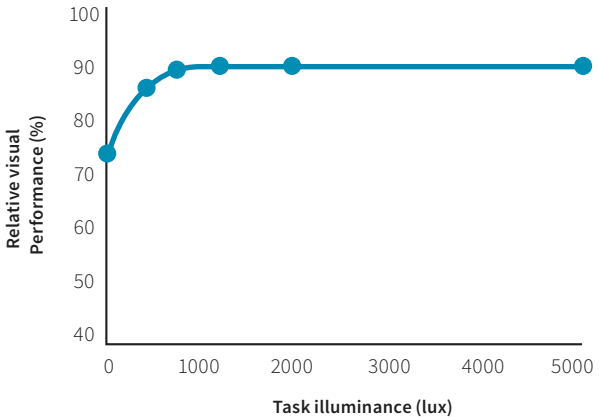
Daylight controls circadian rhythms and sleep patterns. When the sun goes down it triggers the pineal gland (located in the brain) to release the hormone melatonin which induces drowsiness and aids sleep. Lack of daylight can therefore affect evening sleep patterns, in turn affecting alertness during morning work, and may also trigger early (afternoon) drowsiness.

The WGBC[5] reports on the benefits of daylight in offices, showed that workers in offices with windows had 46 minutes more sleep a night compared to workers without them, and being close to windows increased focused work by 15 percent.

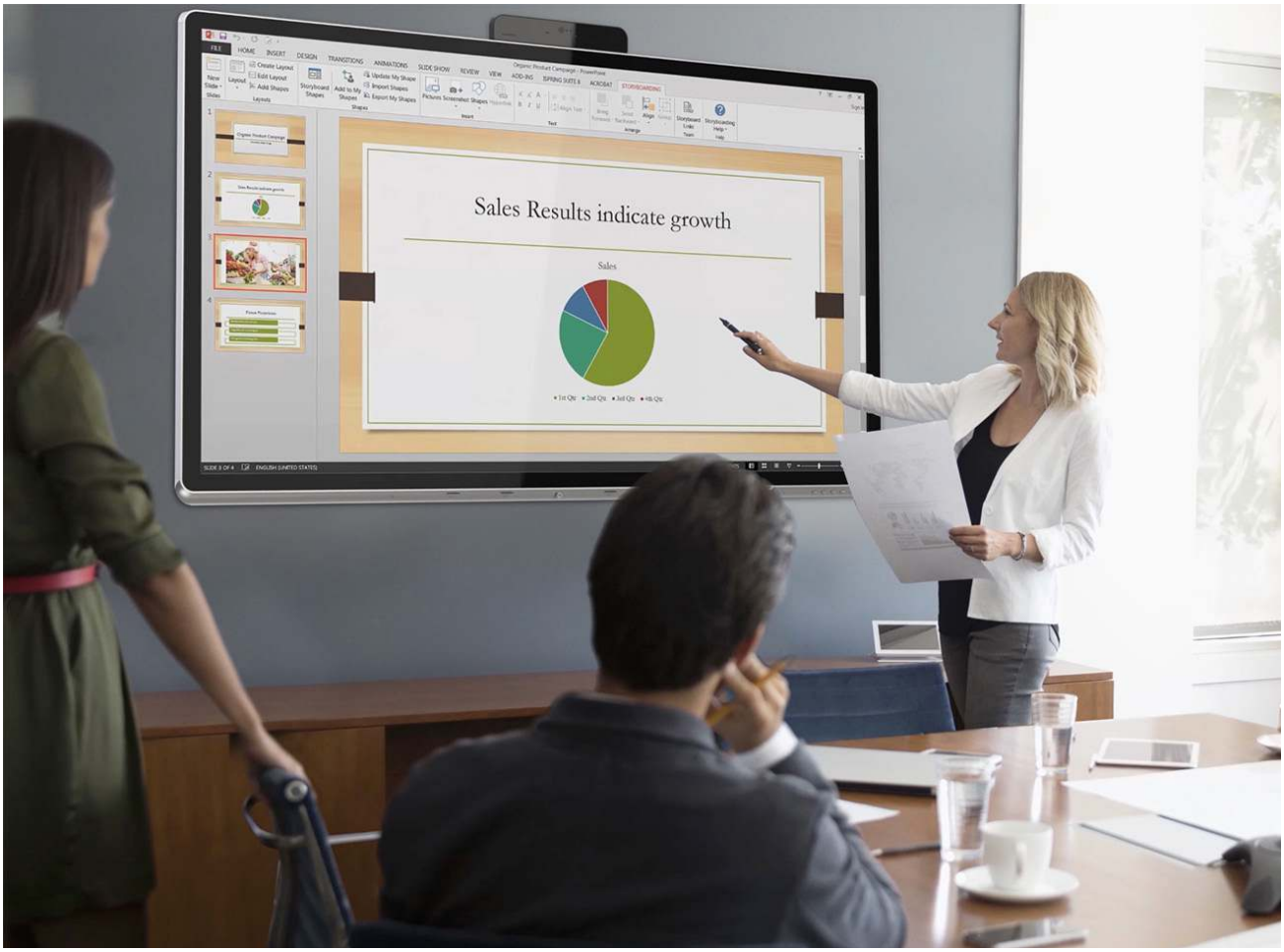
Well-designed office lighting is a balanced mix of good desk/task illuminance, ceiling/wall illuminance, ambient lighting and daylight. It is recommended that spaces with some computer use are maintained at a desk illuminance of 300 to 500 lux (unit of illuminance) and it is usually recommended that meeting rooms are at the higher end of the range[13].

However, the quality of the light and corresponding color spectrum are also relevant. In their review, Attema et al calculated a mean increase in performance of 15 percent due to good lighting[16].

**Figure 3**




Rea & Ouellette[25] monitored the speed and accuracy of reading and understanding high contrast text at typical and low light levels. They found that at typical office light levels, people's visual performance is near maximum. Likewise, Bowers, Meek & Stewart[26] plotted the relationship between the relative visual performance (based on sentence reading acuity) and desk illuminance, and found a performance plateau at 1,000 lux with a relative decrease of 20 percent in dimmer light (see Figure 3).




Barnaby studied workers at a life insurance company conducting difficult paper-based tasks. He found that increasing the illuminance from 550 to 1,100 lux improved performance (reduced errors) by 2.8 percent and increasing it to 1600 lux improved performance by 8.1 percent[4]. The subjects also rated the higher illumination as less stressful and more motivating.

However, Barnaby found that in the areas where reading was not a priority, the spaces were considered over-illuminated. Considering the above research and activities in meeting rooms, it would appear that 500 to 1,000 lux task illumination is appropriate in most cases, lowering to 300 to 500 lux with screen usage.

The studies of de Vries et al[27] and others have shown that altering the lighting in a space can change social behaviour in both positive and negative ways. For example, participants in darker environments are more prone to aggression but, in contrast, cooperation and creativity can also be better in dim conditions.

Borisuit et al[28] studied subjects under electric light or daylighting conditions over several weeks. They found that in blue-enriched light during the daytime, office workers reported higher subjective alertness, enhanced performance and less sleepiness compared to polychromatic white light. In fact, they discovered that just 30 minutes exposure to bright daylight near windows (1,000 lux to 4,000 lux) was as effective as a short nap in reducing post-lunchtime drowsiness.

Lee, Moon & Kim [29] examined computer and paper-based reading tasks at 500 lux and 750 lux illuminance levels under a range of light color temperatures. The participants preferred higher color temperatures at the lower illuminance levels e.g. 500 lux 6,500 K (Kelvin) or 750 lux under 4,000 K. This indicates that perhaps slightly bluer light in meeting rooms would compensate for lower light levels and help maintain focus and alertness in longer meetings.

# Conclusion

Indoor environmental conditions affect performance in the general office space and meeting rooms. Temperature, air quality and lighting affect health, wellbeing, performance, mood alertness and motivation. Studies have repeatedly shown that uncomfortable conditions can adversely affect the performance of typical work activities, for example concentration, creativity, mental arithmetic, reading tasks and attention span.

The conditions required for comfort depend on the activity and personal factors. It is recommended that the environmental conditions in meeting spaces are controlled to provide the recommended default levels, however the system needs to be responsive to meet a diverse range of activities, personal preferences and occupancy levels.

# About the Windows collaboration display from Sharp

## Always smarter meetings

Simply “plug and play” with the Windows collaboration display. Its USB-C cable enables you to connect quickly and easily so you can just get started.

Wherever you are, whether in meetings, boardrooms or training rooms, you can save up to 10 minutes* of waiting for the meeting to start and in setting up video conferencing for those joining remotely.

Using our award-winning capacitive touch technology, along with the best collaboration tools available, such as Microsoft 365 and Microsoft Teams, your meetings can be taken to another level.

* Total Economic Impact™ Study, Forrester Consulting, February 2016.

## Always smarter buildings

With its IoT sensor hub containing a comprehensive array of sensor endpoints, you can monitor the meeting environment in your smart building, looking at areas such as:

- Meeting occupancy
- Temperature and humidity
- Ambient light
- Air quality levels

This spatial intelligence offers the chance for better heating, cooling, and room-booking systems which together create a more comfortable meeting room environment.

## Always smarter insight

New cloud-based services offer exciting ways of managing data and getting new insights into the management of assets and resources. The Windows collaboration display sensor array data can be worked on with AI algorithms based in the cloud, or simply get cleaned up and returned for real-time use. The Azure Digital Twins platform can host innovative subscription apps, which provide tangible value for facilities management, or simply making meeting rooms more comfortable.

Find out more and arrange a demonstration at **www.sharpusa.com/windows-collaboration-display**

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i Herman Miller data showed that the time in meetings, based on 816 responses, is 18.9 percent ±12.5 percent whereas Ecophon data showed the time in meetings, based on 1,847 responses, is 19.5 percent ±16.3 percent.

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