Sandia
National
Laboratories

Workspace and Office Design: A Review of the Literature

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ABSTRACT

The Systems Analysis & Decision Support (02150) group completed a review of the research literature on workspace and office design in 2016 for the Asset Management Department (04853). The goal was to characterize results and lessons learned from existing research to understand the effectiveness of current workspaces at Sandia National Laboratories and inform guidance for future workspace design. The study team reviewed 96 documents, published primarily since the year 2000, covering a range of factors associated with workspace design—workspace costs, acoustics, collaboration and privacy, generational preferences, employee health, performance and productivity, organizational retention, and workspace satisfaction.

The research literature consistently highlighted the relative deficiencies of open-plan office spaces as compared to traditional private enclosed offices for knowledge workers. While open-plan offices can provide some cost savings, they may not be cost effective in the long term due to future hidden costs incurred by degradations in employee productivity, increased attrition, and increased sickness absences as well as any post-construction modifications needed to resolve emerging workspace issues. The chief deficiencies of open-plan offices include lower levels of employee satisfaction due to reduced visual and auditory privacy, increased interruptions, distractions from irrelevant background speech, less physical space, and more ambient noise. The drawbacks reported in the literature tend to outweigh any benefits associated with potential facilitation of coworker interactions and collaboration. Key suggestions identified in the literature to guide and optimize workspace and office design are provided.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The Systems Analysis & Decision Support (02150) group completed a review of the research literature in 2016 for the Asset Management Department (04853), with the goal of characterizing the relative costs, effectiveness, and impacts of various workspace and office designs. The review revealed that a considerable body of academic research consistently highlights the relative deficiencies of open-plan office spaces as compared to traditional private enclosed offices. Open-plan offices are associated with lower levels of employee satisfaction due to reduced visual and auditory privacy, increased interruptions, distractions from irrelevant background speech, less physical space, and more ambient noise. The review focused on addressing four key questions:

- ***What does research demonstrate about the costs associated with various types of office spaces?*** Research reveals that the primary drivers for open-plan offices involve cost savings due to tax benefits for cubicle walls and furnishings as well as reduced rental costs realized by minimizing floor space and increasing occupant density. However, such cost savings can be offset by future hidden costs incurred by degradations in employee productivity, increased attrition, and increased sickness absences as well as post-construction modifications to resolve emerging workspace issues. Further, costs for employee salaries and benefits are approximately 10 to 16 times higher than physical workplace costs, which makes investing in employees far more cost effective than reducing expenditures for real estate and facilities.

- ***Does the research literature provide sufficient detail to identify the most efficient work environments for specific types of workers or specific job functions?*** Very little research characterizes workspace requirements for specific knowledge worker roles and functions beyond the need for space with sufficient visual and auditory isolation to support focus and concentration. The only detailed recommendations regarding workspace needs indicate that software developers require at least 100 square feet of dedicated space and 30 square feet of work surface per person plus noise protection via enclosed offices or six-foot high partitions.

- ***What does research reveal regarding collaboration in open-plan office spaces?*** The drawbacks of open-plan offices outweigh any benefits in terms of facilitating coworker collaboration. Opportunities for interactions may increase in open-plan offices, but such interactions tend to be shorter and more superficial. Further, employee satisfaction with ease of interaction is no higher in open-plan offices compared to private enclosed offices since knowledge workers spend most of their time in solitary work and value privacy over coworker proximity for ease of collaboration.

- ***What does existing research indicate about the impacts of agile workspaces?*** [1] Agile or activity-based workspaces function best for small teams working concurrently on the same project with common goals, deadlines, and needs. A chief advantage of agile workspaces is improved awareness of other colleagues, while significant detractors involve limited opportunities for privacy, concentration, and control over colleague interactions.

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[1]*Agile* or *activity-based workspaces* are flexible and reconfigurable work environments consisting of different types of workspaces, enabling employees to choose and switch workspaces throughout the day, based on the nature of the required work activities (e.g., focus rooms for concentration and open spaces for collaboration and interaction).

The literature review identified several key suggestions that should be considered to guide and optimize workspace and office design.

- Design balanced office spaces that facilitate collaboration among employees, but also provide visual and auditory privacy for solitary work requiring focus and concentration.
- Leverage a multidisciplinary design team that includes intended employee occupants, building designers, architects, managers, organizational behavioral researchers, construction workers, and other stakeholders.
- Conduct in-depth observation and analysis of employee needs and work activities early in the process to design tailored workspaces.
- Proactively plan to facilitate transition to the redesigned workspace and conduct post-occupancy evaluations to understand whether user needs are being met.
- Focus on mitigating the primary detractors of open-plan offices and agile workspaces if such workspaces must be designed.
- Evaluate the utility of non-physical solutions such as modifications in company culture, policies, and practices that can be used to shape employee behavior with minimal cost.
- Evaluate all short-term and long-term workplace design costs and savings, not just those associated with initial construction and reduced footprint. Costs incurred by reduced employee productivity, increased attrition, and sickness absences are far more substantial.

ACRONYMS

Abbreviation	Definition
AIDS	Acquired Immune Deficiency Syndrome
AIMS	Action Item Management System
CA	California
COFCO	Cereals, Oils, and Foodstuffs Corporation
COPE	Cost-effective Open-Plan Environments
CR	Category-Ratio
dB	Decibels (unweighted)
dBA	Decibels (weighted loudness as perceived by the human ear)
DOE	Department of Energy
EIA	Energy Information Administration
FM	Facilities Management
IBM	International Business Machines
ICBEN	International Commission on Biological Effects of Noise
IEEE	Institute of Electrical and Electronics Engineers
IFMA	International Facility Management Association
IQ	Intelligence Quotient
JLL	Jones Lang LaSalle Incorporated
LEED®	Leadership in Energy and Environmental Design
LLT	Laboratory Leadership Team
M	Mean
MIT	Massachusetts Institute of Technology
NM	New Mexico
NNSA	National Nuclear Security Administration
R&D	Research and Development
SNL	Sandia National Laboratories
STEM	Science, Technology, Engineering, and Mathematics
WPD	Workplace Design

GLOSSARY

Term	Definition
Action Office	Predecessor of the modern cubicle developed by the Herman Miller office furniture company in the 1960s. The Action Office was designed to reduce the noise and limited privacy associated with open-plan offices, while maintaining flexibility and communication in the office.
Agile or Activity-Based Workspace	Flexible and reconfigurable work environment consisting of different types of workspaces, enabling employees to choose and switch workspaces throughout the day, based on the nature of the required work activities (e.g., focus rooms for concentration and open spaces for collaboration).
Agile Software Development	Approach to software development that uses adaptive planning, progressive development, early delivery, and continuous improvement to promote rapid and flexible response to change (as opposed to adherence to a rigid pre-established plan).
Allen Curve	Graphically portrays the relationship between collaboration and physical distance between employee workspaces. The probability of face-to-face communication is maximized when people are located within about 30 feet of one another and declines to a stable low level after about 80 feet.
Architectural Privacy	Refers to the visual and acoustic protection provided by the work environment to safeguard sensitive information and shield employees from unwanted sounds.
Borg CR10 Scale	A category-ratio scale used to measure pain and exertion. The scale ranges from 0 (very low pain or exertion) to 10 (very extreme pain or exertion).
Bürolandschaft Design	"Office landscaping" design that began in Germany and was used in the 1950s and early 1960s. It represented the first truly open-plan office concept, with layouts designed around the natural flow of information in an office.
Collaboration	Teamwork, cooperation, and interactions among people to accomplish an objective, such as completing a task or developing or creating a product.
Cross-Sectional Study	Compares different segments of a population at a single point in time, which limits the amount of time required from participants. However, observed differences could be due to the variables of interest or the unique characteristics of the separate samples used in the study.
Cubicle Farm	Consists of a series of compact, uniform office cells that may spread across vast areas of an office building. Cubicle farms dominated office layouts in the 1970s and 1980s and are still commonly used today.
Dot-Com Boom	Period of extreme growth in the use of the Internet in the U.S. in the 1990s, which was accompanied by tremendous investment in Internet-based companies.
Heart Rate Variability	Differences in the amount of time between each heartbeat. Normal, healthy adults generally exhibit large variability between heartbeats. Reduced heart rate variability, with small variations between heartbeats, can be indicative of stress, depression, anxiety, and poor health.
Knowledge Worker	Employee who mentally manipulates information, knowledge, and ideas as opposed to manual laborers who physically or manually manipulate materials.

Term	Definition
Longitudinal Study	Collects data from the same participants repeatedly at multiple points in time. Data collected at the start of the study provide a baseline for later comparisons, minimizing the influence of variables irrelevant to the study.
Matrices-Type IQ Test	Measures reasoning and problem solving by presenting a series of simple graphics and asking participants to select which of eight choices completes the pattern that has been presented.
Objective Metrics	Measures that do not rely on personal inputs or perceptions. For example, office acoustics can be objectively characterized in terms of the sound decibel level, the type of noise, and the frequency of occurrence.
Open-Plan Workspace	Provides less enclosure than fully enclosed private offices that have hard walls and doors. Open-plan offices can be characterized in terms of the number and types of dividers provided and the number of people sharing the space. Open-plan offices range from a completely open bull pen configuration with no dividers between individual workstations to small shared offices with individual workstations separated by partitions.
Psychological Privacy	Stems from employees' sense of control over access to their workspaces and control over their social interactions within the work environment.
Retention	Ability of an organization to keep its employees and attempt to prevent them from leaving to work at external companies.
Speech Transmission Index	Physical measure of the possibility that listeners can hear what was said in a given environment. The index ranges from 0 (not intelligible) to 1 (perfectly intelligible).
Stroop Test	Presents the names of different colors in various font colors. Participants must name the font color in which each word is written, not the word itself. Performance metrics include both speed and accuracy.
Subjective Metrics	Rely on individual perceptions and opinions to measure a phenomenon, typically through surveys using multipoint Likert rating scales.
Taylorist Layout	Office layout developed by American mechanical engineer and economist Frederick Taylor in the early 1900s to maximize efficiency in the office. Layouts mirrored factory production lines from the industrial era, with multiple rows of standardized desks facing a watchful supervisor.
Visual Hacking	Ability to access poorly safeguarded sensitive information (paper and electronic) by coworkers without a valid need to know or by malicious hackers.

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1.   INTRODUCTION

The Systems Analysis & Decision Support (02150) group conducted a review of the research literature on workspace and office design in 2016 for the Asset Management Department (04853). The goal was to characterize key results and lessons learned from existing research to understand the effectiveness of current workspaces at Sandia National Laboratories (SNL) and inform guidance for future workspace design. The study was prompted in part by continuing amendments in the guidance issued by the Department of Energy (DOE)/National Nuclear Security Administration (NNSA) for construction of new buildings at SNL (Office of Management and Budget, 2013; Office of Management and Budget, 2015). In addition, the Laboratories Director and Deputy Laboratories Director at SNL at the time were concerned that the construction of buildings designed to minimize footprint, maximize occupant density, and meet cost stipulations found in the updated guidance memoranda might not be cost-, mission-, and staff-effective in the long term (J. Hruby, personal e-mail communication, March 14, 2016). Typically, such buildings must be further customized after initial construction to create workspaces that more effectively support staff and mission needs, which increases total building costs and potentially erodes any initial cost savings.

1.1.   Evolution of Workspace and Office Design in the U.S.

The importance of effective workspace and office design increased in significance in the U.S. with the transition from the industrial revolution to the information revolution. During the industrial revolution in the 18th and 19th centuries, workspace design was a minor consideration because most employees worked in production lines in factories, mills, and mines. With the advent of the information revolution in the 20th century, however, there was a growing need to develop workplaces where employees could manage information rather than physical materials.

The history of workspace and office design in the U.S. generally begins with the Taylorist approach in the early 1900s and continues to present-day trends of open-plan offices, cubicles, and casual offices. Over the years, the topic of workspace and office design has gained widespread recognition as a critical avenue for further research and exploration. In the early days of workspace and office design, worker needs and preferences were not always considered important (Furniture at Work, 2019; Haslam & Knight, 2010). Today, it is commonly recognized that workspace objects and layouts can be very powerful in shaping and modifying not only individual employee behavior but also interpersonal and group communications and interactions (Elsbach & Pratt, 2007).

1.1.1.1.   Taylorist Layout

The first offices in the 1900s primarily conformed to a *Taylorist Layout*, which was designed by Pennsylvania mechanical engineer and economist Frederick Taylor (Liu, 2012). Taylor pioneered what became known as the scientific management movement, whose core goal was to maximize industrial efficiency by identifying and using the single best method to perform any job. In order to maximize efficiency in the office, Taylor focused on the overarching system rather than the individual needs of the employees (Furniture at Work, 2019). The Taylorist Layout consisted of large open-plan workspaces with multiple rows of standardized desks facing a supervisor (Figure 1-1). Not surprisingly, given the recent transition from the industrial era, the layout resembled a factory production line in a warehouse. Under the Taylorist approach, work was permanently in view so that individual productivity could be continually monitored and maximized (Liu, 2012). Accordingly, privacy was not viewed as a requirement in the workplace. There were no partitions

separating workers, and the supervisor could easily monitor all employees. This layout was adopted in organizations and businesses throughout the U.S. and Europe.
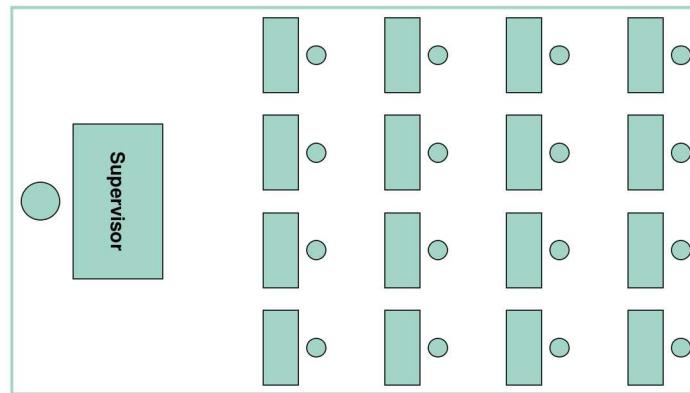
Figure 1-1. Taylorist Office Layout: Offices in the early 1900s mirrored the factory floor by arranging employee desks in an assembly line fashion facing a watchful supervisor.

1.1.1.2. Bürolandschaft Design

Bürolandschaft (which means *office landscaping*) was a sophisticated system of office organization used in the 1950s and early 1960s (Liu, 2012). The concept originated at the Quickborner consulting firm in Germany in 1958 in an effort to increase communication and workflow efficiency in the office. The focus was on meeting the needs of the workforce, creating collaborative workspaces, and emphasizing worker wellbeing (Furniture at Work, 2019). Bürolandschaft represented the first truly open-plan concept, intended to replace the uniform rows of desks in the Taylorist Layout with a non-hierarchical working environment designed around the natural flow of information in the office (Furniture at Work, 2019). The arrangement of desks was determined after extensive study of existing workflow and communication patterns. Workers were separated by plants and curved office screens, and desks were arranged in clusters to facilitate team communications (Furniture at Work, 2019) (Figure 1-2). The lack of walls and the use of movable partitions made the Bürolandschaft design affordable and flexible (Furniture at Work, 2019).
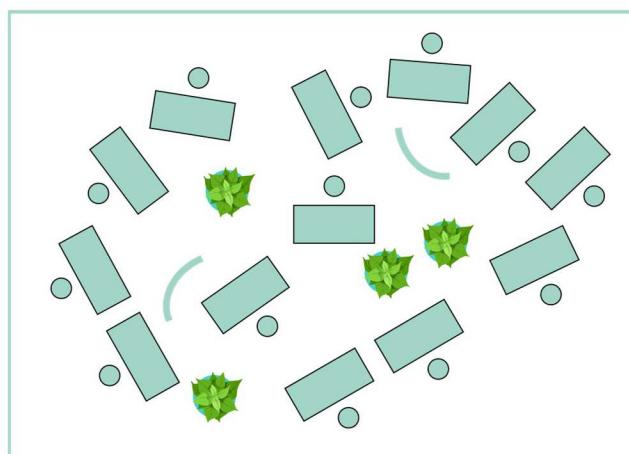
Figure 1-2. Bürolandschaft Office Design: Offices are designed around the natural flow of information in the office.

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1.1.1.3. Action Office

The Action Office is generally considered the first cubicle prototype, or the predecessor of the modern cubicle (COFCO, n.d.; Liu, 2012; Price, 2012;). The lead designer for the Action Office was Robert Propst, director of research at the Herman Miller office furniture company located in Michigan (and still in business today). Propst developed the Action Office after years of prototyping and studying how people work in an attempt to overcome issues of the open-plan office spaces that were prevalent throughout much of the 20th century—large, noisy, open spaces with row after row of desks and chairs—while maintaining flexibility and communication in the office (COFCO, n.d.; Schlosser, 2006). Propst sought to give employees more privacy, reduce noise, and increase productivity by designing spaces where people could spread their work out, rather than leaving it stacked in in-boxes.

The first Action Office I design, which was launched in 1964, did not sell well (COFCO, n.d.). It was expensive and difficult to assemble. Consequently, Propst revised the design and created the Action Office II, which was launched in 1968 (Figure 1-3). The new design included movable shelf space to store frequently used documents and materials and fabric-covered walls where employees could post documents for easy reference. Each office featured two or three mid-height panels that helped define an individual's territory, but still permitted communication when needed (Furniture at Work, 2019). The movable panels could interlock at various angles so that a variety of office shapes could be created. The panels themselves were made from disposable materials. Like its predecessor, the Action Office II did not sell very well—until the U.S. government changed the tax code to allow corporations to write off depreciating assets (COFCO, n.d.) (see Section 1.1.3.2 for more details on the tax code changes). Because the new cubicle design was made from disposable materials, the tax code changes applied, which greatly increased the incentive to invest in Action Office II designs (COFCO, n.d.).

Figure 1-3. Action Office: Robert Propst's Action Office is generally regarded as the precursor to the modern cubicle (picture from Shanahan, 2015).

1.1.1.4. Cubicle Farms

The Action Office design began to be misinterpreted and misused by companies seeking to maximize occupant density in increasingly smaller floor plans in order to keep pace with rising real estate costs (Cornish & Talbott, 2008; Liu, 2012; Price, 2012). The Action Office was never intended as a means to maximize occupant density. Nevertheless, economic situations in the U.S.

drove it down that path. Companies kept reducing the size and configuration of the original Action Office until it turned into a cubicle (Schlosser, 2006). The end result was the cubicle farms that dominated office layouts in the 1970s and 1980s and are still commonly used today (Figure 1-4). Cubicle farms consist of compact, uniform office cells that may spread across vast areas of office buildings. Furniture designers such as Steelcase, Knoll, and Haworth began marketing their own cubicle versions of the Action Office once they realized that many businesses were more concerned about costs than employee wellbeing and satisfaction. Before his death in the year 2000, Propst "lamented his unwitting contribution to what he called 'monolithic insanity'" (Schlosser, 2006, para. 1).

Figure 1-4. Cubicle Farms: Cubicle farms consist of compact, uniform office cells that may spread across vast areas of office buildings (picture from "People Who Make Terrible Things," 2009).

1.1.1.5. Casual Offices and Remote Working

In response to the dot-com boom[2] of the 1990s, alternatives to the open-plan office began to be designed (Haslam & Knight, 2010). Some companies like Google began creating casual and home-like work environments with a variety of workspaces to entice skilled workers away from the competition, promote employee wellbeing, and encourage staff to remain at work longer—quiet rooms, cappuccino bars, pool tables, and sleep pods (Furniture at Work, 2019; Haslam & Knight, 2010). Green offices began incorporating nature into workplaces to improve worker health, wellbeing, and productivity while reducing carbon footprints (Furniture at Work, 2019). Agile or activity-based workspaces also began to be developed to empower employees to decide how and where they should work throughout the day (Furniture at Work, 2019). In an agile workspace design, many different types of workspaces are available to accommodate different types of work.

Workforce mobility is increasingly being recognized as a viable way to reduce real estate costs without using cubicles or large open spaces (Furniture at Work, 2019; Schlosser, 2006). With recent technological advances such as laptop computers and online communications, the variety of spaces in which employees can perform their jobs has expanded considerably. More and more employees can perform some or all of their work at home or in other remote locations such as hotel rooms and planes, which leads to less frequent visits to the office. As a result, in some companies, the need for dedicated workspaces has decreased. Instead, bench-style spaces that provide

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[2]The dot-com boom refers to a period of extreme growth in the use of the Internet in the U.S. in the 1990s, which was accompanied by tremendous investment in Internet-based companies.

temporary locations for network and file access while employees are in the office for a short period of time may be sufficient. As just one example, Cisco Systems switched to a *Connected Workspace*, wherein employees are able to set up work areas anywhere inside the building. The new approach easily accommodated 140 employees, as compared to 88 employees in traditional workspaces (Schlosser, 2006).

1.1.2. Varieties of Modern Workspaces

Workspace types for today's knowledge workers can run the gamut from private, fully enclosed offices to open-plan offices in a completely open bull pen configuration with no dividers between individual workstations. Open-plan offices can further be characterized in terms of the level of enclosure provided and the number of people sharing the space. Many researchers who study workspace and office designs use the classification scheme shown in Table 1-1 (see, for example, Danielsson, Chungkham, Wulff, & Westerlund, 2014).

Table 1-1. Workspace Types

Category	Workspace Type	Description
Individual Office	Private enclosed office	• Single occupant • Hard walls and a door
Open-Plan Office	Shared-room office	• Two to three occupants • Hard walls and a door • Cubicle partitions may separate workstations
	Small open-plan office	• Four to nine occupants • No hard walls • No door
	Medium open-plan office	• 10 to 24 occupants • No hard walls • No door
	Large open-plan office	• More than 24 occupants • No hard walls • No door
	Flex-office	• No assigned workstations • "Hot desk" or "hoteling" approach
	Agile or activity-based workspace (combi-office)	• Combination of workspaces • Open offices • Meeting rooms • Private enclosed focus rooms

1.1.3. Drivers for Open-Plan Workspaces

Historically, private offices have been valued in the workplace because they can symbolize status, rank, and importance within the company (Hatch, 1990; O'Neill, 2008). The latest trend in workspace design in the U.S. and other countries, however, has been a decrease in private offices and an increase in open-plan offices, with 70% or more of U.S. employees now working in something other than traditional private enclosed offices (Henderson, 2014; International Facility

Management Association, 2014). In addition, regardless of their specific configuration, workspaces have been rapidly decreasing in size—from 225 ft^2 in 2010 to 176 ft^2 in 2012 (Soules, 2014).

Three important factors have been largely responsible for the current trend toward the dominance of open-plan office spaces and cubicles in the modern workplace: (1) the shift from industrial work to knowledge work, (2) changes in U.S. tax laws in the 1960s, (3) and a desire to promote collaboration through office design.

1.1.3.1. Rise of Knowledge Work

During the transition from the industrial revolution to the information revolution in the 20th century, the workforce came to be dominated by knowledge workers. Since that time, the relative proportion of knowledge workers in the workforce has continued to expand, influencing office design in the U.S. In particular, open-plan offices and cubicle farms gained popularity in the 1970s and 1980s due to the need to accommodate the significant growth of knowledge workers in the workplace (Liu, 2012).

Knowledge workers are defined as employees who mentally manipulate information, knowledge, and ideas (Davenport, 2005). As such, knowledge workers are distinctly different from manual laborers who physically or manually manipulate materials. For knowledge workers, the role of knowledge is central to their jobs. The resources they need largely consist of their own knowledge and that of their colleagues. Knowledge workers think for a living—their primary purpose is to create, distribute, and apply knowledge (Davenport, 2005). Examples of knowledge workers include managers, engineers, scientists, software developers, medical professionals, educators, and financial analysts. Knowledge workers have high degrees of expertise, education, or experience. On the job, they analyze information to extract meaning, perform non-routine problem solving, make decisions, communicate verbally and in writing, and collaborate with other knowledge workers. Knowledge work is typically less structured than production work because the inputs, outputs, and processes are more difficult to define. Knowledge workers frequently use non-linear creative thinking and can therefore take many different paths to arrive at similar solutions.

1.1.3.2. U.S. Tax Law Modifications in the 1960s

Changes in the tax laws in the 1960s have had a significant and lasting impact on workspace and office design for U.S. corporations. Specifically, tax laws were changed to permit businesses to write off the depreciation of cubicles and their furnishings more quickly than private enclosed offices (ALUR, 2018; Price, 2012; Schlosser, 2006). Depreciation is an income tax deduction that allows businesses to take an annual allowance for property wear and tear, with the deduction spread over the useful life of an item (as determined by the Internal Revenue Service). According to U.S. tax laws, the useful life of furnishings is 7 years, whereas the useful life of buildings is 39.5 years.

Under the new tax codes of the 1960s, demountable or movable cubicle walls are classified as furniture and therefore qualify for accelerated depreciations. Namely, both the furnishings and the divider panels used in cubicles are subject to a reduced seven-year depreciation schedule (ALUR, 2018). In contrast, the drywall and construction used in traditional private enclosed offices must use the 39.5-year rate for fixed assets (ALUR, 2018). Private offices and conference rooms constructed from drywall are depreciated on the same schedule as buildings because drywall is considered a permanent fixture of the building (ALUR, 2018). In other words, the walls and furnishings used in traditional drywall enclosures for private offices offer lower depreciation

deductions and higher taxes every year. With cubicles, businesses can write off 100% of the purchase price in the first year if the amount is $1M or less and use a bonus depreciation in the first year if the amount exceeds $1M (ALUR, 2018).[3] These tax advantages apply only to U.S. corporations, however, not government-owned facilities.

With such changes in the tax code, corporations became incentivized to prioritize open-plan office spaces made from disposable and movable materials over private enclosed offices built with conventional construction techniques (drywall and traditional furnishings). The dominance of the cubicle farm in the 1970s and 1980s is attributed in part to the significantly shorter depreciation periods for cubicle walls (Liu, 2012). As a result, cubicles became a convenient solution to maximize occupant density in limited office space with rapid cost recovery.

1.1.3.3. Attempts to Promote Collaboration through Office Design

Another reason why open-plan office spaces have become increasingly popular derives from an assumption that teamwork and collaboration will be enhanced through the provision of more open working environments (Yu, 2013). The trend was stimulated in part by a 1996 study that demonstrated the benefits of open workspaces for *manufacturing* tasks (Majchrzak & Wang, 1996). Switching from a traditional office environment to an open workspace led to a fourfold increase in productivity. The open configuration made sense in a manufacturing setting, where it was beneficial for all workers involved in the process to be able to comprehend status and progress at a glance. The study researchers did not evaluate the impacts of open space designs for any other types of tasks such as those involved in knowledge work. Nevertheless, the results began to be applied to contexts in which the open floor plan had not been evaluated. The study author herself acknowledge that the approach has been over-applied and generalized well beyond the original intent (Yu, 2013).

1.2. Metrics to Assess Workspace and Office Design

The metrics used to assess workspace and office design can be categorized broadly as subjective or objective. *Subjective metrics* tend to dominate the literature because they are generally easier to collect. Subjective metrics rely on employee perceptions and opinions. One of the most common subjective metrics for workspace and office design research is employee satisfaction, typically measured on a multipoint Likert scale ranging from high dissatisfaction to high satisfaction. Some subjective perceptions represent personal appraisals and emotions that cannot be verified, but other subjective measures may be empirically verifiable (Cox & Ferguson, 1994). For example, employee statements that they dislike their workspaces represent emotional characterizations that cannot be objectively verified. On the other hand, employee perceptions and statements that their allocated spaces are *too small* (for whatever reasons) can be supported by actual measurements of their office sizes in comparison to those of other employees or other companies.

Objective metrics for workspace and office design are used to determine if specific office features are related to objective indicators that do not require subjective input from employees. Examples of objective metrics used in the literature include office acoustics (e.g., noise level, type, and frequency of occurrence) and employee productivity, health, and retention. As just one example, some studies of the health impacts of workspace and office design have analyzed the number and

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[3]Dollar amounts represent the 2019 deduction limits, which increased from $500k to $1M. Although the dollar amounts changed, the policy itself remained the same after the 2018 tax reforms under the Trump administration.

duration of employee sickness absences before and after employees move from private offices to open-plan offices. In terms of productivity, some laboratory studies have examined the impacts of different simulated office designs on the number and types of errors that occur during task performance.

1.3. Limitations of Open Source Research

The open source literature offers a rich source of research investigating the impacts of workspace and office design on employee perceptions and behavior. However, possible variations across studies present limitations that can make it difficult to synthesize results from this large body of research.

1.3.1. *Quality and Level of Rigor*

Studies may differ widely in terms of quality and the level of rigor applied. At one end of this spectrum are first-person accounts based largely on anecdotal evidence and personal experiences. Such narratives are rarely peer reviewed and may be reported in popular media sites such as blogs and personal Web pages. In some cases, the individuals reporting the information may be experts in their fields, but they generally convey opinions rather than true research. Nevertheless, their messages may reach and influence thousands of people, despite the fairly weak technical basis for their conclusions. At the opposite end of the spectrum are controlled experimental studies led by academic research institutions, conducted at a very high level of rigor, and published in peer-reviewed scholarly research journals. Experimental research is objective, with data and results that are unbiased by personal opinion. Further, peer review provides an additional level of quality control wherein independent parties evaluate the adequacy of the research (e.g., validity, reliability, and contributions to the literature) before the research is published. In between the two extremes are studies that may undergo some level of screening and editing before publication, albeit not a formal peer review. The information is presented in magazines or periodicals like the *Harvard Business Review*, not professional refereed journals.

1.3.2. *Originating Source*

The overall trend of the results reported in a study can depend heavily on the originating source of the research (Walker, 2016). First-person accounts in blogs and popular magazines tend to feature executives and office designers who praise the benefits and positive features of open-plan office designs. The primary issue with such accounts is the potential lack of independence when executives and office designers provide their personal accounts. Office designers focus on the aesthetics of workplace layout. They do not typically evaluate the suitability of the design for the work that must be performed or conduct post-design follow-up to identify whether their designs are successful for employees (Walker, 2016). In other words, office designers extol the virtues of the furnishings and external features of workspaces, some of which they may have designed themselves, with little to no consideration of employee needs (Walker, 2016). Ultimately, they may promote open-plan offices in order to enjoy the benefits of increased office furniture and design sales (Newman, 2016). Likewise, executives appreciate the benefits of initial cost savings afforded by open-plan offices and the ability to maximize occupant density. They tend to see the increased level of noise in open-plan offices as proof that their goal of increased collaboration has been met, but do not generally probe further to understand the advantages and disadvantages of such workspaces (Compernolle, 2014; Meerwarth, Trotter II, & Briody, 2008; Vischer, 2008).

Academic studies, on the other hand, are led by independent researchers who do not have a stake in the results. Such studies report scholarly research that predominantly reveals the negative aspects of working in open-plan offices; e.g., reduced satisfaction and diminished productivity (Walker, 2016). Academic researchers are interested not only in characterizing the workspace conditions but also in understanding the impacts on employee perceptions and behaviors to evaluate the effectiveness of a given design. At a broader level, they may also seek to uncover any underlying theoretical bases or develop models to explain observed results.

1.3.3.   Inconsistent Terminology

Another issue with open source research is the inconsistent usage of terms across studies. Different researchers may use the same terms, but define them differently, if at all. This variation can lead to apparent inconsistencies in results in the literature. One common example is the term *collaboration*. Some studies may define collaboration very broadly to include any type of interaction between people in the workplace, including brief greetings and salutations in hallways and common areas. Other studies may define workplace collaboration more narrowly in terms of work-related communications among people in order to accomplish a mission or task. Another example is the definition of *sickness absence*. In some studies, sickness absences may be defined strictly in terms of illnesses that prevent employees from reporting to work. In other studies, sickness absences may include time away from work for doctor's appointments. As a result of such differences, one study may demonstrate that a particular office design increases collaboration or increases sickness absences, while another study concludes that the same office design decreases collaboration or decreases sickness absences.

1.3.4.   Methodological Variations

Variations in methodological approaches can also interfere with consolidating results across multiple studies. First, the timeframe used in a study can impact the results. Whereas *longitudinal studies* include data collection from the same participants repeatedly at multiple points in time, *cross-sectional studies* compare different segments of a population at a single point in time. If a cross-sectional study is repeated at a later time, different samples of participants are used. Longitudinal studies are advantageous because data collected at the start of the study provide a baseline for later comparisons, minimizing the influence of variables irrelevant to the study. As a result, longitudinal studies can provide data that more definitively support conclusions, as compared to cross-sectional studies. Cross-sectional studies are advantageous because they limit the amount of time required from participants to a single point in time. However, with cross-sectional studies, it can be more difficult to establish that any observed differences are due to the variables of interest and not simply the unique characteristics of the samples used in the study. As an example of research into the health impacts of workspace and office design, a cross-sectional study might investigate the number of sickness absences in a sample of employees working in private enclosed offices and in a separate sample of employees working in open-plan offices. Observed differences between the two samples could be due to the different workspace designs, or one sample might simply have a higher baseline level of sickness absences overall. A longitudinal study helps control for these types of issues by observing sickness absences over time in the same employees as they move from private enclosed offices to open-plan offices.

Second, the tools used to collect data, primarily the surveys and questionnaires used to collect subjective data, can lead to divergent results. Surveys designed to measure the same construct such

as employee satisfaction may use very different questions, different wording for the same questions, and different numbers and types of response options. The instructions used in each survey may also differ. For example, one survey may instruct respondents to answer based upon their workplace experiences over the past six months, while another survey covers the past year. All of these factors can impact the nature of the results derived from the study and complicate synthesis across multiple studies.

1.4. Internal SNL Research

Two complementary research efforts occurred at SNL while the current study was in progress. First, Cognitive Sciences and Human Factors collaborated to evaluate employee satisfaction and productivity in recently constructed open office environments located in six different SNL buildings in New Mexico and California (Aviña, St. Pierre, & Silva, 2016). Second, a group of five student interns researched industry trends in innovative workspaces and evaluated impacts of existing SNL innovative workspaces on employee productivity and motivation (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016). The results of these efforts are documented separately in two internal SNL reports.

1.5. Purpose of the Present Study

The Asset Management Department was interested in understanding the costs and impacts associated with various types of workspaces at SNL—existing, under construction, and planned. Specifically, Asset Management inquired whether SNL workspaces are suitable for the types of workers and job functions at SNL and whether such workspaces are cost effective.

To support Asset Management's efforts to address this inquiry, the Systems Analysis & Decision Support group was consulted to provide research and analysis regarding four questions:

- What does research demonstrate about the costs associated with various types of office spaces?
- Does the research literature provide sufficient detail to identify the most efficient work environments for specific types of workers or specific job functions?
- What does research reveal regarding collaboration in open-plan office spaces?
- What does existing research indicate about the impacts of agile workspaces?

2. METHODOLOGY

The methodological approach for this literature review consisted of searching the literature for relevant research, retrieving documents applicable to the study purposes, selecting a subset of documents to review, analyzing and summarizing selected documents, and synthesizing research results across multiple studies within a given topic.

2.1. Search Criteria

To identify relevant documents for the literature review, the study team searched both SNL-internal documents and external research databases. Internal SNL documents were identified through previous related Systems Analysis efforts and through coordination with teams leading concurrent complementary research. Relevant external research was identified via 11 databases and search engines commonly used for scholarly research, government documents, trade journals, books, and popular magazines:

1. Business Source Corporate/Ebsco
2. Defense Technical Information Center
3. eBook Central/Proquest
4. Safari Books/O'Reilly
5. IEEE Xplore
6. Office of Scientific and Technical Information/DOE
7. Google
8. Google Scholar
9. Web of Science
10. Science Direct
11. Skillsoft Books 24x7®

Table 2-1 shows the topic areas and keywords used to search for documents in external databases and search engines. The initial list of topics and keywords began with terms and phrases from Asset Management's four study questions. This list was expanded after the initial search, which highlighted additional relevant keywords. All searches were designed to identify the most recent research published since the year 2000 in an effort to focus the literature review on the latest trends in workspace and office design. However, some older documents that appeared to represent critical contributions to the field were also retrieved. Additional documents were located from the reference lists in retrieved documents and from items in the news. Only English language papers were retrieved, but documents reporting research conducted in Western culture countries outside the U.S. were considered relevant and were included. In all, the study team retrieved a total of 171 documents for further inspection and review.

2.2. Document Selection

The study team screened all retrieved documents at a high level for applicability and relevance to the current study. A subset of 96 of the 171 retrieved documents was selected for in-depth review and inclusion in the report for the purposes of addressing the study questions. The selection strategy was guided by two objectives. First, the study team sought to ensure representative coverage of 12 topics prominent in the workspace and office design literature (Table 2-2). The 12 topic areas were identified as the most prevalent themes covered in the literature, based upon the study team's initial high-level review of all retrieved documents. Many documents described research concurrently in multiple areas, but were categorized according to the primary topic of interest only. For example, 25 documents were referenced in the section on performance and

productivity, but only 14 documents were unique to that topic (i.e., focused on performance and productivity as the primary area of research interest).

Table 2-1. Search Terms

Topic	Keywords			
Space	• Activity-Based • Agile • Architecture • Building	• Closed Office • Conventional • Cubicle • Ergonomics	• Laboratory • Office Space • Open Plan • Privacy	• Workspace • Work Environment • Workstation
Distractions	• Acoustic • Background • Behavior	• Cognitive • Communication • Distraction	• Noise • Privacy • Spatial	• Stress
Generations	• Aging • Baby Boomer	• Generation Y • Generational	• Millennials • New Recruits	• Workforce
Health	• Blood Pressure • Cortisol • Health	• Health Impact • Heart Rate • Human	• Sick Leave • Sickness • Stress	
Issues	• Attention • Attrition • Concentration	• Impact • Privacy • Recruitment	• Retention • Satisfaction • Sustainable	• Work Performance
Occupations	• Accountant • Analyst • Computer • Cyber • Data Entry • Electrical	• Engineer • Knowledge Worker • Mechanical • Occupation • Physicist • Planner	• Productivity • Programmer • Project Manager • Research • Scientific • Scientist	• Software • STEM • Talent • Technician
Organizations	• Business • Corporate	• Government • National Lab	• Organization • Research Lab	

Second, the study team focused on reviewing documents with the highest level of rigor and value for the current study. Blogs, personal Web pages, and popular magazines provide enlightening information regarding employee views of trends in workspace and office design. Such documents provide a context to understand the background in which research is conducted, but they are not rigorously controlled and may contain biases. Therefore, most documents selected for further review and analysis were professional journal articles reporting scholarly academic research in peer reviewed sources (Table 2-3).

Table 2-2. Number of Documents Retrieved and Included in the Report

Topic	Retrieved	Included in Report
Acoustics	19	7
Agile Workspace	14	10
Collaboration and Privacy	13	12
Generational Research	14	6
Headphone Usage	4	4
Health	12	8
Job Role	17	9
Performance and Productivity	44	14
Retention	5	5
Workspace Costs	14	8
Workspace Design Approaches	7	7
Workspace Satisfaction	8	6
Total	**171**	**96**

Table 2-3. Rigor of Reviewed Documents

Rigor	Description	Example	Number
High	Publication in peer reviewed, scholarly, professional sources	*Journal of Environmental Psychology*	65
Medium	Some level of screening and editing before publication, but not peer reviewed	*Harvard Business Review*	25
Low	Documents expressing opinions that have not been reviewed before posting and may be influenced by biases	*Knoll, Inc.**	6

*Knoll, Inc. is a furniture designer that produces office desks, chairs, storage cabinets, and accessories.

In addition to rigor, the value of each document (high, medium, or low) with respect to applicability for the purposes of the present study was rated. Low value documents were not necessarily low rigor—they may have reported rigorous research that simply was not directly applicable to the current objectives. As just one example, Tabanelli, et al. (2008) catalogued 33 tools used to measure psychosocial factors that impact health and wellbeing in the workplace, but did not report any research to inform an analysis of the 12 topics of interest for the current study.

The overall value of reviewed documents was rated *high*, with the exception of two topics—job role and retention were rated *medium*. In terms of job roles, very little research explicitly specified the workspace features needed to support different specific job roles within the broader category of knowledge workers. In terms of retention, there was very little scholarly research that directly investigated the impacts of workspace and office design on employee commitment to the organization or retention. Some useful information was generally presented, but only two of five

documents provided results directly indicative of a relationship between workspace and office design and employee retention (Earle, 2003; Vischer, 2008).

2.3. Analytical Approach

The three analysts comprising the study team each independently reviewed, analyzed, summarized, and rated a subset of the documents selected for inclusion in the study. The entire process required approximately four to eight hours per document, depending on length and complexity. Analysis included examining the independence and objectivity of the originating source, peer review status, sufficiency of methodological detail for replication, adequacy of reported data to support conclusions, appropriateness of statistical tests, and professionalism of the final product. After reviewing a document and rating its rigor and value, the analyst wrote a comprehensive summary of the rationale, methodology, results, and conclusions. After all of the documents within a topic area had been reviewed, the lead analyst for that topic prepared a topic summary that consolidated research results across studies within that topic. For each summary document, the analyst described major themes, key points, and similarities and discrepancies among the documents. Possible explanations for observed discrepancies were also documented (e.g., methodological differences).

2.4. Topic Areas Reviewed

This section provides brief descriptions and relevant methodological details for each of the 12 topic areas reviewed in the study.

2.4.1. Acoustics

Acoustics refers here to the nature of the background noise in a given workspace or office design. Background noise can vary in terms of intensity (generally expressed in decibels), type (e.g., speech, ringing telephones, and copiers), and frequency of occurrence (e.g., ranging from intermittent to constant). Acoustics also encompasses the use of various types of noise generators to mask or attenuate office background noise. Noise generators may use white, pink, or blue noise, depending on the desired effects (Neal, 2016) (Table 2-4). White, pink, and blue noise are the only colors that have official definitions in the federal communications standard. Other colors of noise exist, but have not been formally defined or officially accepted within the standard.

Table 2-4. Types of Noise

Noise	Description	Examples
White	Random audio tone that has all frequencies audible to the human ear (20 to 20,000 hertz), with equal intensity at each frequency	Hissing sound from a radio tuned to an unused frequency; air conditioner
Pink	White noise with energy concentrated in the bass spectrum, which sounds more balanced and less harsh to the human ear	Rainstorm—a "shhh" sound with a low rumble mixed in
Blue	High-frequency white noise that has more energy concentrated at the high end of the sound spectrum, with no bass tones at all	Hiss of a water spray or a high-pitched screech

Descriptions and examples derived from Neal (2016).

Office acoustics can be measured subjectively by asking employees to characterize surrounding noise in terms of their personal impressions and levels of satisfaction. Subjective metrics are important because noise in and of itself can be a very subjective experience—not all individuals experience noise the same way and can therefore be affected differently by the same sounds (Pierrette, Parizet, Chevret, & Chatillon, 2015; Roelofsen, 2008). Office acoustics can also be measured objectively by characterizing the intensity, type, and frequency of background noise. With respect to speech intelligibility in particular, the most common objective metric is the speech transmission index, which ranges from 0 (not intelligible) to 1 (perfectly intelligible) (Table 2-5). The speech transmission index provides a physical measure of the possibility that listeners can hear what was said. Another common metric is reverberation time, the amount of time it takes for sound to fade or diminish by 60 dB (Passero & Zannin, 2012). Reverberation time improves (decreases) when sound reflections contact sound-absorbing surfaces such as curtains, dividers, and carpets.

Table 2-5. Speech Transmission Index

Value	Intelligibility of Speech	Speech Privacy
.00 – .30	Bad	Good
.30 – .45	Poor	Reasonable
.45 – .60	Reasonable	Bad
.60 – .75	Good	Very Bad
.75 – 1.00	Excellent	None

From Roelofsen (2008).

2.4.2. Agile Workspace

Agile or *activity-based workspaces* provide a balance between the exclusive use of either private enclosed offices or open-plan offices for all employees and all activities (de Been, Beijer, & Hollander, 2015; Keeling, Clements-Croome, & Roesch, 2015; Hoendervanger, le Noble, Mobach, & Van Yperen, 2015). Agile workspaces are designed to reduce construction costs as compared to private enclosed offices, while also providing a variety of workspace choices beyond the cubicles that typify open-plan offices. The underlying assumption when agile workspaces are developed is that most work is collaborative, whereas work requiring privacy and concentration occupies a minor part of the knowledge worker's day. As a result, the predominant design is an open-plan office, but with flexibility to add other types of spaces for collaboration as well as privacy:

- Shared desks (hoteling, hot desking, free-address)
- Workstations partitioned by cubicle walls
- Informal meeting and collaborative spaces
- Enclosed focus rooms for solitary work requiring concentration
- Formal conference rooms for larger meetings

In an agile workspace environment, there are generally no assigned work areas; i.e., nobody "owns" any workspace. Employees sit at any workspace that is available and suitable for the type of work performed. Agile spaces are also intended to be reconfigurable to accommodate changes in activity.

2.4.3. Collaboration and Privacy

Collaboration and privacy are often two conflicting goals in workspace and office design. As described earlier in this report, recent trends in the U.S. have been to emphasize collaboration over privacy in the office. In the strictest sense of the term, collaboration refers to teamwork, cooperation, and interactions among people to accomplish an objective, such as completing a task or developing or creating a product. However, as pointed out earlier, different research teams may use different definitions for collaboration, which can impact the results. Privacy can be defined as either a psychological state (psychological privacy) or a physical feature of the environment (architectural privacy) (Sundstrom, Burt, & Kamp, 1980). *Psychological privacy* stems from employees' sense of control over access to their workspaces and control over their social interactions within the work environment (Sundstrom, Burt, & Kamp, 1980). Can employees prevent unwanted intrusions in their physical workspaces? *Architectural privacy* refers to the visual and acoustic protection provided by the work environment (Sundstrom, Burt, & Kamp, 1980). Can employees shield themselves from unwanted sounds? Can they easily protect sensitive information from prying eyes?

Both collaboration and privacy can be measured objectively or subjectively. For example, the number of collaborative encounters in various types of workspaces can be independently observed and counted to characterize ease of collaboration in a workspace, in accordance with the definition adopted by the researchers. Employees can also be asked to rate the ease of collaboration afforded by different workspaces or their preferences for using various workspaces to collaborate.

2.4.4. Generational Research

Generational research seeks to understand whether different generations in the workplace have different needs and preferences in terms of workspace and office design. The five different generations in the workplace today are typically defined in terms of common birth dates, experiences, characteristics, and behaviors (Coates, 2007):

- *Veteran Generation:* people born between 1920 and 1933; defined by experiences growing up during the Great Depression and serving in World War II; value sacrifice, hard work, conformity to rules, and respect for authority.
- *Silent Generation:* people born between 1933 and 1946; defined by the lean times of the Great Depression and World War II in an era when children were supposed to be seen and not heard; regarded as extremely hard working, with a strong sense of purpose and duty to the country.
- *Baby Boomers:* people born 1946 to 1964 during the baby boom after World War II; defined by experiences such as the first space flight, the assassination of John F. Kennedy, the Vietnam War, and Watergate; they value work and view it as more central to their lives than younger generations.
- *Generation X:* people born 1965 to 1981; defined by the aftermath of the Vietnam War and Watergate, a series of recessions, the Reagan presidency, and the AIDS epidemic; they value autonomy and their own careers over the organization itself, with less focus on work than previous generations.
- *Generation Y:* people born 1982 to 2004; also known as Millennials; defined by experiences such as growing up during a time of economic prosperity, the proliferation of technological advances such as the Internet, and the end of the Cold War; having entered the workforce

during a time of recession, they expect quick advancement but do not expect to remain very long at any one organization.

2.4.5. Headphone Usage

Headphone usage has been a topic of research to understand the prevalence and effectiveness of headphones and similar devices for working in various office types. Effectiveness can be measured in terms of productivity impacts, employee satisfaction, and effects on collaboration. Headphones represent a common means of coping with distractions and lack of privacy in the workplace. Other methods that employees frequently use to signal a need for quiet and privacy in open-plan office spaces include building barriers with books or boxes, applying barricade tape around their cubicles, and posting *Quiet Please* or *Do Not Disturb* signs.

2.4.6. Health

The impact of the physical work environment on employee physical and mental health is a widely researched topic dominated by rigorous scholarly research articles. Numerous objective indicators can be used to measure the impacts of workspace and office design on employee health. Examples include short-term and long-term sickness absences, blood pressure, heart rate variability (differences in the amount of time between each heartbeat), salivary cortisol levels, and professional diagnoses of anxiety or depression. Poor health is generally associated with increased sickness absence, higher blood pressure, reduced heart rate variability, increased cortisol levels, and increased risk of diagnoses of anxiety or depression. For example, with respect to heart rate variability, large variability between heartbeats occurs for individuals in good health. Small variations can be indicative of stress, depression, anxiety, and poor health. Subjective measures, which typically consist of self-ratings of employee health, are also used to study the effects of workspace and office design on employee health. However, subjective measures alone can be misleading because physiological changes in the body can occur without employee conscious awareness (which means genuine health effects may not be reflected in perceived health reports).

2.4.7. Job Role

Job role research examines the fit between the precise type of knowledge work being conducted and the types of workspaces provided. Although this topic is critical to design the right workspaces for the right job roles, very little research has been conducted. Most of the research that has been done has explored knowledge worker job roles in general. Some research has focused on the needs of one particular type of knowledge worker—software developers. A few researchers have also investigated the workspace needs of managers, engineers, and administrative staff. In general, job role research tends to report subjective appraisals of workspace effectiveness (primarily privacy) for various types of work that must be conducted. Objective indicators of the types of workspaces required (e.g., square footage, size of available work surfaces, and type of enclosure) are rare.

2.4.8. Performance and Productivity

Employee performance/productivity is a critical topic in the study of workspace and office design because it affects organizational labor costs, product quality, and company reputation. Ideally, workspace and office designs fully support employees to achieve optimal performance levels. At a minimum, any modifications should not degrade performance or productivity as compared to existing levels. If workspace and office design modifications do degrade performance, employees

may need to work extra hours, invest more effort, or involve more people to compensate. Performance/productivity metrics may be either subjective or objective. Subjective metrics involve employee personal judgments and perceptions of the impacts of workspace and office design on performance and productivity. Objective metrics include historical or experimental data to determine impacts on performance accuracy, task completion times, work quality, and the effort or workload required to complete tasks.

2.4.9. Retention

Retention in the workplace refers to the ability of an organization to keep its employees and attempt to prevent them from leaving to work at external companies. Employee retention is an important topic in workspace and office design due to the high costs associated with turnover and the subsequent hiring and training of replacements (Earle, 2003). The impacts of workspace and office design on employee retention can be measured objectively by comparing retention rates among employees working in different office types. Impacts can also be measured subjectively by asking employees whether physical workspace affects their decisions to accept or leave a job.

2.4.10. Workspace Costs

This topic describes the factors that impact workplace costs and provides a high-level comparison of the relative costs to construct and use private enclosed offices and open-plan office spaces. The costs associated with performing work in U.S. office buildings stem from four different sources (Olson, 2001):

- *Workplace:* the building and furnishings.
- *Technology:* equipment, software, infrastructure, and training.
- *Operations:* energy (electricity, lighting, heating, and cooling) and ongoing maintenance and repairs.
- *Employees:* salary and benefits.

Direct comparisons among different types of workspaces can be difficult because different references may use different methods to report the costs associated with these four sources. In addition, very few sources in the open source literature provide cost estimates in the form of actual dollar amounts.

2.4.11. Workspace Design Approaches

This topic covers various approaches for designing workspaces and offices that have been identified in the literature. Best practices for several different aspects of workspace and office design approaches have been identified in the literature. These areas included composition of the teams responsible for workspace design, observation and analysis during initial strategic planning, and follow-through during and after workspace occupancy.

2.4.12. Workspace Satisfaction

Workspace satisfaction is one of the most widely used subjective metrics in the field of workspace and office design. Typically, workspace satisfaction is assessed through questionnaires that list various workspace features (e.g., lighting, temperature, noise, amount and type of enclosures) and

ask employees to rate their satisfaction with each one on Likert scales. Measuring workspace satisfaction is important because dissatisfaction is a critical mediating factor impacting health, performance, and retention (Oommen, Knowles, & Zhao, 2008; Vischer, 2008).

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3. RESULTS

Research consistently highlights the relative deficiencies of open-plan office spaces as compared to traditional private enclosed offices for knowledge workers (Table 3-1). While open-plan office spaces can provide some cost savings in initial construction and energy expenditures, they may not be as cost effective as private enclosed offices in the long term due to future hidden costs incurred by degradations in employee productivity, increased attrition, and health impacts as well as any post-construction modifications needed to resolve emerging workspace issues. Open-plan offices are associated with lower levels of employee satisfaction due to reduced visual and auditory privacy, increased interruptions and distractions, less physical space, and more ambient noise. Noise from irrelevant background speech degrades performance and productivity. Open-plan offices are also associated with increased risk for sickness absences and attrition. Such outcomes are consistent across the different types of employees in the workforce today, regardless of generation or age. The drawbacks reported in the literature outweigh any benefits associated with potential facilitation of coworker interactions. Opportunities for interactions may increase in open-plan offices, but such interactions tend to be shorter and more superficial due to limited visual and auditory privacy. The most effective workspaces balance privacy for focused work, proximity for interactions, and organizational permissions regarding appropriate spaces for interaction; however, employees prioritize privacy over coworker proximity for interactions.

Table 3-1 summarizes high-level results for each of 12 topics included in the literature review. These results are described in more detail in subsequent sections. Subsections in the results are generally ordered to reflect the relative prevalence or importance of various topics in the workspace and office design literature. Toward that end, the results section begins with a description of research regarding employee performance and productivity. This topic is particularly critical because workspaces that are ill suited to the tasks and activities employees must perform for their jobs can degrade performance and productivity, which translates into increased organizational costs. Workspace factors that are disruptive to employee performance are covered next, beginning with the primary detractors in open-plan office spaces—limited visual and auditory privacy and background noise in the form of unwanted speech. Impacts of such environments on workspace occupants are then described—adverse health effects, increased attrition, and reduced employee satisfaction. The next section of the results describes workspace needs for different types of employees—different generational cohorts and specific knowledge worker job roles. Results regarding agile workspaces are then presented, as agile workspaces represent a compromise or bridge between exclusive use of private enclosed offices and exclusive use of open-plan offices. Finally, the results wrap up with descriptions of workspace costs and workspace design approaches, as they represent broad, overarching topics in the field of workspace and office design.

3.1. Employee Performance and Productivity

All of the documents reviewed in this topic area reported or demonstrated some type of negative impact of open-plan offices on employee performance or productivity. Such effects occur due to greater background noise, primarily in the form of irrelevant background speech, which leads to increased interruptions and distractions during task completion. As several authors pointed out, the performance degradations observed in open-plan offices may very well negate any savings associated with the initial construction of less expensive physical designs (Seddigh, Stenfors, Bertsson, Bååth, Sikström, & Westerlund, 2015; Smith-Jackson & Klein, 2009). One estimate

suggests that simply designing better office environments could boost organizational productivity by 21% (Andrew, Chang, & Nicholson, 2008).

Table 3-1. Results Summary by Topic[1]

Topic	Summary
Acoustics	Increased noise due to unwanted speech is a major detractor for open-plan offices. Degradations in cognitive performance cannot be resolved by post-construction attempts to improve acoustics (e.g., higher cubicle walls).
Agile Workspace	Activity-based workspaces can have both advantages and disadvantages as compared to private enclosed offices and open-plan offices. Ability to control information and enhanced awareness of colleagues have been identified as advantages, whereas limited privacy and concentration represent the most salient detractors.
Collaboration and Privacy	Opportunities for interactions may increase in open-plan offices, but such interactions tend to be shorter and more superficial. Effective workspaces balance privacy, proximity for collaborations, and permissions.
Generational Research	Regardless of generation, all knowledge workers have a common need for a quiet workspace free from noise and distractions.
Headphone Usage	Headphones and similar devices interfere with communication, but can improve productivity in open-plan offices by reducing distractions from ambient conversations and promoting a sense of privacy.
Health	Open-plan offices are associated with increased risk for sickness absences as compared to private enclosed offices.
Job Role	All knowledge worker job roles necessitate private space for focused work. Ability to concentrate is critical for high-level problem solving and creativity.
Performance and Productivity	Open-plan offices degrade performance, primarily due to the presence of irrelevant background speech and primarily for tasks requiring short-term or working memory processes or high concentration.
Retention	Physical workspace can impact both recruitment and retention, largely by affecting employee satisfaction and sense of belonging. Retention improves as individual and assigned workspaces increase (i.e., minimal hot desking).
Workspace Costs	Open-plan office spaces can provide some cost savings in initial construction and energy expenditures. However, they may not be as cost effective as private enclosed offices in the long term. Future hidden costs are incurred by degradations in employee productivity, increased attrition, and health impacts as well as post-construction modifications to resolve emerging workspace issues.
Workspace Design Approaches	Best practices include involving a multidisciplinary team throughout design, strategic planning in the form of observation and analysis of employee needs, and continued support and evaluation during transition to a new workspace.
Workspace Satisfaction	Open-plan offices are consistently associated with reduced employee satisfaction due primarily to auditory distractions and lack of privacy. Drawbacks outweigh any potential benefits for collaboration.

[1]Because the current trend involves moving away from private enclosed offices toward more open workspaces, results are typically phrased in terms of the effects of open-plan offices as compared to traditional private enclosed offices.

3.1.1. Types of Performance Degradations

The types of performance degradations observed in open-plan offices encompass quantity, quality, time to completion, workload, and creativity. Two studies used working memory tasks to demonstrate that fewer words from previously presented lists were correctly recalled in work environments with high overall levels of noise or in medium and large open-plan office spaces (Jahncke, Hygge, Halin, Green, & Dimberg, 2011; Seddigh, Stenfors, Bertsson, Bååth, Sikström, & Westerlund, 2015). In another study, participants who completed a 10-minute editing task made more false alarms when irrelevant background speech was present; i.e., they were more likely than participants in quiet conditions to incorrectly identify errors in good text (Smith-Jackson & Klein, 2009). When 114 employees working in one of 66 different buildings in New Zealand completed the Stroop test periodically for eight months, both speed and accuracy suffered in the presence of environmental stressors such as noise (Lamb & Kwok, 2016) (Figure 3-1). In their *Coding War Games,* DeMarco and Lister (1987) discovered that top performing software developers worked 11.1 times faster than the worst performers and were one-third more likely to deliver zero-defect work. The performance differences were due to differences in workspaces—the top performers worked in larger, quieter, and more private offices that were better protected from interruptions.

Participants must name the font color in which each word is written, not the word itself. Performance metrics include both speed and accuracy.

Figure 3-1. Stroop Test: Both speed and accuracy suffered in the presence of office noise in Lamb and Kwok's (2016) study.

In some cases, the quantity of work may not be affected, but other effects that alter performance in some way may be observed. For example, mental workload may increase, indicating that people must work harder to accomplish the same level of work, in part because their brains must not only perform the work but also actively block out surrounding noise and interruptions (Haapakangas, Kankkunen, Hongisto, Virjonen, Loiva, & Keskinen, 2011; Smith-Jackson & Klein, 2009). As another example, DeMarco and Lister (1987) reported a study demonstrating that worker creativity may be degraded in noisy workspaces. Computer science students were asked to solve a Fortran programming problem from specification in a quiet room or a room with background music. Both groups performed similarly in terms of speed and accuracy. However, students in the quiet room were more likely to figure out a shortcut to the solution by seeing patterns in the input and output data streams. Students in the noisy room were more likely simply to continue working through the manipulations required in the specification, without noticing the patterns that led to the shortcut.

Finally, employee perceptions of their own work performance may be impacted. In their eight-month study of office workers in New Zealand, Lamb and Kwok (2016) found that environmental stress in the form of noise was associated with significant reductions in self-reported work performance. In a study that surveyed employees before and after a move from private enclosed offices to an open-plan office, employees' own perceived performance decreased significantly three months and six months after the move and was still lower than baseline at twelve months (Bergström, Miller, & Horneij, 2015). A perception of decreased performance is important because it may lead to reduced motivation and job satisfaction, regardless of whether productivity actually diminishes. Along these lines, Paul (2012) reported a study demonstrating that background noise in open-plan offices can undermine motivation. Specifically, clerical workers exposed to open-plan office noise for three hours gave up on a problem-solving task much sooner than people who worked in quiet offices.

3.1.2. Factors Affecting Performance in Open-Plan Offices

Three basic factors combine to negatively impact performance and productivity in open-plan offices. These factors include (1) background noise and task type, (2) interruptions and distractions, and (3) the need to search for coworkers or appropriate workspaces to complete tasks.

3.1.2.1. Background Noise and Task Type

The overall intensity of background noise can have a negative impact on performance (Jahncke, Hygge, Halin, Green, & Dimberg, 2011; Lin, 2014). In fact, Lin (2014) recommended noise intensity levels of less than 30 dBA for knowledge work such as reading for comprehension. However, degradations are primarily due to the presence of irrelevant background speech rather than other types of office noise such as copiers and ringing telephones, and the intelligibility of the speech matters more than the overall volume (Haapakangas, Hongisto, Hyönä, Kokko, & Keränen, 2014; Jahncke, Hygge, Halin, Green, & Dimberg, 2011; Roelofsen, 2008; Sayiner, 2015; Smith-Jackson & Klein, 2009). The best conditions for optimal performance occur when background speech is absent (Haapakangas, Hongisto, Hyönä, Kokko, & Keränen, 2014).

If background speech is present, performance losses can vary between 4% and 45%, depending on speech intelligibility and the type of task being performed (Haapakangas, Kankkunen, Hongisto, Virjonen, Loiva, & Keskinen, 2011; Roelofsen, 2008). The most severe performance degradations occur for tasks requiring short-term or working memory processes or high concentration (Haapakangas, Hongisto, Hyönä, Kokko, & Keränen, 2014; Jahncke, 2012; Jahncke, Hongisto, & Virjonen, 2013; Seddigh, Berntsson, Danielson, & Westerlund, 2014; Smith-Jackson & Klein, 2009). These effects appear to be due to the lack of enclosed spaces in open-plan offices, not the number of people occupying the space (Seddigh, Berntsson, Danielson, & Westerlund, 2014; Seddigh, Stenfors, Berntsson, Bååth, Sikström, & Westerlund, 2015).

Research indicates the negative effects associated with background noise do not attenuate over time; i.e., employees do not adapt to the background noise with ongoing and repeated exposure (Haapakangas, Hongisto, Hyönä, Kokko, & Keränen, 2014). In addition, recovery from the negative effects of background noise may not occur if employees continue to remain in the noisy open-plan office space, even if they are not actively performing work-related tasks (Jahncke, Hygge, Halin, Green, & Dimberg, 2011).

3.1.2.2. Interruptions and Distractions

In addition to noise, an increase in interruptions and distractions can degrade performance and productivity in open-plan office spaces. Estimates indicate that approximately 2.1 hours of productivity per day are lost due to interruptions and distractions (Seddigh, Stenfors, Bertsson, Bååth, Sikström, & Westerlund, 2015; Spira & Feintuch, 2005). Employees working in cubicles tend to be interrupted 29% more frequently than those working in private enclosed offices (Shellenbarger, 2013). Most interruptions come from other coworkers; not e-mails, phone calls, or instant messages. Perlow's (1999) observations of 17 software engineers at a Fortune 500 corporation over nine months revealed that the typical block of uninterrupted time was only 30 minutes or less in duration. Approximately 86% of interruptions were not urgent and could have been avoided altogether by planning them for a later time more convenient to both employees.

Frequent interruptions can degrade both performance accuracy and task completion times. Gensler Research (2015) found that most software developers felt that productivity was degraded by interruptions to answer questions or engage in conversations. Shellenbarger (2013) reported a study of 300 participants performing a series of computer tasks, which demonstrated that error rates can double after a three-second interruption. Further, it may cost up to 40 minutes to fully recover from an interruption and resume the original task with the same level of focus (DeMarco & Lister, 1987). Part of the recovery time (25 minutes) is consumed by tackling several other easy or more enjoyable tasks before returning to the main task, and part of the recovery time (15 minutes) occurs when employees need time to regain the same level of intense focus. Generally, because resuming a task is effortful, employees stall by attending to less demanding tasks first.

Spira and Feintuch (2005) report a small study demonstrating that effective IQ can decrease by about 10 points upon distraction during task completion. Eight participants completed parts of a matrices-type IQ test (Figure 3-2), once in quiet conditions and once in distracting conditions (ringing phones and arriving e-mails). Mean effective IQ scores dropped from 143 points in quiet conditions to 133 points in distracting conditions. Effects such as these can lead to costly mistakes. A manufacturing design engineer working in an open-plan office space at Gulfstream Aerospace Corporation, Inc., once discovered a $30k mistake that he attributed to distractions from background noise (Kupritz, 1998).
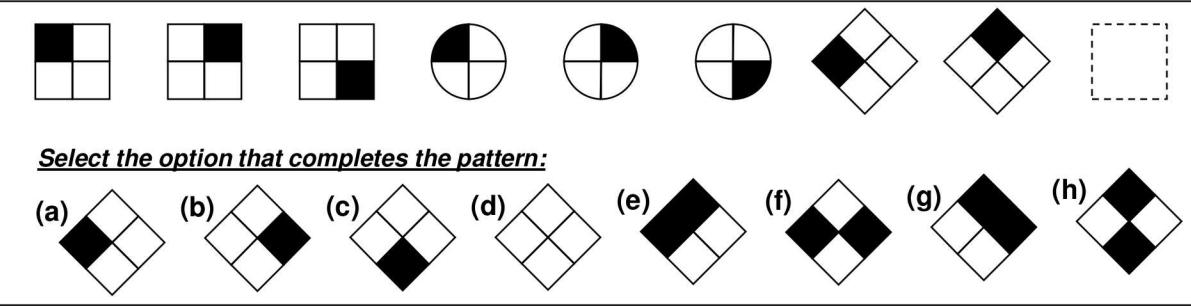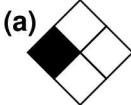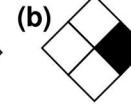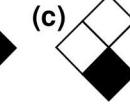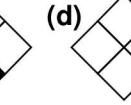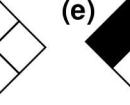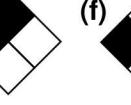
A matrices-type IQ test measures reasoning and problem solving. Participants select which of eight options best completes the pattern.

Figure 3-2. Matrices IQ Test: Mean effective IQ test scores dropped 10 points in distracting conditions as compared to quiet conditions (as reported in Spira & Feintuch, 2005).

3.1.2.3. Searching for Coworkers and Workspaces

Productivity can suffer when employees must spend time searching for coworkers with whom they need to collaborate or for suitable places to work. In some open-plan spaces in which employees do not have assigned workspaces, it can take time to locate people since everyone works in different locations from day to day (Brager, Heerwagen, Buaman, Huizenga, Powell, Ruland, & Ring, 2000). In other cases, a limited number of quiet rooms for phone calls and other tasks that require privacy results in employees roaming the office in an attempt to find a private place where they can work without disturbing other employees (De Been, Beijer, & den Hollander, 2015; Koroma, Hyrkkänen, & Vartiainen, 2014). Employees in open-plan office spaces generally cannot hold one-on-one meetings at their own desks because of potential interference in both directions—from the meeting attendees to nearby workers and from nearby workers to the meeting attendees. For instance, according to one General Motors R&D employee, when visiting colleagues who work in open-plan offices, they cannot talk in front of a computer because they disturb other people and are in turn disturbed by other people's conversations (Meerwarth, Trotter, & Briody, 2008). This time spent not working, while searching for colleagues or workspaces, can add up throughout the day, degrading productivity. Further, as Olson (2001) points out, it is not practical for employees to relocate every time they need to make a telephone call or hold a small meeting—the workplace should "not force people into unnatural behaviors because of design shortcomings" (p. 40).

3.2. Collaboration and Privacy

While opportunities for interactions may increase in open-plan offices, such interactions tend to be shorter and more superficial due to limited visual and auditory privacy. Knowledge workers tend to prioritize privacy over accessibility of coworkers for collaboration. They are typically satisfied with opportunities for interaction, regardless of the type of workspace provided. Designing appropriate workspaces where employees can perform solitary focused work actually equips employees to support collaborative group work when needed. Research suggests that knowledge worker needs for both collaboration and privacy can best be met by balancing proximity, privacy, and permissions.

3.2.1. Nature of Interactions in the Workplace

Many open-plan offices are designed ostensibly to promote collaboration by co-locating employees, and there is research evidence to support the validity of this view. Specifically, the probability of face-to-face communication in the workplace decreases exponentially with the distance between employees' workspaces (Allen, 1977). This relationship is illustrated in the Allen curve, which shows that the probability is maximized when people are located within about 30 feet of one another and declines to a stable low level after about 80 feet (Allen, 1977). Moreover, employees rarely communicate with coworkers on different floors of the same building or in separate buildings. More recent research indicates that the Allen curve continues to apply to the digital workspace (Waber, Magnolfi, & Lindsay, 2014). (Figure 3-3). For example, engineers were 20% more likely to communicate digitally with coworkers who occupied their physical space than with those who worked elsewhere. In addition, co-located coworkers e-mailed four times more often than employees in different locations when they needed to collaborate closely.
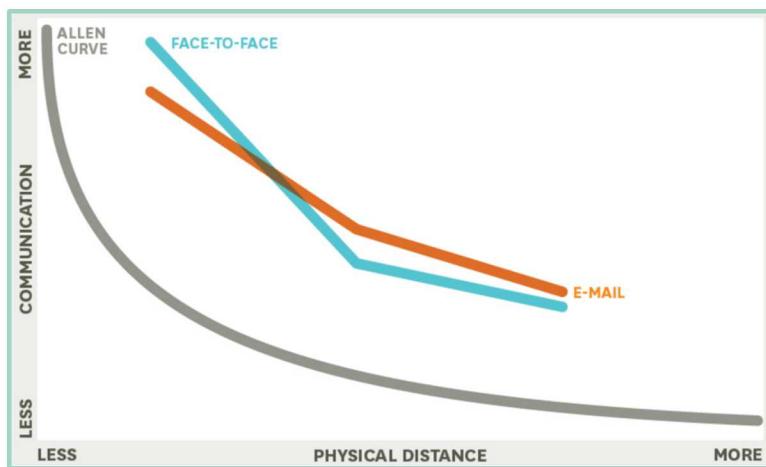
Figure 3-3. Allen Curve: The Allen curve indicates that the frequency of communication decreases as the physical distance between employees increases (Waber, Magnolfi, & Lindsay, 2014).

However, while proximity has a powerful influence on coworker interactions, proximity alone is not a guarantee that face-to-face communication will occur. In other words, simply moving people from private enclosed offices to open-plan office spaces does not in and of itself increase face-to-face communication (Stryker & Santoro, 2012). Face-to-face communications may remain stable or even decrease following greater co-location of employees. In fact, Sundstrom, Burt, and Kamp (1980) found that increasing architectural accessibility by reducing the amount of enclosure or increasing occupant density did not increase social interactions among coworkers, which suggests that people achieve the interaction they desire in spite of architecture. Stryker and Santoro's (2012) research in two R&D laboratories at a life sciences company revealed that workspace location within the overall facility, regardless of whether it is open or closed, can be a key differentiator—employees in high-visibility locations (e.g., near highly traveled hallways or near break rooms) reported nearly 60% more face-to-face communications than those in low-visibility areas.

Opportunities for interactions may increase in open-plan office environments, in part because the increased visibility of employees increases the likelihood of chance encounters, but such interactions tend to be shorter and more superficial due to the lack of visual and auditory privacy (Boutellier, Ullman, Schreiber, & Naef, 2008; Fayard & Weeks, 2011; Paul, 2012). In their observations of 2355 communication events over 120 hours, Boutellier, et al. (2008) found that the frequency of communications was nearly three times higher in more open workspaces as compared to private enclosed offices, but such communications were about three times shorter. Employees in private enclosed offices tended to have longer meetings with more participants. Further, employees may be hesitant to take advantage of unplanned interactions in open workspaces since they may disrupt other people working in the area (Brager, Heerwagen, Buaman, Huizenga, Powell, Ruland, & Ring, 2000; De Been, Beijer, & den Hollander, 2015).

Arranging purposeful places for people to collaborate also does not guarantee that communication and collaboration will occur (Boutellier, Ullman, Schreiber, & Naef, 2008; Brager, Heerwagen, Buaman, Huizenga, Powell, Ruland, & Ring, 2000; Brown, 2009). Communication events typically occur in designated workspaces such as reservable conference rooms rather than in soft seating areas or team spaces designed explicitly to facilitate face-to-face communication. Brager, et al. (2000) found that specially designed team spaces may be used infrequently due to acoustical problems (disturbances in both directions), poor furnishings (tables and chairs), or lack of required

equipment (computers and projectors). Further, attempts to promote collaboration by offering communal work areas may backfire altogether and increase territorial behaviors, prompting employees to mark and defend workspaces against intrusions instead of focusing on collaboration (Brown, 2009).

3.2.2. Employee Needs for Collaboration and Privacy

Several studies have indicated that knowledge workers generally spend most of their time engaged in solitary work that requires focus and concentration (Brager, Heerwagen, Buaman, Huizenga, Powell, Ruland, & Ring, 2000; Gensler Research, 2015; Olson, 2001; Walker, 2016). Estimates vary across studies due to methodological differences; however, research consistently indicates that knowledge workers spend the majority of their time performing solitary work in their own workspaces (Table 3-2). The implication is that appropriate workspaces for collaboration may be less important for knowledge workers than appropriate workspaces for solitary work.

Table 3-2. How Knowledge Workers Spend Their Time

Source	Study Sample	Estimate
Brager, et al. (2000)	Sun Microsystems computer firm in California	80% of employees spent more than half their time in solitary rather than group-oriented work.
Gensler Research (2015)	Software developers and other engineers at a global technology company	Software developers spent about 65% to 70% of their time on focus work such as coding, testing, and debugging as well as handling e-mails and instant messages.
Olson (2001)	13,000 surveys representing 45,000 U.S. managers, professionals, engineers, and administrative workers	Employees spent approximately 80% of their time in their own workspaces. Well over half of all their time in the workplace was spent on quiet work alone in their own workspaces.
Perlow (1999)	Seventeen software engineers at a Fortune 500 corporation	Software engineers spent approximately 60% of their time in individual work and just over 30% in interactive activities.
Walker (2016)	Gensler 2013 U.S. Workplace Survey of 2035 professionals	Knowledge workers spent 54% of their time on tasks requiring deep concentration.

In addition, there can be a very real need for privacy in the workplace in order to protect sensitive and confidential information. Open-plan offices may be more poorly equipped to handle this need. In a study conducted at several government facilities, this concern was frequently voiced by recent occupants of newly constructed open-plan office spaces (Aviña, St. Pierre, & Silva, 2016). For example, staff were concerned about the accessibility of classified material in the open environment to employees who had not yet received security clearances. As one participant commented, the "security posture is compromised with low walls" surrounding occupant cubicles (Aviña, St. Pierre, & Silva, 2016, p. 24). Other participants remarked that the limited auditory privacy due to a lack of soundproofing represents a security concern.

Research conducted by the Ponemon Institute (2016) revealed that these concerns are well founded. The Ponemon Institute (2016) conducted a global study of visual hacking[4] sponsored by the 3M company and found that 91% of hacking attempts were successful, with most occurring in 15 to 30 minutes. The most frequently breached data types were contact lists, directories, information about customers, and information about employees. Approximately 75% of visual hacks involved documents visible on employee desks and information displayed on unprotected computers, laptops, tablets, and other mobile devices. According to the Ponemon Institute (2016), the increasing prevalence of open-plan office spaces is one of the chief reasons behind the success of visual hacking. "To increase productivity, many organizations are creating open workspaces without walls and cubicles. As a result, it is more likely that sensitive and confidential documents and unprotected computer screens will be visible to prying eyes" (Ponemon Institute, 2016, p. 1). In fact, the average number of successful breaches during the experiment was higher in open-plan offices ($M = 4.5$) than in traditional private enclosed offices ($M = 3.2$) (Ponemon Institute, 2016).

When knowledge workers do have a need for collaboration, it does not represent a constant demand; rather, it tends to occur in natural cycles throughout the workweek and generally does not impact all employees equally (Brager, Heerwagen, Buaman, Huizenga, Powell, Ruland, & Ring, 2000; Congdon, Flynn, & Redman, 2014; Cross, Rebele, & Grant, 2016; Leroy, 2016). At the beginning of an effort, people usually need time alone or in pairs to focus on processing information and generating ideas. Afterwards, they convene in larger collaborative groups to further develop those ideas and plan future work. After the meeting, people again need time to focus on their individual assignments and prepare for the next meeting. Congdon, et al. (2014) maintain that privacy does not compromise collaboration—companies can actually enhance collaboration by improving employee privacy (i.e., providing quiet workspaces where people can focus, concentrate, and avoid distractions in order to prepare for future collaborative meetings).

3.2.3. Employee Preferences for Collaboration and Privacy

Three correlational studies of supervisory, administrative, clerical, and technical employees working in a range of workspaces revealed that architectural privacy was consistently associated with psychological privacy (Sundstrom, Burt, & Kamp, 1980). That is, employees felt they had more privacy and control when their physical workspaces provided visual and acoustic isolation. A sense of privacy was related to the amount of enclosure provided by the employee's workspace, the number of people working concurrently near the workspace, and proximity to high-traffic areas (Kupritz, 1998; Sundstrom, Burt, & Kamp, 1980). Workspaces that received higher privacy ratings were partitioned from other areas, had a door, were not visible to neighboring coworkers, and were located away from high-traffic areas. Oommen, Knowles, and Zhao (2008) further specify that partitions should extend all the way to the ceiling to achieve optimal privacy. Open-plan workspaces received lower privacy ratings and were viewed as crowded and noisy, with too many people occupying the same room.

Research indicates that employees in all types of job roles prefer and prioritize privacy over accessibility to coworkers for collaboration (Budie, 2016; Oommen, Knowles, & Zhao, 2008; Sundstrom, Burt, & Kamp, 1980). In fact, across all office configurations, dissatisfaction with ease of interaction with coworkers tends to be very low, suggesting that coworker interactions are not generally a major concern for employees (Kim & de Dear, 2013; Olson, 2001). In an analysis of

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[4]Visual hacking refers to the ability to access poorly safeguarded sensitive information (paper and electronic) by coworkers without a valid need to know or by malicious hackers.

42,764 samples from 303 office buildings, Kim and de Dear (2013) found that employee ratings of satisfaction with ease of interaction were no higher in open-plan offices than in private enclosed offices. Budie's (2016) analysis of surveys from 322 Dutch knowledge workers in 13 organizations further revealed that employees rated concentration as the most important need in the workplace. In contrast, communication ranked fifth.

3.2.4. Balancing Collaboration and Privacy

The most effective work environments are designed to address both collaboration and privacy by balancing three important factors—privacy, proximity, and permissions—the so-called *three P's* (Fayard & Weeks, 2011) (Figure 3-4). Such work environments effectively provide adequate privacy to enable people to interact without being overheard or interrupted (privacy), bring people together and remove barriers (proximity), and reinforce permission to interact freely (permissions). *Privacy* ensures that employees have appropriate spaces with sufficient auditory isolation such that they can interact without being overheard as well as sufficient visual isolation such that they can avoid interactions when needed. *Proximity* is intended to bring people together and remove obstacles in order to promote communication and interaction. Proximity stems not only from physical closeness (in accordance with the Allen curve described earlier) but also traffic patterns that are heavily influenced by social and psychological factors. For example, interactions can be improved to some extent by creating spaces with shared resources that employees must visit periodically (e.g., elevators, coffee makers, watercoolers, and vending machines) (Stryker & Santoro, 2012). *Permissions* refer to cultural rules that explicitly or implicitly identify appropriate spaces for interactions and appropriate behaviors in various spaces. For example, employees may be reluctant to interact in the break room over coffee if management explicitly or implicitly views such encounters as idle down time.
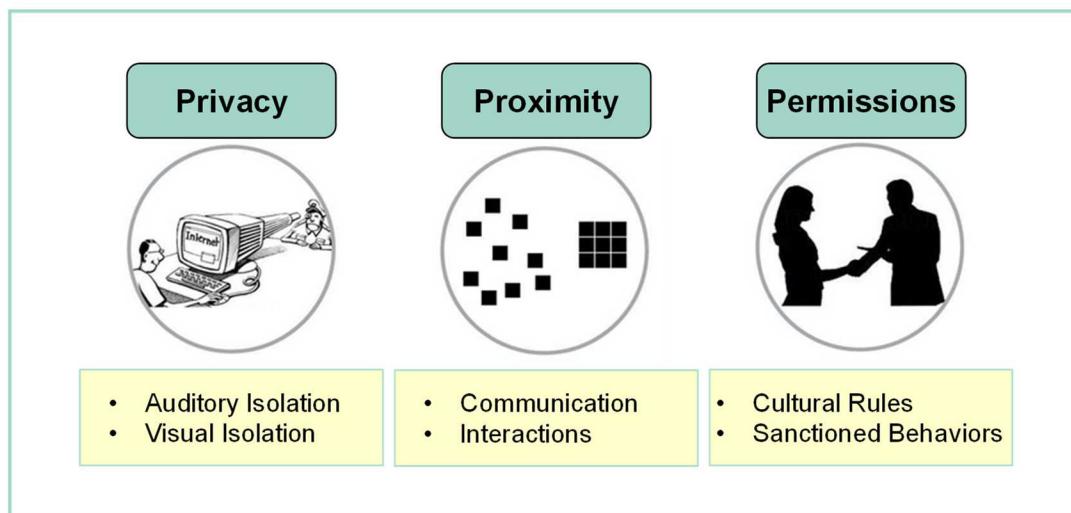
Figure 3-4. Three P's in Workspace and Office Design: Needs for privacy, proximity, and permissions must be balanced to address both collaboration and privacy in the workplace (Fayard & Weeks, 2011).

3.3. Acoustics and Headphones

Acoustics is routinely identified as the number one problem in open-plan office designs (Freihoefer, Guerin, Martin, Kim, & Brigham, 2015; Haapakangas, Kankkunen, Hongisto, Virjonen, Loiva, & Keskinen, 2011; Passero & Zannin, 2012; Pierrette, Parizet, Chevret, & Chatillon, 2015; Roelofsen, 2008). According to guidelines for Leadership in Energy and Environmental Design (LEED®) buildings, the *required* decibel standards for an office environment are less than 55 to 60 dBA (threshold) and *recommended* levels are less than 50 to 55 dBA (objective) (Freihoefer, Guerin, Martin, Kim, & Brigham, 2015). Most offices, even open-plan offices, generally meet these standards. However, open-plan offices tend to be noisier by 10 dBA to 15 dBA on average than private enclosed offices (Freihoefer, Guerin, Martin, Kim, & Brigham, 2015; Gensler Research, 2015). A difference of this magnitude is not trivial—it can make a sound seem twice as loud to the human ear.

3.3.1. *Types of Office Noises and Their Impacts*

The increased decibel level in open-plan offices originates from several sources. Common office noises from keyboards, ringing phones, copiers, telephone conversations, and ventilation systems are louder when there are minimal or no partitions to absorb some of the sound. Background noise is also magnified as the occupant density increases because more people are generating sound. Further, the overall increased decibel level prompts employees to speak more loudly to overcome the background noise, which in turn increases the noise level (Pierrette, Parizet, Chevret, & Chatillon, 2015).

As described earlier, however, the primary acoustic factor that detracts from open-plan offices is background noise in the form of unwanted intelligible speech (Haapakangas, Hongisto, Hyönä, Kokko, & Keränen, 2014; Passero & Zannin, 2012; Pierrette, Parizet, Chevret, & Chatillon, 2015; Roelofsen, 2008; Smith-Jackson & Klein, 2009). Speech transmission indices of .20 or lower are generally recommended to support good speech privacy in office environments (Basner, et al., 2015; Roelofsen, 2008). At such levels, background speech will be virtually unintelligible such that it does not contribute to the overall surrounding noise.

Office noise has very broad disruptive effects in the workplace, impacting productivity and performance, physical and mental health, and worker satisfaction (Freihoefer, Guerin, Martin, Kim, & Brigham, 2015; Lee & Brand, 2005; Lin, 2014; Newman, 2016; Pierrette, Parizet, Chevret, & Chatillon, 2015; Roelofsen, 2008). With respect to productivity and performance, as described earlier in this report, noise may negatively impact the quantity and quality of work, time to completion, workload, and creativity. With regard to physical and mental health; symptoms of headache, fatigue, and stress tend to be more prominent in large open-plan office spaces (Pierrette, Parizet, Chevret, & Chatillon, 2015) (covered more thoroughly in Section 3.4). Finally, in terms of employee satisfaction, the percentage of occupants complaining about noise is about 10 times greater in large open-plan office spaces as compared to private enclosed offices (Pierrette, Parizet, Chevret, & Chatillon, 2015). Further, high levels of annoyance with background noise in open-plan offices are associated with reduced workplace satisfaction. Employees in open-plan office spaces are significantly less satisfied with workspace acoustics than occupants in private enclosed offices, even though the decibel levels meet the required standard (Freihoefer, Guerin, Martin, Kim, & Brigham, 2015). Workspace satisfaction is covered in depth in Section 3.6.

3.3.2. Headphone Usage

If the workspace does not provide sufficient acoustical privacy, employees will begin using one or more techniques to cope. Employees may initially attempt to compensate for background noise by simply trying to concentrate harder on their work, which can lead to tiredness, irritation, depression, poor performance, and poor cooperation with coworkers (Roelofsen, 2008). More than likely, however, employees will begin to use headphones or similar devices to block out background noise in an effort to minimize disruptions. At one architecture and engineering firm in Houston, estimates indicate that about 75% of coworkers wear headphones at work (Shellenbarger, 2012). An informal survey of people under the age of 35 working in a range of knowledge worker jobs in the U.S. suggests that employees wear headphones about 50% of the time they are at work (Kreamer, 2012). According to one software engineer, "headphones are the new walls" (Newman, 2016, p. 168). In the absence of walls, doors, and sometimes even cubicle partitions, workers must create what Newman (2016) calls a "metaphorical space between themselves and their nattering, farting, burping, yelling, coughing, sneezing, eating, slurping coworkers" (p. 179).

Headphones have both advantages and disadvantages in open-plan office spaces (Table 3-3). On the one hand, they help employees regain a sense of auditory privacy and control, and they provide a visual "do not disturb" signal to help curb impromptu conversations and maintain concentration (Berinato, 2012; Kreamer, 2012; Newman, 2016). Noise-cancelling headphones can be good at blocking distractions from the higher-frequency sounds of speech and improving productivity (Berinato, 2012; Newman, 2016; Shellenbarger, 2012). In a case study of his own work habits, one knowledge worker used specialized software to track his computer activities and estimate productivity at work. He found that he experienced more periods of high productivity and fewer periods of very distracted work when he wore headphones (Berinato, 2012).

On the other hand, headphones can have their downsides. First, the effectiveness of listening to music through headphones is questionable. Some research shows that listening to vocal music may degrade concentration and performance (Shellenbarger, 2012). The extent of the degrading effects may depend on the nature of the task being performed. As one software engineer stated, music facilitates performance when writing code, but interferes when writing e-mails or document summaries (Shellenbarger, 2012). Another study suggests that listening to music may be least beneficial for those employees who have very strong feelings about it. Performance may be negatively impacted for employees who either love or hate listening to music while working because it diverts their attention away from their primary tasks and forces the brain to work harder in order to maintain focus and concentration (Shellenbarger, 2012).

Second, headphones can also hinder communication—which negates the very reason many open-plan office spaces are being designed (Kreamer, 2012; Newman, 2016; Shellenbarger, 2012). Headphone usage can be viewed as poor office etiquette and cause resentment among coworkers (Shellenbarger, 2012). A 2010 survey of 1400 chief information officers revealed that headphone usage is considered a major office etiquette problem (Shellenbarger, 2012). Further, because they are effectively isolated from background activities, employees who use headphones may miss many collaborative opportunities to exchange information and ideas with colleagues (Kreamer, 2012). Such missed opportunities can negatively impact not only mission accomplishment but also individual career development. Employees who wear headphones may be more likely to experience a lack of belongingness at work, which can reduce their organizational commitment and possibly lead to attrition (Kreamer, 2012). As Kreamer (2012) put it, employees who don headphones effectively become remote telecommuters, even though they are physically present.

Table 3-3. Advantages and Disadvantages of Headphones at Work

Advantages	Disadvantages
Promote auditory privacy and control	Create office etiquette problems
Provide "do not disturb" signal	Cause coworker resentment
Minimize impromptu conversations	Hinder communication and collaboration
Help employees focus and concentrate	Degrade mission accomplishment
Block background speech	Impede career development
Improve productivity and performance	Reduce organizational commitment

3.3.3. Post-Construction Attempts to Manage Acoustics

Attempts to improve office acoustics post-construction may help to a degree, but they are not sufficient to achieve the levels of satisfaction and performance that occur in workspaces that have been built to provide high levels of auditory isolation. As compared to open-plan offices in which background speech is not masked in any way, employee satisfaction is higher when noise masking devices of any type are used. Further, architectural changes to increase sound absorption in open-plan offices may not lead to performance improvements, but they do make the environment seem subjectively less distracting to employees.

3.3.3.1. Noise Masking Devices

Artificial noise masking solutions represent one technique used in open-plan office spaces to cover up background noise and attempt to reduce the negative effects on employees (Haapakangas, Kankkunen, Hongisto, Virjonen, Loiva, & Keskinen, 2011). The masking sound is designed to decrease the intelligibility of background speech and minimize performance effects. Haapakangas, et al. (2011) compared the effects of seven sound conditions—complete silence with no background speech present, unmasked intelligible background speech, and five different masking sounds overlaid on intelligible background speech (pink noise, white noise, vocal music, instrumental music, and the sound of spring water)—while participants performed three different cognitive tasks. Results indicated that unmasked intelligible speech degraded both cognitive performance and ratings of acoustic satisfaction. Satisfaction was significantly lower for speech and all masked speech conditions as compared to silence; however, masking did help to some extent—satisfaction was higher in all masked speech conditions as compared to speech alone. The spring water sound was associated with the most benefits in terms of both satisfaction and performance. Both vocal and instrumental music created the most disturbances for participants.

3.3.3.2. Architectural Modifications

Post-construction attempts to improve room acoustic design (e.g., by installing higher cubicle walls or sound-absorbing ceiling tiles and cubicle panels) can positively change objective indicators of acoustics such as speech transmission index and reverberation time (Passero & Zannin, 2012). However, the negative effects of noise in open-plan offices on employees cannot be fully resolved with this approach (Haapakangas, Hongisto, Hyönä, Kokko, & Keränen, 2014). In their experiment, Haapakangas, et al. (2014) attempted to improve room acoustics by using more and higher cubicle walls around workstations, applying a pink noise generator to mask background speech, and maximizing absorption in ceilings and walls. Although participants rated

such workspaces as subjectively less distracting than workspaces with no such improvements, objective performance metrics for three of four cognitive tasks used in the experiment remained unchanged.

3.4.   Health Impacts

This topic is characterized by very strong scholarly research that demonstrates a clear association between the physical work environment and employee health, using both subjective and objective data. All eight documents reviewed for this topic provided evidence that features associated with open-plan office spaces negatively impact employee health.

3.4.1.   Health Effects and Symptoms

Open-plan office spaces have been associated with both physiological and psychological reactions. *Physiological reactions* include increased blood pressure levels; fatigue and physical exhaustion; increased risk of acquiring the flu from coworkers carrying the virus; susceptibility to eye, nose, and throat irritations; and musculoskeletal problems (Oommen, Knowles, & Zhao, 2008). Reduced heart rate variability and increased salivary cortisol, which are indicators of higher stress levels that serve as intermediate mechanisms in stress-related illnesses, have also been observed (Thayer, et al., 2010). Decreased heart rate variability is an independent risk factor for poor health, disease, and death. Healthy people typically show significant increase at night. Individuals suffering from health problems such as acute stress and chronic alcoholism exhibit reduced heart rate variability. High morning cortisol levels are another indicator of the body's hormonal stress response and have been associated with increased risk for cardiovascular disease.

Physical factors in the workplace such as noise and privacy have been shown to be strongly related to employee *psychological wellbeing* (Klitzman & Stellman, 1989). In fact, physical factors appear to be more important than psychosocial working conditions (e.g., job demands, decision-making flexibility, and relationships with other people at work), with noise representing one of the strongest predictors of psychological wellbeing. In their survey of 1830 nonmanagerial office workers at four different workplaces in North America, Klitzman and Stellman (1989) report that symptoms of poor wellbeing attributable to workplace physical factors such as noise include increased anxiety, depression, and irritation. In an experimental study using a simulated open-plan office with background noise (a pre-recorded sound track featuring people talking on the telephone, in-person conversations, laughter, and office equipment sounds), participants completing demanding computer tasks reported an increase in *perceived exertion in the head* on the Borg CR10 scale used to measure perceptions and experiences such as pain and exertion (Kristiansen, et al., 2009).[5] In other words, participants felt their brains had to work harder in the presence of office noise.

Other symptoms of poor psychological wellbeing associated with open-plan offices include stress, insecurity, mental exhaustion, and aggression (Oommen, Knowles, & Zhao, 2008). As just one example, stress, insecurity, and aggression may occur in open-plan offices that do not have assigned workspaces. When many different employees use a single workspace; the workspace may constantly be rearranged, resources may be misplaced, and personal or confidential items may get

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[5] The Borg CR10 scale is a category-ratio (CR) scale (i.e., a categorical scale with ratio data level properties) used to measure pain and exertion. The scale ranges from 0 (very low pain or exertion) to 10 (very extreme pain or exertion).

left behind. Further, staff who are subject to hot desking and hoteling cannot express themselves by personalizing their workspaces.

Physiological and psychological reactions to open-plan offices can have very tangible impacts. One prominent effect involves increased sickness absences in open-plan offices (Clausen, Kristiansen, Hansen, Pejtersen, & Burr, 2013; Danielsson, Chungkham, Wulff, & Westerlund, 2014). Higher stress levels have also been associated with an increased probability of accidents in the workplace and increased turnover (Lee, 1997; Oommen, Knowles, & Zhao, 2008). The American Institute of Stress reports that stress can lead to violence in the workplace (Lee, 1997; The Marlin Company, 2001). In their surveys, approximately 20% of U.S. workers indicated they have witnessed or been aware of physical or verbal bullying in the workplace, and nearly 10% knew of an assault or violent act.

3.4.2. Results from Subjective Data Analyses

Subjective data analyses of employee self-ratings of health in various office types have demonstrated poorer perceived health in open-plan offices. A survey analysis of 469 employees from 26 different Swedish companies indicated that private enclosed offices were associated with high self-ratings for employee health and job satisfaction, whereas open-plan offices scored low (Danielsson & Bodin, 2008). Employees in open-plan offices indicated they had taken more days of sick leave in the past year, and they rated their overall health more poorly, as compared to occupants of private enclosed offices (Table 3-4). Open-plan offices were significantly inferior with respect to employee emotional health, with more ratings of sadness and depression in open-plan offices. A survey of 1830 nonmanagerial office workers in the U.S. and Canada revealed that physical factors such as air quality and noise were strongly related to employee psychological wellbeing and more important than psychosocial working conditions (Klitzman & Stellman, 1989). In particular, the types of noisy backgrounds that typify open-plan offices were associated with poorer psychological wellbeing. The degrading effects of environmental stressors such as noise appear to work indirectly by reducing employee perceptions of wellbeing—greater incidences and severity of headaches, more reports of simply "feeling off," and poorer mood (Lamb & Kwok, 2016). For example, in Lamb and Kwok's (2016) study, self-reported mood was highest when annoyance from background noise was completely absent and lowest when noise annoyance was perceived as extreme.

Table 3-4. Self-Reported Sick Leave and Perceived Health in Various Office Types

Questionnaire Item	Private Enclosed Office	Open-Plan Office
Percentage of employees who took any sick leave in the past year	61%	71%
Percentage of employees rating overall health as *not very good*	32%	53%

Note: Percentages for open-plan offices represent averages across small, medium, and large offices (see Table 3 in Danielsson & Bodin, 2008).

3.4.3. Results from Objective Data Analyses

Physiological changes can occur without the employee's conscious awareness; as a result, they may not be reflected in perceived stress levels (Thayer, et al., 2010). For that reason, research that measures objective indicators of health impacts is generally considered more informative. Perhaps the strongest evidence for linkages between open-plan office spaces and employee health comes from two different prospective analyses that demonstrated an increased risk for sickness absences for employees working in open-plan offices and for office workers exposed to disturbing noise, as might be encountered in open-plan offices (Clausen, Kristiansen, Hansen, Pejtersen, & Burr, 2013; Danielsson, Chungkham, Wulff, & Westerlund, 2014).

Clausen, et al. (2013) first asked 2883 Danish office workers to rate whether they were frequently, occasionally, or rarely/never subjected to noise that disturbed their work (e.g., other people talking and ventilation). In this study, disturbances were characterized as distractions or annoyances due to office noise. The researchers then used a registered Danish database of sickness absence compensations to track employees for one year and identify long-term sickness absences, defined as more than two consecutive weeks away from work due to illness. Results indicated that office workers who were frequently exposed to disturbing noise at work had a significantly increased risk of long-term sickness absence, as compared to employees who were rarely or never exposed to disruptive noise (Table 3-5). This association was stronger for females than for males. Given that sick leave extended for more than two weeks, the relationship suggests that high levels of office noise are associated with poor employee health (i.e., health issues that require considerable recovery time).

Table 3-5. Long-Term Sickness Absence and Exposure to Noise at Work

Noise Exposure	Hazard Ratios	
	Model 1	Model 2
Frequently	2.08	1.90
Occasionally	1.24	1.18
Rarely/Never	1.00	1.00

Hazard ratios greater than 1.00 represent increased risk (Clausen, et al., 2013). In Model 1, hazard ratios were adjusted for participant age and interview mode (telephone versus postal questionnaire). Model 2 adjusted for these factors plus gender, smoking status, and manager status (yes/no). In both models, employees frequently exposed to disturbing noise were twice as likely to have long-term sickness absences than those rarely or never exposed to noise.

Danielsson, et al. (2014) conducted a prospective examination of sick leave for 1852 Swedish employees working in seven different office types (identified previously in Table 1-1). Employees first provided information regarding office type. Two years later, the researchers analyzed sick leave data from the previous one-year period for the same employees. Results indicated that risks for *short* sickness absences of one week or less were significantly elevated in all open-plan offices (small, medium, and large), as compared to private enclosed offices. Risks for *long* sickness absences of more than one week were significantly higher for women in large open-plan offices. Total number of sick days over the past year was higher for men who worked in flex-offices that relied on hot desking or hoteling. The researchers surmised that the odds of sick leave are lower in office types that afford a high degree of personal control and have a lower degree of

environmental stressors such as noise and reduced privacy. They concluded that "open-plan offices are less good for employee health" (Danielsson, Chungkham, Wulff, & Westerlund, 2014, p. 145).

Finally, research has shown that office design modifications that improve working conditions (e.g., by reducing distracting noise) and thereby improve employee satisfaction are associated with reduced work-related stress, as reflected in physiological measures of heart rate variability and salivary cortisol (Thayer, et al., 2010). Thayer, et al. (2010) studied 60 employees working in a U.S. government facility over 17 months and discovered reduced nighttime heart rate variability and higher morning cortisol levels for staff who worked in noisy workspaces characterized by considerable low-frequency noise. Results such as these for heart rate variability and cortisol levels are indicative of an unhealthy pattern reflecting higher stress, and higher stress is a known risk factor for cardiovascular disease.

3.5. Organizational Retention

Very little scholarly research that directly investigates the impacts of office design on employee commitment to the organization or retention has been conducted. Nevertheless, there are several strong indicators that the physical workplace can impact both recruitment and retention.

A survey of 663 adults indicated that the majority considered salary to be the number one factor impacting recruitment and retention; however, benefits and physical workplace tied for second place (Earle, 2003) (Table 3-6). When asked specifically whether the physical workplace would affect their decision to accept (or leave) a position, 41% (51%) of employees and job seekers said it would (Earle, 2003). At Internet-based career center Monster.com, 68% of new employees said the physical environment was an important factor in their decision to accept the position (Earle, 2003). Further, 55% of employees who received outside job offers said the physical environment at Monster.com was important to their decision to stay with the company (Earle, 2003). Oommen, Knowles, and Zhao (2008) report that people who dislike working conditions characterized by high occupant density have a higher turnover. The IDEO industrial design company in Palo Alto, California, attributes its extremely low attrition rate of less than 4% per year in part to its work environment (Earle, 2003).

Table 3-6. Self-Reported Factors Impacting Recruitment and Retention

Rank	Factor	Percentage of Respondents
First	Salary	62%
Second (tie)	Benefits / Physical Workplace	22% / 21%

Based on a survey of 663 adults who were asked to identify and list factors that influence their decisions to accept or leave jobs (Earle, 2003).

Employee satisfaction is an important factor that can reduce staff turnover, and the physical environment is one feature in the organization that affects job satisfaction (Oommen, Knowles, & Zhao, 2008). According to Earle (2003), physical workplace ranks in the top three for job satisfaction. Employees who are satisfied with their physical workspaces are 31% more likely to have high job satisfaction than those who are dissatisfied with their workspaces (Earle, 2003). Along these lines, a 2008 literature review revealed that workspace design can impact employee commitment to the organization and organizational retention by influencing employees' sense of belonging (Vischer, 2008). Two factors that affect a sense of belonging at work are employee

perceptions of privacy and control, both of which have been shown to suffer in open-plan office designs—complaints of lack of privacy abound in before-and-after studies of transitions from private to open-plan offices (Vischer, 2008). In fact, according to the founder of consulting firm Chicago Creative Space, the rooms that employees use most are the smaller rooms designed to provide employee privacy (Douglas, 2014). Additional research from a survey administered to 150,000 employees at 194 office locations in 52 countries indicates that increasing (1) the proportion of individual workspaces, (2) the number of assigned spaces (i.e., by minimizing hot desking), and (3) the quality of meeting spaces can improve employee engagement and retention (O'Neill, 2013). One estimate suggests that highly engaged employees are 87% less likely to leave an organization (O'Neill, 2013).

Finally, research conducted during renovation of one of the R&D facilities at General Motors revealed interesting differences among researchers and executives that impact workspace design, employee satisfaction, and potentially retention (Meerwarth, Trotter, & Briody, 2008). When testing life-size mockups of various potential workspace designs, researchers found the open space noisy and distracting and expressed a clear preference for enclosed workspaces for privacy and work requiring focus and concentration. Workability of the space (e.g., access to resources such as whiteboards and adequate work surfaces to complete tasks) was also extremely important to researchers. Executives were much more positive about the open spaces intended for researchers and placed considerably less emphasis on the workability of the office design. Executives also viewed researcher productivity as much more of a communal effort that is best achieved in more open workspaces, whereas researchers focused on individual actions and felt productivity is best achieved through an individual, private enclosed office design that reduces both visual and auditory distractors. If differences such as these are poorly addressed or ignored, employee dissatisfaction with the workspaces they must use can potentially contribute to attrition.

3.6. Workspace Satisfaction

All six documents reviewed for this topic reported lower levels of employee satisfaction in open-plan offices as compared to private enclosed offices. These differences have been attributed to dissatisfaction with privacy and acoustics, primarily because employees in open-plan offices cannot control these features of the physical environment.

3.6.1. *Satisfaction with Open-Plan Office Features*

An analysis of questionnaire data from 779 open-plan office occupants in North America provided a foundation in which to interpret relationships between environmental features and workspace satisfaction (Veitch, Charles, Farley, & Newsham, 2007). Veitch, et al. (2007) first demonstrated that environmental features in the workplace can be grouped into three major categories: (1) privacy and acoustics, (2) lighting, and (3) ventilation and temperature (Figure 3-5). The researchers discovered that open-plan office employees who were satisfied with the physical environment also had higher job satisfaction overall. They concluded that a satisfactory physical environment is one critical component of a satisfied workforce and an effective organization (Veitch, Charles, Farley, & Newsham, 2007).

Privacy and Acoustics	**Lighting**
• Amount of noise from nearby conversations • Frequency of distractions from people • Degree of workspace enclosure • Level of visual privacy • Distance from coworker workspaces • Level of isolation for private conversations • Workspace size • Ability to change workspace physical conditions • Aesthetic appearance of office space	• Quality of lighting in work area • Amount of desktop lighting • Amount of light for computer work • Amount of glare • Access to exterior views from work area
	Ventilation and Temperature
	• Air movement in work area • Overall air quality in work area • Temperature in work area

Figure 3-5. Workplace Environmental Features: Environmental features in the workplace can be grouped into three categories (Veitch, Charles, Farley, & Newsham, 2007).

In accordance with the first major category identified in Veitch, et al.'s (2007) study, research has shown that the two most prominent factors generating dissatisfaction in open-plan office spaces are auditory distractions and lack of privacy. Auditory distraction consistently represents the most negative feature of open-plan offices (Kim & de Dear, 2013; Paul, 2012; Shafaghat, Keyvanfar, Ferwati, & Alizadeh, 2015; Sundstrom, Burt, & Kamp, 1980). In terms of privacy, both architectural privacy (visual and acoustic isolation supplied by the physical environment) and psychological privacy (sense of control over information transmission and input) have been shown to be important for workspace and job satisfaction (Sundstrom, Burt, & Kamp, 1980). In Sundstrom, Burt, and Kamp's (1980) research; three separate studies of 213 employees in supervisory, administrative, clerical, and technical roles demonstrated that satisfaction was consistently higher in work areas that employees viewed as private. This outcome was true regardless of the type or complexity of work being performed. Job satisfaction was highly related to workspace satisfaction, which was higher in workspaces considered private, not crowded, not visible to the supervisor, and located away from major pathways through the office. The presence of a large number of people in the same room was associated with lower ratings of privacy and higher ratings of noise (Sundstrom, Burt, & Kamp, 1980).

At an even deeper level, the common cause contributing to dissatisfaction with both auditory distractions and lack of privacy appears to be lack of control over the environment (Kim & de Dear, 2013; Oommen, Knowles, & Zhao, 2008; Sundstrom, Burt, & Kamp, 1980). In open-plan office spaces, employees cannot control where and when potentially disruptive colleague activities occur—phone conversations, nearby discussions, and in-person interruptions. In private enclosed offices, on the other hand, employees can close their office doors to control their environment and minimize distractions and interruptions whenever they recognize a need to concentrate and focus deeply. Employees in open-plan offices do not have this option. As described earlier, circumstances such as these have led employees in open-plan office spaces to exert control in other ways; e.g., by wearing headphones.

3.6.2.   Relative Satisfaction in Private Enclosed and Open-Plan Offices

In their analysis of 42,764 samples from 303 office buildings in the Center for the Built Environment post-occupancy evaluation database, Kim and de Dear (2013) found that private enclosed offices were rated highest overall in workspace satisfaction. For private enclosed offices, all of the office environment factors in the survey (e.g., acoustics, lighting, and thermal) were rated positively. Private enclosed offices also significantly outscored other types of offices across most of the environmental factors. In particular, noticeable differences between private enclosed offices and open-plan offices appeared in ratings of visual privacy, sound privacy, noise level, and amount of space. In open-plan offices, the highest levels of dissatisfaction were associated with auditory privacy. Further, satisfaction with visual privacy declined as the degree of enclosure provided by the office decreased. One area in which private enclosed offices and open-plan offices did not differ was satisfaction with ease of interactions. Although increased interaction and collaboration is often cited as a benefit of open-plan offices, satisfaction ratings were no higher for open-plan offices as compared to private enclosed offices. Any positive impacts of ease of interaction in open-plan offices on workspace satisfaction were much smaller than the combined negative effects of noise and poor auditory and visual privacy. Kim and de Dear (2013) concluded that the drawbacks of open-plan offices (reduced visual and sound privacy, less space, and more noise) outweigh any purported benefits (ease of interaction).

Research has also demonstrated that employee moves from traditional offices to open offices are associated with lower levels of occupant satisfaction with the physical environment; conversely, moves in the opposite direction lead to improvements in task privacy, communication privacy, crowding, and office satisfaction (Andrew, Chang, & Nicholson, 2008). Research further suggests that employees may not grow to accept and like open-plan offices over time—a study of one group of employees found they disliked the new open-plan offices even more over time (Walker, 2016). In accordance with the previous discussion in this report of the need for office environments that support both privacy and collaboration, workspace satisfaction can be significantly improved by providing both a distraction-free workspace and opportunities for informal interactions (Andrew, Chang, & Nicholson, 2008).

3.7.   Analyzing Workspaces for Different Employee Types

A segment of the literature has focused on understanding whether workspace customization is needed to accommodate different types of workers. Two aspects that are most frequently investigated involve different generational cohorts and different job roles. Results suggest that intergenerational workspace preferences are more similar than different, although there are some inconsistencies in the research. With respect to job roles, a similar conclusion is reached when the overall knowledge worker job role is examined, mirroring research presented elsewhere in this report regarding the need for private, distraction-free space to focus and concentrate. The only research in which detailed workspace requirements have been provided for specific types of knowledge worker job roles applies to software developers.

3.7.1.   Generational Cohorts

In recognition of the possibility that differences among the five different generations in today's workplace (see descriptions in Section 2.4.4) could potentially compromise organizational performance, some researchers have focused on understanding how the different generations view workspace and office designs. There has also been concern that workspace design may impact the

crucial process of knowledge transfer from older to younger employees as the older generations retire and leave the workforce. While most research indicates that all generations of workers have similar workspace needs, the literature is not entirely consistent.

3.7.1.1. Intergenerational Workspace Preferences

In a six-month case study of 63 knowledge workers from three different generations in the United Kingdom, all employees had a common need for a quiet workspace free from noise and distractions to conduct work requiring a deeper level of concentration (Joy & Haynes, 2011). Further, when performing work that requires concentration, all three generations expressed a preference for working at home, indicating that noise and distractions in the office hinder the ability to focus. All generations also preferred a designated team-based area for collaboration and knowledge transfer, but interacted frequently in informal "break room" type areas as well. One generational difference that did emerge involved preferences for scheduling meeting rooms. Baby Boomers preferred booking conference rooms in advance for scheduled meetings to protect confidentiality. Generation Y employees tended to prefer using more flexible workspaces with no need for advance reservations.

Similarly, an Internet survey completed by more than 1100 office employees in 21 organizations in Helsinki, Finland, identified more similarities than differences among the different age groups (Rothe, Lindholm, Hyvönen, & Nenonen, 2012). While younger participants appeared to value work environments that support collaboration and networking more than other age groups, privacy and the opportunity to perform concentrated work were regarded as important elements of the workplace, regardless of age. All of the different generations valued privacy in the workplace to the same extent. Preferences for mobility and opportunities to work virtually also did not differ significantly between older and younger respondents.

Although an interview study of 20 employees at a Finnish telecommunications company contact center concluded that Generation Y workers like open-plan office designs, participants identified the same issues that have been cited throughout the literature (Rasila & Rothe, 2012). As has been found in other research, those Generation Y employees who were disturbed by background noise resorted to headphones to cope with it. Study interviewees also found the high occupant density irritating because it meant working inside each other's comfort zones, and it hindered movements around the office. Interviewees further admitted they would like to have more isolated workspaces for private phone conversations or short discussions. Limited visual privacy was even more problematic—interviewees had issues shielding their computer screens from passersby. As has been described in other research, participants in this study indicated that the most common distractions came from background noise and interruptions from other staff. Moreover, interviewees voiced dissatisfaction with a lack of control over their environment.

Unlike the previous studies, which highlight intergenerational similarities, O'Neill (2010) reported that a survey of 15,500 professional employees working in three U.S.-based companies across 40 countries uncovered real generational differences in preferences for workspace features. All of the generations did rate office workspace as very *important*—mean scores were 4.0 or higher on a five-point scale ranging from 1 (least importance) to 5 (highest importance). However, the different generations provided relatively different ratings for six workspace features. For example, Baby Boomers rated *acoustic privacy* and the *quality of meeting rooms* highest and an *engaging workplace* lowest, whereas Generation Y provided the exact opposite ratings. In general, the quality of meeting spaces may be less important to Generation Y employees because current

technology enables them to work anywhere at any time, not just in the meeting rooms the company has provided. However, meeting spaces may be just as important for Generation Y employees as it is for Baby Boomers if their work routinely involves highly confidential or classified information that cannot be taken outside the office.

3.7.1.2. Designing Workspaces for Multiple Generations

Research described in the previous section indicates that all generations have a similar need and preference for quiet workspaces in which to focus and concentrate. Yet many recent open-plan office spaces have been designed to resemble college campus student unions in order to appeal to the recent college graduates comprising Generation Y (Kreuze, 2016). Other generational cohorts, and even some Generation Y employees, have indicated that such work environments are distracting and fatiguing (Kreuze, 2016). Further, such environments may no longer be appealing and suitable for Generation Y as the group matures. In addition, stimulating open-plan office environments may not work at all for Generation Z, people born since the year 2000 who are just now entering the workforce. Kreuze (2016) maintains that members of Generation Z will have different workspace needs because they have been "wired and multi-modal" since birth (p. 3)—digitally connected everywhere all the time. Consequently, Generation Z may need work environments that minimize, not create, stimulation and help them tune out technological distractions. As Kreuze (2016) points out, providing workspaces that help people focus benefits all generations. Although the reasons may differ, older and younger generations ultimately have similar workplace needs.

Finally, two different studies concur that facilitating knowledge transfer in the multi-generational workforce requires a combination of workspaces (Bennett, Pitt, & Price, 2012; Earle, 2003). Bennett, et al. (2002) point out that effective workspace design can be used to manage knowledge transfer in both directions. Specifically, there must be a balance between collective spaces for collaboration and interactions and individual spaces for focus work. Similarly, Earle (2003) maintains that encouraging people to share what they know requires a combination of formal and informal meeting spaces where people can interact.

3.7.2. Job Roles

Most of the research regarding workspace design and job roles has categorized knowledge work into a single "knowledge worker" job role and has not therefore explored requirements for more specific job roles in depth. In general, research involving workspace needs for the knowledge worker job role is consistent with research that has already been described in this report. Namely, for a large portion of the day, all knowledge workers need private space with sufficient visual and auditory isolation to support work requiring focus and concentration—reading, editing papers, performing calculations, creating and writing text, searching for information, organizing ideas, and analyzing and solving problems. The quality of the knowledge worker's work product suffers in open-plan workspaces due to interruptions and distractions, which degrades the time required to complete tasks. Frequent interruptions and distractions compound the time it takes to recover, return to, and finish the task at hand. In fact, across all organizations and job types in Olson's (2001) analysis of 45,000 U.S. managers, professionals, engineers, and administrative assistants, the most important workspace feature contributing to job satisfaction and both individual and team performance was the ability to perform distraction-free solo work (Table 3-7).

Table 3-7. Workspace Features Important for Satisfaction and Performance

Rank	Workspace Feature
1	Ability to perform distraction-free solo work
2	Support for impromptu interactions (both in one's workspace and elsewhere)
3	Support for meetings and undistracted groupwork
4	Workspace comfort, ergonomics, and enough space for work tools
5	Workspace supports side-by-side work and "dropping in to chat"
6	Located near or can easily find coworkers
7	Workplace has good places for breaks
8	Access to needed technology
9	Quality lighting and access to daylight
10	Temperature control and air quality

From Olson (2001).

Despite such consistencies across a large number of U.S. workers, Elsbach and Pratt's (2007) review of empirical research on physical environments in professional work settings revealed that "no common elements of the physical environment…are consistently and exclusively associated with desired outcomes in these work settings" (p. 181). For every element of the physical environment that has been frequently researched—workspace enclosures and barriers; adjustable workspaces, equipment, and furnishings; workspace personalization; and the presence of natural features in the ambient environment—both desired and undesired outcomes can occur (Elsbach & Pratt, 2007). Many of these disparities have already been discussed in this report. For example, workspace enclosures and barriers can have desired effects by supporting knowledge worker preferences for privacy over accessibility to coworkers for interaction. On the other hand, workspace enclosures and barriers can have undesired effects if they do not fully block auditory distractions. Some of the disparities also arise because of the complex interrelationships among the various aspects discussed in this section of the report such as task and individual factors.

3.7.2.1. Effects of Job Role Task Characteristics on Workspace Design

The characteristics of the tasks comprising a job role can impact the type of workspace design that will best promote employee satisfaction and performance. These characteristics include job complexity, creativity, and monotony.

Job Complexity. Research is not completely consistent with respect to the impact of job complexity on workspace design. One study demonstrated that the importance of privacy may not be related to job complexity among administrative assistants, bookkeepers and accountants, and office managers (Sundstrom, Town, Brown, Forman, & McGee, 1982). Despite differences in self-rated job complexity, all three of these groups had similar ratings of the importance of privacy for their work. That is, rated privacy did not become more important for workspace and job satisfaction as the complexity of the job increased. Similarly, based on their review of empirical research on the physical environment in professional work settings over the past 30 years, Elsbach and Pratt (2007) discovered that any job that requires considerable focused "heads down" thinking, regardless of whether it is simple or complex, will benefit from private enclosed workspace.

On the other hand, Dansoh (2006) suggests that privacy does become more important as job complexity increases. In an analysis of questionnaire responses from 132 administrative, engineering, and managerial office workers in Ghana, privacy was rated as highly important across all job roles, though ratings were slightly lower for administrative workers. Dansoh (2006) concluded that clerical work may be best suited to open-plan spaces because the extra stimulation will facilitate completion of the low complexity tasks that clerical workers perform. Similarly, Elsbach and Pratt (2007) point out that clerical workers may function best in open spaces because they frequently need to visually scan the environment and know who is available. However, they also acknowledge that even clerical workers need uninterrupted time for tasks requiring deep thought, which is difficult to achieve in the open-plan office spaces due to staff interruptions.

Creativity. Some types of knowledge work require high levels of creativity to develop novel and useful ideas, alternatives, processes, and procedures. Telephone interviews with 1722 U.S. employees revealed that workspace features that promote a sense of control at work (e.g., partitions and walls) enhance employee creativity (Shalley, Gilson, & Blum, 2000). For these reasons, highly creative work may require more private workspaces to support focus and concentration. Shalley, Gilson, and Blum's (2000) research showed that accommodating the need for creativity by providing appropriate work environments can generate higher employee satisfaction and lower intentions to leave an organization.

Task Monotony. Elsbach and Pratt (2007) point out that jobs requiring less cognitive focus but more stimulation (e.g., sorting tasks and brainstorming) may benefit from less privacy and less enclosure. Such tasks are often thought to apply predominantly to clerical job roles. However, not all clerical tasks are boring and routine (Elsbach & Pratt, 2007). Some clerical tasks such as data entry can require intense concentration to minimize errors. In one study, clerical workers performing data entry preferred conducting such tasks in private enclosed offices to avoid the distractions of open-plan office spaces (Sundstrom, Burt, & Kamp, 1980). Even though the work was routine and repetitive in nature, clerical workers had higher self-rated satisfaction if the work could be done in private enclosed offices (Sundstrom, Burt, & Kamp, 1980).

3.7.2.2. Workspace Perceptions by Job Role

As with other topics presented in this report, knowledge workers in different job roles tend to have workspace perceptions that are more similar than different. For example, administrative assistants, bookkeepers and accountants, and office managers had similar views of the types of workspace features required for privacy in Sundstrom, et al.'s (1982) study. Namely, the best predictor of rated privacy for all job groups was the number of partitions surrounding the workspace (Figure 3-6). In all three job roles, occupants of private offices that were fully enclosed by four walls rated their workspaces most private and were most satisfied with their workspaces. Thus, as stated elsewhere, privacy is associated with physical workspace features that permit employee control over auditory and visual isolation in order to regulate distractions and interruptions.

In an analysis of 13,000 surveys representing 45,000 managerial, professional, engineering, and administrative employees in the U.S., Olson (2001) found that the perceived benefits of increased workspace enclosure exceed the perceived benefits of increased size. As compared to employees in open-plan office spaces, employees in acoustically private workspaces, regardless of size, self-reported numerous benefits—higher job satisfaction, greater productivity, better performance in teams, more useful informal interactions, enhanced opportunities to perform focused work, fewer visual distractions, and greater physical comfort. Positive perceptions for people in *larger*

workspaces, on the other hand, were much more limited. They felt only that they had enough space, their work surfaces were large enough, and they were more satisfied with their workspaces. In addition, workspace size alone bore very little relationship to the ability to reduce distraction.
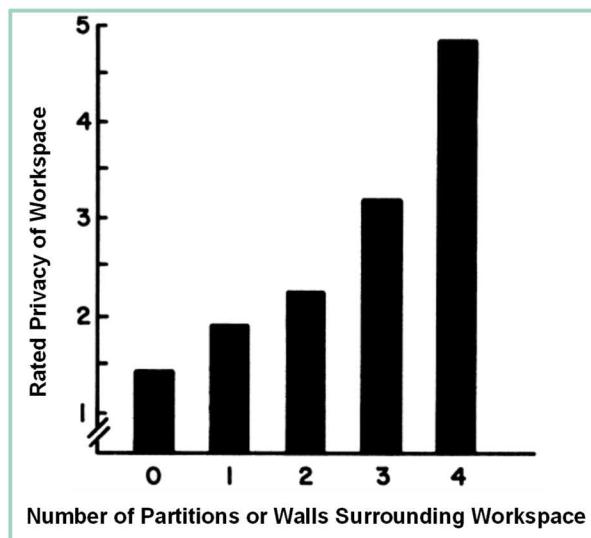
Figure 3-6. Number of Partitions and Rated Privacy: Ratings of privacy increased as the number of partitions or walls surrounding a workspace increased (Sundstrom, et al., 1982).

It should be noted, however, that employee perceptions, beliefs, and preferences may not always correspond to objective indicators of the functionality of a workspace for a given job role (Elsbach & Bechky, 2007). For instance, proofreaders working in a room with walls painted red thought the color of the room was more distracting than a similar room with the walls painted white. They predicted their work would be more error prone in the red room because they thought that color would increase stress. In reality, though, the employees performed better in the red room, committing fewer errors.

3.7.2.3.   Workspace Features Required for Different Job Roles

Very little research has explicitly specified the workspace features needed to support different job roles (aside from the broad category of knowledge workers in general). In their study of administrative assistants, bookkeepers and accountants, and managers; Sundstrom, et al. (1982) concluded that workspace needs do not vary greatly by job role. Specifically, employees in all three job roles had similar perceptions of the importance of privacy for their work. Similar conclusions have been reached in studies of scientific research job roles and software developers.

Scientific Research Job Roles. Stringer and Ostafi (2013) focused on workspace needs in scientific research organizations where knowledge workers require support for a variety of activities such as deep thinking, collaboration, creativity, innovation, knowledge transfer, and mentorship. Their analysis suggests that scientific research job roles, now and in the future, require highly flexible work environments that can be easily reconfigured to support rapidly changing needs. Stringer and Ostafi (2013) also maintain that a scientific research workplace should support mobility at some level for all employees so they can continue to be productive when they are not physically in the office. The workplace should also allow for choice, control, and customization to enhance employee satisfaction and productivity. Diverse spaces are needed to support the

complexity and variety of activities involved in scientific research—quiet focused work, one-on-one discussions, videoconferencing, breaktime and lunchtime conversations, brainstorming, and collaborative interactions. In order to promote collaboration, Stringer and Ostafi (2013) recommend designing "neighborhood" environments that create traffic patterns and position shared resources in such a way as to facilitate connections and cross-talk.

Software Developer Job Roles. With respect to software developers, DeMarco and Lister (1987) conducted the most comprehensive investigation and have provided detailed recommendations regarding workspace needs for software developers. The recommendations are based in part on the results of DeMarco and Lister's (1987) software development competitions conducted from 1984 to 1986 and involving more than 600 developers from 92 companies. In these so-called *Coding War Games*, developers competed to finish a series of benchmark coding and testing tasks as quickly and accurately as possible, while working in their own offices during normal business hours. When DeMarco and Lister (1987) analyzed the data, they were surprised to find that the primary differentiator between the best and worst performers was the type of workspace provided. The workspaces of top performers were larger, quieter, more private, and better protected from interruptions (Table 3-8).

Table 3-8. Workspace Features of Best and Worst Software Developers

Workspace Feature	Best Performers	Worst Performers
Amount of dedicated workspace	78 square feet	46 square feet
Acceptably quiet	57%	29%
Acceptably private	62%	19%
Prone to interruptions	38%	76%

From DeMarco and Lister's (1987) *Coding War Games*.

DeMarco and Lister (1987) also found that the best developers tended to be clustered within the organizations that provided the types of work environments conducive to focus work for all employees, not just its best performers. The end result was that the best organization worked 11.1 times faster than the worst organization. When the sample was divided into those who found the workplace acceptably quiet and those who did not, workers in quiet workplaces were 33% more likely to deliver zero-defect work. Factors that had no bearing on performance included the coding language used, years of experience, and salary.

Workspace recommendations for software developers are also based in part on the results of an IBM study that DeMarco and Lister (1987) report in their book. Before planning its new Santa Teresa facility, IBM conducted a study to understand the work habits of the people who would occupy the new space. The researchers observed work processes during performance of day-to-day tasks. They concluded overall that employees would need sufficient space and quiet in order to perform optimally. Minimum accommodations included the following:

- 100 square feet of dedicated space per worker
- 30 square feet of work surface per person
- Noise protection in the form of enclosed offices or six-foot high partitions

In contrast to these recommendations, DeMarco and Lister's (1987) surveys during the *Coding War Games* demonstrated that only 16% of participants had 100 square feet or more of dedicated

workspace. Only 11% worked in enclosed offices or cubicles with partitions at least six feet high. Only 42% had acceptably quiet workspaces, and 39% had acceptably private workspaces.

Work Styles. In a case study of Capital One Financial Corporation's new approach to workspace design, Khanna and New (2008) describe workspace designs that were specifically created to accommodate five different work styles (Table 3-9). Namely, different types of workspaces were designed to accommodate differences in the ways employees routinely worked by tailoring amount of space, furnishings, and technologies provided. Before the move, all employees met with their managers to discuss their preferred work styles and the available workspace options. Employees were then given complete control to choose their preferred workspaces. For example, large dedicated workspaces with ample work surfaces and storage capacity were designed for anchors, who predominantly work every day in a single location. By emphasizing work styles, Capital One was able to improve both employee satisfaction and organizational productivity and performance. Satisfaction ratings increased from 57% before the move to 80% after the move. Similarly, perceived productivity increased from 43% before the move to 65% after the move.

Table 3-9. Work Styles and Workspace Design

Work Style	Work Behavior	Workspace
Anchor	• Resides in one location • Leverages other work environments	Large, dedicated, individual workspace used every day
Resident	• Resides primarily in one location • Limited mobility	Medium, dedicated individual workspace used nearly every day
Director/Executive	• Highly mobile onsite and beyond • Minimal time working at external sites	Small, dedicated workspace
Mobile Worker	• Highly mobile primarily on site • Minimal time working at external sites	Shared medium-sized workspace No dedicated workspace onsite
Teleworker	• Works from home	Desk at home Shared desk at work

From Khanna and New (2008).

3.8.   Agile Workspaces

Research shows that agile or activity-based workspaces can have both advantages and disadvantages as compared to private enclosed offices and open-plan offices (Table 3-10). In some cases, the same feature can be viewed both positively and negatively. Given the research to date, Walker (2016) cautions that it would be premature to accept agile workspaces as better than open-plan offices.

3.8.1.   Advantages and Positive Staff Reactions

A survey study of 179 employees occupying seven buildings in the United Kingdom was conducted to understand similarities and differences in perceptions of privacy, crowding, and satisfaction in private enclosed offices, open-plan offices, and agile workspaces (Keeling, Clements-Croome, & Roesch, 2015). With respect to advantages, results revealed that agile workspaces are better than open-plan offices and can be as good as private enclosed offices in terms of *ability to control information* (e.g., working with confidential documents) (Keeling,

Clements-Croome, & Roesch, 2015) (Table 3-11). It should be noted, however, that all mean ratings for ability to control information were at or below the midpoint of the scale, suggesting that employees have difficulty in this area, regardless of office type. Agile workspaces were also viewed as better than private enclosed offices for *awareness of other colleagues.*

Table 3-10. Staff Reactions to Agile Workspace Features

Agile Workspace Feature	Staff Reactions		Research Results
	Positive	Negative	
Ability to Control Information	✓		• Confidential documents can be controlled in the workspaces provided
Privacy		✓	• Reduced privacy and concentration in open space areas • Inability to control colleague interactions • Distractions from nearby phone calls and conversations
Concentration		✓	
Workspace Diversity	✓	✓	• Focus rooms are a positive • Desired space may be unavailable due to popularity or late arrival • Some spaces may be seldom used • People rarely switch workspaces • Reduced access to resources • Disuse of reconfigurability and adjustable features
Communications	✓	✓	• Greater potential for knowledge sharing • Difficulty discussing private issues • More frequent interactions, but shorter and more superficial

Table 3-11. Ratings of Ability to Control Information and Awareness of Colleagues

Item	Mean Ratings By Office Type		
	Private Enclosed Office	Open-Plan Office	Agile Workspace
Ability to work with confidential documents	2.6	2.0	2.7
Satisfaction with awareness of colleagues	3.1	3.6	3.7

Ratings ranged from 1 (Not at All) to 5 (Extremely or Many Times a Day), with higher scores indicating greater satisfaction (Keeling, Clements-Croome, and Roesch (2015).

Some research has suggested that agile workspaces may best meet the needs of small groups or teams of employees who work concurrently on the same project (e.g., agile software development teams characterized by high levels of interaction to develop solutions rapidly and flexibly throughout the process) (Gensler Research, 2015; Mishra, Mishra, & Ostrovska, 2012; Moore, Reff, Graham, & Hackerson, 2007; Plante, 2007). Such groups generally have common overarching goals, deadlines, and needs and frequently need to interact to accomplish their work. As a result, an activity-based workspace can increase awareness among team members and improve coordination and collaboration (Mishra, Mishra, & Ostrovska, 2012). Further, interruptions from colleagues may be viewed as essential contributions to the end goal rather than

annoying distractions. According to Gensler Research (2015), developers co-located with team members and working on the same project tended to perceive overheard conversations more positively because they were "relevant to their work and beneficial to them and the team" (p. 19). In addition, such interruptions do not always translate into reduced team or organizational productivity (Gensler Research, 2015). In a California State University study, a group forced to interact more frequently than normal during task completion outperformed a group that interacted less, despite perceptions in the high interaction group of more interruptions, lower productivity, and degraded concentration.

3.8.2. Disadvantages and Negative Staff Reactions

The most significant negative aspects of agile workspaces involve limited opportunities for privacy and concentration. The predominantly open-plan design of agile workspaces does not adequately support the primary activity in which knowledge workers are engaged for most of the day— solitary work requiring focus and concentration. Another frequently cited disadvantage is the tendency to disregard potential reconfigurability of such spaces and leave them unchanged.

3.8.2.1. Lack of Privacy and Ability to Control Interactions

Activity-based workspaces have the same shortcomings observed in open-plan offices with respect to privacy and ability to control interactions with colleagues (Appel-Meulenbroek, Kemperman, van Susante, & Hoendervanger, 2015; Keeling, Clements-Croome, & Roesch, 2015) (Table 3-12). Agile workspaces are considered less private than fully enclosed offices, and occupants find it more difficult to control interactions with other colleagues. In fact, research has demonstrated that limited opportunities for privacy and concentration tend to be the most salient negative aspects of activity-based offices (Appel-Meulenbroek, Kemperman, van Susante, & Hoendervanger, 2015; De Been, Beijer, & den Hollander, 2015; Keeling, Clements-Croome, & Roesch, 2015). Lack of privacy was specifically identified in 43 of 57 group interviews with 271 Dutch employees working in agile workspaces, and difficulty concentrating was identified in 46 interviews (De Been, Beijer, & den Hollander, 2015). A survey of 322 Dutch knowledge workers in 13 organizations revealed that regulation of interactions in the workplace (communication, proximity of coworkers, concentration, and privacy) was associated with greater dissatisfaction in agile workspaces as compared to private enclosed offices (Budie, 2016). Further, work environment factors such as ability to regulate interactions impacted dissatisfaction to a much greater extent than did personal characteristics such as age, gender, educational level, and job rank.

Table 3-12. Ratings of Privacy and Ability to Control Colleague Interactions

Item	Mean Ratings By Office Type		
	Private Enclosed Office	Open-Plan Office	Agile Workspace
Satisfaction with privacy	2.2	1.4	1.6
Ability to control interactions with colleagues	1.8	1.4	1.5

Ratings ranged from 1 (Not at All) to 5 (Extremely or Many Times a Day), with higher scores indicating greater satisfaction (Keeling, Clements-Croome, & Roesch, 2015).

The predominantly open-plan design used in agile workspaces does not adequately support the knowledge worker's frequent need to perform solitary focused work. At a Dutch public sector organization, 114 employees self-reported their work locations, activities, and satisfaction in real time at random points throughout the day for 10 workdays (Hoendervanger, le Noble, Mobach, & Van Yperen, 2015) (Figure 3-7). Results indicated that dissatisfaction is likely to occur if the activity-based work environment does not match staff needs to focus and concentrate (Hoendervanger, le Noble, Mobach, & Van Yperen, 2015). As in research described elsewhere in this report, Hoendervanger, et al. (2015) discovered that the majority of all work was perceived as "individual work that requires high concentration" (p. 8). Given the largely open plan nature of agile workspaces, many of the satisfaction ratings associated with performing solitary focus work were therefore low. Dissatisfaction was highly correlated with the use of workspaces in open areas and shared rooms.
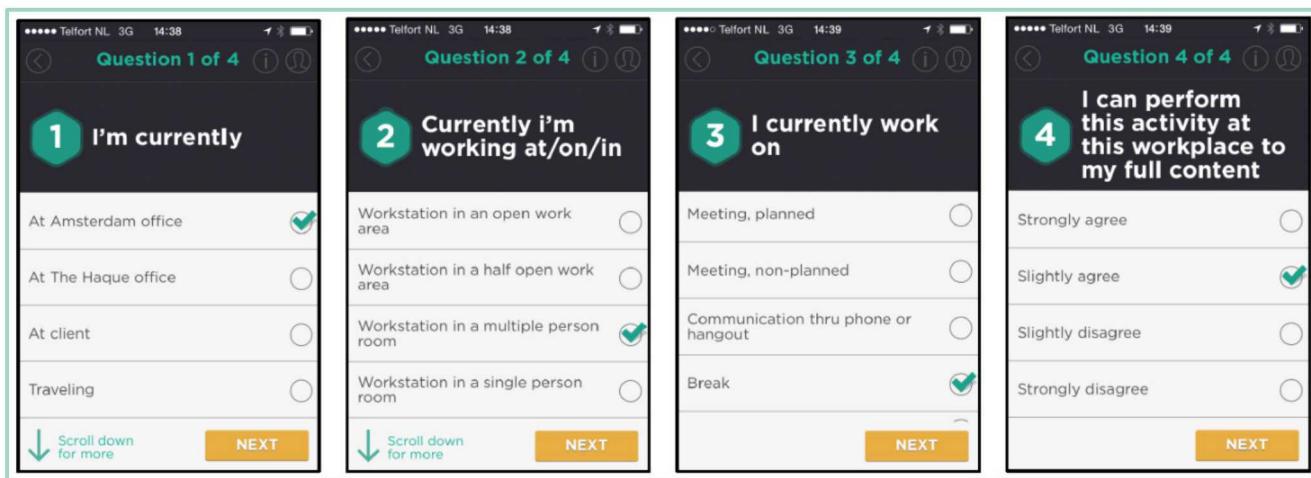
Figure 3-7. Workspace and Work Activity Tracking: Participants were asked to complete four questions randomly throughout the workday to track locations, activities, and satisfaction (Hoendervanger, le Noble, Mobach, & Van Yperen, 2015).

3.8.2.2.   Agile Workspace Reconfigurations

Flexible spaces, when proposed, are justified in part as being easily modifiable, changeable, and capable of meeting unforeseen needs. However, once constructed, such workspaces are subsequently treated as fixed feature space, are not flexible, and are often not changed on the basis of the high costs to change them (Meerwarth, Trotter, & Briody, 2008). Adjustable features are often not used at all, but left in their original configurations (Elsbach & Pratt, 2007). For example, Elsbach and Pratt (2007) report a study of 649 employees who had recently moved from traditional private enclosed offices to a more open office. Once the office layout plans had been prepared, the new office space remained relatively static for several years.

3.8.3.   *Mixed Staff Reactions*

The variety of different workspaces available in agile designs can have both advantages and disadvantages. Similarly, communicating in agile workspaces can be viewed both positively and negatively.

3.8.3.1. Workspace Diversity

Diversity of available workspaces in activity-based work environments can be viewed both positively and negatively. On the positive side, employees in activity-based work environments appreciate the availability of seclusion or focus rooms that can be used to focus and concentrate (Appel-Meulenbroek, Kemperman, van Susante, & Hoendervanger, 2015; De Been, Beijer, & den Hollander, 2015; Keeling, Clements-Croome, & Roesch, 2015). However, although diversity of workspaces can be viewed positively, it is more frequently identified as a negative aspect of activity-based workspaces (De Been, Beijer, & den Hollander, 2015). In De Been, et al.'s study (2015), diversity of workspaces was identified as a negative factor in 45 of 57 interviews. Specifically, some spaces tend to be more popular than others and are therefore not always available. As a result, people who arrive late may not have the opportunity to select a suitable workspace. In addition, less popular spaces that are used infrequently represent a waste of valuable and limited office space.

Creating a space intended to enhance collaboration is no guarantee that employees will use it in that manner—most communication events in one activity-based workspace rarely occurred in the soft seating areas designed especially for that purpose (Boutellier, Ullman, Schrieber, & Naef, 2008). Instead, as in traditional private enclosed offices, most interactions occurred at employees' desks. Moreover, research shows that people dislike moving to different workspaces and rarely switch throughout the day (De Been, Beijer, & den Hollander, 2015; Hoendervanger, le Noble, Mobach, & Van Yperen, 2015). In the majority of cases, switching to a different type of activity does not coincide with switching to a different type of workspace (Hoendervanger, le Noble, Mobach, & Van Yperen, 2015). Employees also find it time consuming and burdensome to move personal items and files during the day if they need to switch workspaces (De Been, Beijer, & den Hollander, 2015). Additional research suggests that lack of easy access to resource materials, archives of past projects, and current work is not only frustrating but can also degrade decision making (Elsbach & Bechky, 2007). When professional workers do not have easy access to resources, decision making can become more intuitive and based less on a careful process of data collection, analysis, and reflection.

In addition, some employees may even find it stressful to move around from workspace to workspace throughout the day (Oommen, Knowles, & Zhao, 2008). When advertising firm Chiat/Day redesigned its workspaces to support activity-based working, observations indicated that employees did not want to relocate as much as the organization would have liked (Brager, Heerwagen, Buaman, Huizenga, Powell, Ruland, & Ring, 2000). The company had to resort to "peer policing" to keep employees from using the same workspace every day.

3.8.3.2. Communications

As with diversity of available workspaces, communications in agile workspaces are seen as both positive (possibilities for knowledge sharing and more chance encounters with coworkers) and negative (difficulties discussing private issues in open space) (De Been, Beijer, & den Hollander, 2015). As demonstrated in De Been, et al.'s (2015) study, people tend to experience more communication and knowledge sharing because they encounter more employees and more people from different departments in the largely open work environment. It is easy to see who is around and to meet new employees. However, as described earlier in this report, while the frequency of interactions is nearly three times higher in open and agile workspaces, such meetings tend to be shorter and more superficial, with fewer participants than comparable meetings in private enclosed

workspaces. In fact, the duration of communications in agile workspaces is about three times shorter, with a net effect of less time communicating in activity-based workspaces (Boutellier, Ullman, Schrieber, & Naef, 2008) (Table 3-13). As a result, the time spent *without* communications ends up being approximately six times higher in agile workspaces, even though such spaces are expected to increase collaboration and interactions (Boutellier, Ullman, Schrieber, & Naef, 2008).

Table 3-13. Interactions in Private Enclosed Offices and Agile Workspaces

Metric	Means by Office Type	
	Private Enclosed Office	Agile Workspace
Frequency of interactions per person per hour	2.1	5.4
Duration of interactions (in minutes)	9	3
Average number of participants per interaction	2.4	2.1
Time without communication	5%	29%

Communications in private enclosed offices are compared to communications in one type of agile workspace explored in Boutellier, et al.'s (2008) study. Time without communication in a given area was calculated as a ratio of the total minutes when no communication was observed to the total minutes of observation time, expressed as a percentage.

3.9.   Workspace Costs

Research indicates that open-plan offices can provide some cost savings, particularly in terms of initial construction and energy expenditures. However, in the long term, open-plan offices may not be as cost effective as private enclosed offices due to future hidden costs resulting from degraded productivity, increased sickness absences, and higher attrition.

3.9.1.   *Cost Savings Comparisons*

When organizations seek to cut costs, the physical workplace tends to be viewed as the prime candidate (Davenport, 2005; DeMarco & Lister, 1987). As a result, many open-plan office designs are selected in order to realize the cost savings associated with constructing buildings that have fewer walls and doors and can simultaneously maximize occupant density within a minimal footprint. Open-plan offices do have tangible economic benefits such as increased net usable area, higher occupant density, and ease of reconfiguration (Kim & de Dear, 2013; Walker, 2016). Accordingly, it has been estimated that organizations can save up to 20% in development costs when creating an open-plan work environment as compared to traditional private enclosed offices due to reduced building costs and increased energy efficiency for heating and cooling during occupancy (Oommen, Knowles, & Zhao, 2008). Other estimates suggest that the relative advantages of open-plan offices over private enclosed offices with respect to lower rental costs due to reduced floor space range from 3:1 to as high as 5:1 (James, 2016). For example, a rented area that accommodates five employees in private enclosed offices could hold 15 to 25 employees in open-plan offices, reducing the cost per person.

As one example of initial cost savings, real estate firm JLL completed cost benchmarking for three types of office spaces in the U.S. and Canada, using data from more than 2800 of its projects across 17 industries (JLL, 2018). The three types of office spaces varied in terms of the amount of private enclosed space provided. Calculated costs reflect costs required to design, construct, and furnish the physical workplace in an existing building. Total costs included construction and installation

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of walls, floors, and lighting (hard costs); design and fees for architecture, engineering, project management, and consulting (soft costs); furniture, fixtures, and equipment; and tenant factors such as audio/video installation, security costs, technology costs, and moving fees. Table 3-14 compares the average cost per square foot for the three types of office spaces. The cost per square foot increased as the number of enclosed offices increased. As JLL (2018) points out, compared to progressive spaces, hard costs are higher for traditional spaces due to the increased use of materials for dividing walls and private enclosed offices. In addition, costs for furnishings tend to be higher in traditional spaces due to "costly private office furniture and large high-walled workstations" (JLL, 2018, p. 16).

Table 3-14. Relative Costs of Three Types of Office Spaces

Type of Office Space	Description	Average Cost Per Square Foot
Progressive	• Open floor plan, 100% bench style space • Conference and collaboration space • No enclosed offices	$152
Moderate	• Agile plan with mostly open workspaces • Conference space and two to four collaboration spaces • 10% enclosed offices	$158
Traditional	• Large, open floor plan workspaces • Several conference rooms and one collaboration space • 40% enclosed office space	$177

From JLL (2018). Estimates are averaged across three levels of space quality (base, medium, and high).

Although cost per square foot is still a primary driver for workspace and office design, there are several subtleties to understanding the costs per square foot for open-plan office spaces that may go unrecognized. First, while the square footage allocated to individual workspaces has been decreasing over time (Soules, 2014), the space that once would have been given to individual workers has been re-allocated to common areas such as brainstorming spaces, breakout rooms, quiet rooms, huddle rooms, and coffee bars (Friedman Real Estate, 2014). The end result is that while individual spaces for workers have been decreasing significantly, the overall space for the entire office has remained the same. Thus, the overall square footage for a given office building has not actually decreased in many cases. As a result, any cost savings due to reduced square footage are not realized. Moreover, common areas can actually be 10% to 15% more expensive to build than individual workspaces due to higher-end finishes (e.g., coffee bars and noise dampening for quiet rooms) (Friedman Real Estate, 2014).

Second, as described in the introduction of this report, many non-government corporations are driven to open-plan office designs in order to realize the tax advantages that emerged in the 1960s (ALUR, 2018; Price, 2012; Schlosser, 2006). With the changes in the tax code, corporations had a substantial cost-savings incentive to prioritize open-plan office designs over traditional private enclosed offices. As a result, even if some components of open-plan office designs are relatively more expensive than comparable components for private enclosed offices, the expenses can be depreciated over a much shorter time period—which saves money in the long term.

3.9.2.   *Cost Effectiveness Comparisons*

While costs for initial construction and ongoing maintenance and repair can be lower for open-plan offices, such costs can be completely offset by future hidden costs that stem from the comparatively high costs for employee salaries and benefits. Research consistently demonstrates that the costs for employee salaries and benefits by far constitute the largest proportion of the total costs of performing work for a given organization (Andrew, Chang, & Nicholson, 2008; Earle, 2003; Olson, 2001). Estimates for employee costs range from 78% to 82% of the total costs. Such costs are 10 to 16 times higher than the cost of the physical workplace itself (5% to 8% of total costs) (Earle, 2003; Olson, 2001). Employee costs are 10 times the costs of the physical workplace *and* ongoing operations combined (Olson, 2001). Compared to employee costs, the workplace represents a relatively minor expense. Consequently, as Earle (2003) points out, attempting to enhance the value of the investment in employees is far more cost effective than trying to reduce the already low costs for real estate and facilities.

Future hidden costs may be incurred by degradations in employee productivity, health impacts, and attrition as well as any post-construction modifications that may be necessary to resolve emerging workspace design issues. Several researchers have attempted to estimate the costs associated with losses in employee productivity, health effects, and attrition.

3.9.2.1.   **Productivity Costs**

One estimate that has been provided of the direct annual cost of poor workspace design on lost productivity in the U.S., excluding illness, places the total amount between $20B and $160B annually (Fisk, 2000). Fisk (2000) derived these estimates after extensive review and analysis of the existing research at that time that explored the relationships between work environments and human performance. Human performance indicators were derived from measures of real-world performance on the job, results from experimental investigations of specific skills such as proofreading accuracy, and subjective self-reports of performance impacts. The resulting cost estimates were confined solely to productivity degradations unrelated to health effects.

James (2016) refers to the cost associated with reduced productivity from working in open-plan offices as a *productivity tax*. It represents a hidden cost that must also be considered when calculating the cost savings associated with open-plan offices. As described in Section 3.1 of the current report, productivity losses can range from 4% to 45%, (Andrew, Chang, & Nicholson, 2008; Haapakangas, Kankkunen, Hongisto, Virjonen, Loiva, & Keskinen, 2011; Roelofsen, 2008). Using a conservative estimate of 15% for the productivity tax, James (2016) performed basic calculations to demonstrate the cost impacts of open-plan offices. If office space costs $60 per square foot per year, then the cost of private offices for 100 employees would equal $216k per year, while the cost of open-plan office space would equal $43,200 per year (assuming the higher 5:1 savings described earlier). Thus, the use of an open-plan office space would immediately save $172,800 per year. If the 100 employees are each paid $50k per year, total expenses for salaries would equal $5M per year. However, with a 15% productivity tax, the reduction in work from employees translates into a $750k loss for the company. When the cost savings due to space are offset by the loss in productivity, the net loss is approximately $578k—much greater than the initial cost savings and a sufficient amount to hire 11 more employees in this notional example.

3.9.2.2. Health Costs

In addition to his estimates of the costs of lost productivity, Fisk (2000) also directly examined the costs for health effects. He estimated that annual U.S. costs of poor workspace design on employee health, specifically respiratory illnesses, range from $6B to $14B. These estimates include the combined costs from three different sources: (1) health care to treat the illness, (2) sickness absences, and (3) reduced performance during periods of illness. This analysis focused on the costs associated with only one form of health impairment—communicable respiratory illnesses such as the common cold, influenza, pneumonia, and bronchitis. With respect to performance decrements during illnesses, research has demonstrated that degradations can begin before symptoms are apparent and persist after symptoms have cleared (Fisk, 2000). Therefore, to derive the costs for reduced performance, Fisk (2000) estimated performance decrements as 100% during sickness absences and 25% during restricted-activity days when employees continue to work before and after the full-blown illness. As identified in the paper, some of the workspace factors associated with increased risks for respiratory illnesses include shared office spaces and increased occupant density.

3.9.2.3. Attrition Costs

As O'Neill (2013) points out, open-plan offices can reduce employee engagement, which has a potentially significant long-term cost in terms of organizational attrition (O'Neill, 2013). In general, the costs of losing a trained employee are typically equivalent to 1.5 to 3 times that individual's salary as a result of the need to screen and interview job candidates and hire and train replacement employees (Earle, 2003). According to some estimates, it may take five months or more for a new employee to achieve full working capacity and much longer to function at the same level as a very knowledgeable and highly skilled former employee (Walker, 2016).

3.9.2.4. Cost Effectiveness Implications

According to Fisk (2000), businesses should be motivated to invest in changes to building designs or building operations "if these changes improve worker performance by even a significant fraction of a percent or reduce absence from work by a day or more per year" (p. 558). The potential health savings and productivity gains from improved workspace designs are larger than the total estimated costs of energy used in commercial buildings (Fisk, 2000). According to a 1995 DOE report, commercial building owners in the U.S. paid about $70B for electricity, natural gas, fuel oil, and heat at that time; most of the expenditures were allocated to electricity (Energy Information Administration, 1998). By comparison, Fisk (2000) estimated that the combined costs of respiratory illnesses and reduced performance due to poor workspace design ranged from $26B to $174B.

3.10. Workspace Design Approaches

According to Davenport (2005), "fad, fashion, and faith drive most decisions about new work environments for knowledge workers. The other powerful 'f-factor' is finances, which are always given paramount consideration in the form of cost savings" (p. 172). Following fad and fashion is an inherently flawed approach because effective workspaces cannot be created by simply "copying and pasting" the surface level features of popular examples such as the agile workspaces at Google and Facebook (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016, p. 3). A narrow focus on reducing occupancy-related costs such as cost per square foot or following the

latest trend in office design is ultimately detrimental to the design process and may create greater problems in the future. Many potentially innovative design features end up never being considered at all or are easily dismissed, which results in suboptimal workspace designs for organizational and employee needs (Chan, Beckman, & Lawrence, 2007).

Alternative approaches to workspace and office design are embodied in the building delivery process and lifecycle, which begins with strategic planning and needs analysis and concludes with facilities management review and adaptive reuse (Preiser & Vischer, 2005) (Table 3-15). Some of the best practices that have been identified in the research literature throughout the building delivery process are described in this section.

Table 3-15. Six Phases of the Building Delivery Process and Lifecycle

Phase	Description
1. Strategic Planning/Needs Analysis	Medium- and long-term organizational and employee needs that impact building design are established
2. Program Review	Needs, goals, resources, and context for the building project are documented
3. Design Review	Schematic design, design development, and construction documentation are produced
4. Construction and Post-Construction Evaluation Review	Building construction occurs in accordance with national and local standards and codes; inspections and evaluations occur afterwards
5. Occupancy and Post-Occupancy Evaluation	Occupants move in and may remain in the building for 50 years or more; occupant feedback and evaluations are used to improve the quality of decisions made in earlier phases
6. Facilities Management Review/Adaptive Reuse	Potential recycling of a building for different uses near the end of its useful life

From Preiser and Vischer (2005).

3.10.1. Multidisciplinary Design Team

One of the most difficult aspects of workspace design involves understanding who exactly constitutes the "workplace designer" (Launis, Vuori, & Lehtelä, 1996). Historically, facilities management has typically been regarded as the workplace designer. However, it is now more commonly recognized that many different people are part of the workplace design process and must be involved.

> Workplace design today cannot be just the purview of the facilities management organization, but must involve organizational designers as well as information technology designers and must be cognizant of the overarching objectives of the organization…Facilities management must shake off its notoriety as stodgy cost-cutters and embrace the strategic ambiguities associated with designing and maintaining an environment supportive of various organizational goals" (Chan, Beckman, & Lawrence, 2007, pp. 16-17).

Accordingly, a multidisciplinary approach is highly recommended when designing workspaces (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016; Oommen, Knowles, & Zhao, 2008). The team should include building designers, architects, employees (intended occupants), managers, organizational behavioral researchers, construction workers, and other professionals. All of these entities represent stakeholders in the building design in one form or another.

With respect to the employees who will occupy the finished building, participation in the process is critical, regardless of whether it ultimately results in change (Oommen, Knowles, & Zhao, 2008). First, employees are the ones who will have to learn how to work in the types of environments that are created. Second, research has shown that employee involvement in workspace and office design is directly related to job satisfaction (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016; Haley, 2004; Oommen, Knowles, & Zhao, 2008; Stringer & Ostafi, 2013). Employees need to be consulted before design begins, and throughout the entire process, in order to identify the issues they envision with various office types and to assist in proactive planning and evaluation of appropriate mitigation strategies (Oommen, Knowles, & Zhao, 2008).

With respect to managers, Oommen, Knowles, and Zhao (2008) point out that managers need to be involved in order to achieve a thorough understanding of the intended work environment before they approve the design. Namely, managers need to consider the implications of the physical environment on worker wellbeing in the design and redesign of offices (Klitzman & Stellman, 1989). Elsbach and Pratt's (2007) review of the literature on physical environments in professional work settings suggests that "choosing objects and their arrangements in professional, organizational work settings is one of the most difficult tasks a manager faces" (p. 182). Difficulties for managers arise from balancing the costs and benefits among the vast number of office design options from which to choose. Weighing advantages and disadvantages of various options in terms of employee needs and preferences is no small task for managers.

Given the many different types of entities that can and should be involved in the workspace design process, conflicts and disagreements are inevitable. Each different group has its own point of view, goals, and expected outcomes, which can lead to four "tensions" that must be managed throughout the process (Chan, Beckman, & Lawrence, 2007) (Figure 3-8).

The tensions that can occur are represented by four axes or interdependent pathways comprising the overall workplace design effort:

- *Social-Physical Axis:* represents the tension between the "hardware" thinking of facilities managers (e.g., open-plan versus enclosed offices) and the "software" view of organizational design and human resources (e.g., employee needs for personal space). The hardware approach tends to be driven by costs, which can limit the ability to view the workplace as a strategic asset or a mechanism to promote employee satisfaction and retention. The hardware approach has also been a key driver prompting many organizations to follow the current fad and fashion in workspace and office design.

- *Spatial-Network Axis:* reflects the tension between the concrete and local nature of physical facilities and possibilities for virtual or remote activities (i.e., all alternative workplace strategies ranging from telecommuting to virtual collaboration that are not confined to any particular physical facility).

- *Knowledge-Communication Axis:* emphasizes the tension between knowledge management (effectiveness) and information management (efficiency). Organizational effectiveness is

achieved through the tacit and explicit knowledge of individual employees, whereas efficiency is driven by the use of information technologies to facilitate information access and transfer. Most organizations tend to fall into one of two camps: (1) highly effective, but not efficient or (2) not effective, but highly efficient. Appropriate workplace design provides an opportunity to achieve both efficiency and effectiveness.

- *Cost-Strategy Axes:* link the financial management dimension to each of the other three dimensions and highlight the tension between the cost-focused financial community and the achievement of other less measurable strategic objectives. Financial considerations are critical, but must be appropriately balanced against other measures of organizational performance such as quality, speed, innovation, and creativity.
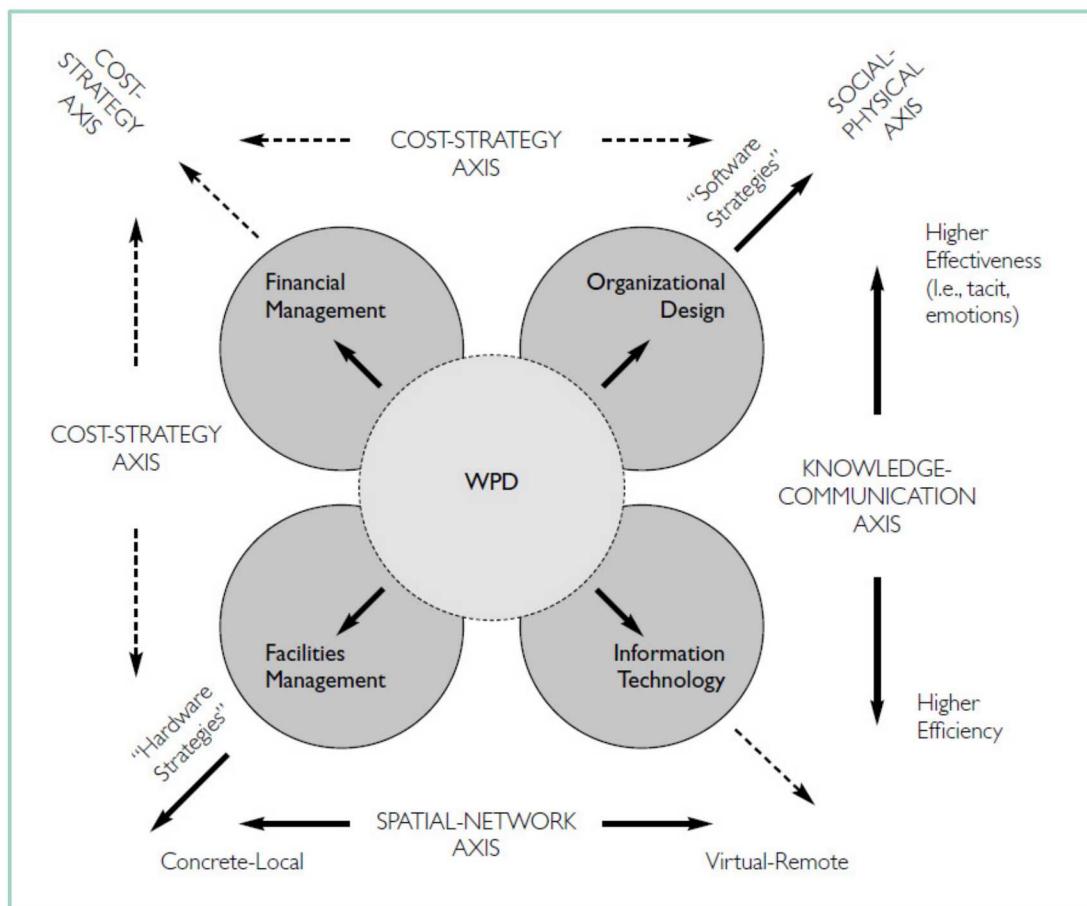
Figure 3-8. Four Dimensions of Workplace Design: Workplace design must integrate the goals, objectives, and considerations of four dimensions and manage the tensions created by four axes (Chan, Beckman, & Lawrence, 2007).

The recent experiences at a Fortune 500 manufacturing company during creation of a work environment that would best support agile software development highlight the tensions that can occur with facilities management (Moore, Reff, Graham, & Hackerson, 2007). Even something as simple as selecting the color of paint for the walls required three weeks of negotiation between management and facilities. Management wanted to create an atmosphere of a new and different working environment by using different colors, but facilities had always painted all walls a generic

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beige color. Facilities was also not pleased with the agile workspace that was created, wherein a common open area for impromptu collaboration was surrounded by separate cubicles with lower-than-normal walls. Facilities viewed the open space in the middle as "wasted" space that could have accommodated up to six more cubicles (thereby maximizing occupant density). Facilities further disliked having to modify the standard cubicle walls for each office to create the more open feel.

3.10.2.   Observation and Analysis

Two key aspects of the planning phase of the building delivery process are observation and analysis. The intent is to plan a physical design that supports employee needs and required workspace functions. It is also important to clarify non-physical solutions that may support desired behaviors and ways of working just as well as physical solutions.

3.10.2.1. Employee Needs

Good office design begins with an analysis that identifies business objectives, success factors, employee behaviors needed to achieve success factors, and the workplace qualities needed to support those behaviors effectively and efficiently (Olson, 2001). Stringer and Ostafi (2013) advocate the importance of understanding the science of people—"how they work individually, how they interact, and how they react to the physical environment around them" (p. 41). They maintain that by understanding human nature, designers can more effectively create workspaces that minimize perceptions of crowding, control noise, and offer choices for employees.

Accordingly, multiple researchers have recommended an approach that begins with observing employee behaviors throughout the workweek and analyzing employee needs to perform their work effectively (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016; Olson, 2001). Knowing the users and recognizing the diversity of tasks they perform are both critical to workspace design. Workspaces are likely to be most effective when they are congruent with user needs based on job roles and the types of tasks that occur (Meerwarth, Trotter, & Briody, 2008). Examples of analyses that should be conducted include evaluating workflow processes, culture, and architecture (e.g., data to indicate where the most foot traffic occurs before construction begins) (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016). Lamb and Kwok (2016) suggest that observing the interactions between the current building environment and its occupants is necessary to fully comprehend how proposed changes in building design or in the indoor environmental quality will affect occupants and their behavior.

3.10.2.2. Workspace Functions

Elsbach and Bechky (2007) have identified three different functions that workspaces and offices must fulfill. Thus, observation and analysis must include evaluating design options in terms of their ability to fulfill these three functions. (1) *Instrumental functions* improve performance, productivity, efficiency, and satisfaction of knowledge workers and help them capture, organize, and exploit information. Examples include accessibility of resources and supplies, suitability of furnishings, and the quality of ambient lighting. (2) *Symbolic functions* are those aspects of office layout and décor that affect perceptions of workplace identity and culture in organizations. For example, layout and locations of executive and staff offices convey organizational culture and priorities. Likewise, the ability to personalize a workspace provides a means to signal identity in the workplace. (3) *Aesthetic functions* impact employee sensory experiences (both cognitive and

emotional) and ultimately their sense of belonging in the organization. For example, physical environments can be designed to promote feelings of excitement or calmness. During analysis of workspace functions, it is important to recognize that a particular design may effectively support one function but create problems for another (e.g., a particular option may work symbolically and aesthetically, but not instrumentally). Designers must carefully consider what tasks are to be performed in a given workspace and design it to flexibly accommodate those different tasks.

3.10.2.3. Non-Physical Solutions

Physical workspace is not the only means to shape employee behavior (e.g., to promote collaboration) (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016; Khanna & New, 2008). In fact, simply implementing new workspaces and work environments is not enough to achieve positive work outcomes because it might not change actual behavior (Appel-Meulenbroek, Kemperman, van Susante, & Hoendervanger, 2015). Company culture, policies, and practices can have a very powerful impact. For example, for an organization that wishes to encourage cross-functional communication, open-plan offices could be created in an attempt to provide a physical solution. On the other hand, non-physical solutions that would be easier and more cost effective to implement include creating Web sites, blogs, and electronic discussion boards for this purpose. Another alternative might include management authorization for all employees to devote specific amounts of paid time outside their departments to collaborate and interact with other employees they may not normally encounter.

As an example of considering both physical and non-physical solutions, Khanna and New (2008) described Capital One Financial Corporation's efforts to improve employee satisfaction and group performance while reducing costs. These goals were accomplished by combining the creation of new types of tailored workspaces (physical solutions) with new distributed work practices, change management, and education (non-physical solutions). As described earlier in this report, workspaces were tailored in terms of amount of space, furnishing, and technologies to accommodate employee work styles. One key for non-physical solutions was establishing policies and practices that would authorize employees to choose where and when to work, based on their needs. The effort also focused on providing the resources needed to support both effective onsite work and mobile work. The change did not start with thinking about buildings and furnishings. It began with thinking about how Capital One employees currently work best.

3.10.3. Facilitating the Transition

Change management is critical before, during, and after implementation of a new workspace design in order to facilitate employee transition (Andrew, Chang, & Nicholson, 2008; Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016; O'Neill, 2008). Change management is necessary to minimize disruptions and stress during the renovation and move to new facilities (Andrew, Chang, & Nicholson, 2008; O'Neill, 2008). Support from high-level stakeholders is critical to achieve any cultural changes that may be needed post-occupancy (e.g., permissions to hold discussions in break rooms) (Bates, Garcia-Gonzales, Mohyuddin, Neuenswander, & Rosa, 2016). O'Neill (2008) recommends using a workplace change communication program to discuss the business reasons for the change, understand employee perceptions and expectations, and mitigate any concerns.

In many cases, occupancy is viewed as the end of the building delivery process. On the contrary, post-construction evaluation after the transition is essential to understand whether the workspace

design meets user needs and identify what works and what does not work (Preiser & Vischer, 2005). Not all of the effects of changes in office design can be anticipated in advance (Elsbach & Bechky, 2007). Further, once workers move in, they often make their own adjustments to the workspace. Such adjustments can be useful to identify lessons learned for future redesigns. As Walker (2016) points out, there needs to be more attention to how to rigorously measure the impacts and outcomes of workspaces that are being designed. The consequences of the building design for work activities should be followed, employee feedback should be systematically collected, and the experiences should be documented for use in future projects (Launis, Vuori, & Lehtelä, 1996).

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4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

Research in the workspace and office design literature consistently highlights the relative deficiencies of open-plan office spaces compared to traditional private enclosed offices for knowledge workers. Open-plan offices are associated with lower levels of employee satisfaction due to reduced visual and auditory privacy, increased interruptions, distractions from the presence of irrelevant background speech, less physical space, and more ambient noise. The drawbacks reported in the literature tend to outweigh any benefits associated with potential facilitation of coworker interactions and collaboration in open-plan office spaces. The research provided in the literature can be used to answer the four Asset Management questions that prompted the study.

- ***What does research demonstrate about the costs associated with various types of office spaces?*** Research reveals that the primary drivers for open-plan offices involve cost savings due to tax benefits for cubicle walls/furnishings and reduced rental costs realized by minimizing floor space and increasing occupant density. However, such cost savings can be offset by future hidden costs incurred by degradations in employee productivity, increased attrition, and increased sickness absences as well as post-construction modifications to resolve emerging workspace issues. Further, costs for employee salaries and benefits are approximately 10 to 16 times higher than physical workplace costs, which makes investing in employees far more cost effective than reducing expenditures for real estate and facilities.

- ***Does the research literature provide sufficient detail to identify the most efficient work environments for specific types of workers or specific job functions?*** Very little research characterizes workspace requirements for specific knowledge worker roles and functions beyond the need for space with sufficient visual and auditory isolation to support focus and concentration. The most important workspace feature contributing to knowledge worker job satisfaction and both individual and team performance is the ability to perform distraction-free solo work. The only detailed recommendations regarding workspace needs indicate that software developers require at least 100 square feet of dedicated space and 30 square feet of work surface per person plus noise protection via enclosed offices or six-foot high partitions.

- ***What does research reveal regarding collaboration in open-plan office spaces?*** Opportunities for interactions may increase in open-plan offices, but such interactions tend to be shorter and more superficial due to limited visual and auditory privacy. Further, employee satisfaction with ease of interaction is no higher in open-plan offices compared to private enclosed offices since knowledge workers spend the majority of their time engaged in solitary work as opposed to interactive work. Moreover, employees tend to value privacy over coworker proximity for ease of collaboration. Research suggests that knowledge worker needs for both collaboration and privacy can best be met by balancing three important factors: (1) privacy for focused work, (2) proximity for interactions, and (3) organizational permissions regarding appropriate spaces for interaction.

- ***What does existing research indicate about the impacts of agile workspaces?*** Research shows that agile or activity-based workspaces function best for small teams working concurrently on the same project with common goals, deadlines, and needs. A chief advantage of agile workspaces is improved awareness of other colleagues, while significant detractors involve limited opportunities for privacy, concentration, and control over colleague interactions. While

employees in activity-based workspaces appreciate the inclusion of focus rooms for private work, desired workspaces may not always be available. Further, knowledge workers generally dislike moving to different workspaces and rarely switch locations, finding it time consuming to move personal items and files throughout the day. As one researcher cautions, it would be premature at this point to accept agile workspaces as better than open-plan offices, based on the research available to date.

4.2.   Recommendations

The results of this literature review have highlighted numerous suggestions that should be considered in order to optimize workspace and office design.

- Office space should be designed to balance employee needs for both privacy and collaboration. Workspaces should facilitate collaboration among employees, while also minimizing disruptions and distraction for people engaged in solitary work requiring focus and concentration. In other words, the workplace should provide a balance between collective spaces for social and interactive engagement to foster collaboration as well as individual spaces for focus work to support needs for privacy and for visual and auditory isolation. This process may involve deliberately balancing the three P's of privacy, proximity, and permissions.

- Given that many different entities are stakeholders in the final designed workspace, a multidisciplinary approach throughout the design process is highly recommended. The team should include building designers, architects, employees (intended occupants), managers, organizational behavioral researchers, construction workers, and other professionals. Employees are especially critical because they are the ones who will occupy the workspace. Their involvement has been shown to be directly related to subsequent job satisfaction in the redesigned workspace.

- Along these lines, workspace design should begin with in-depth observation and analysis to understand employee needs and required workspace functions. Knowing the users and recognizing the diversity of tasks they perform are both critical to workspace design. Simply copying and pasting current fad and fashion is rarely an effective approach for workspace design.

- The design team should plan well in advance to facilitate the transition to the redesigned workspace and conduct post-occupancy evaluations. Employee feedback is essential to understand whether the workspace meets user needs and develop mitigations. Understanding employee reactions can also be useful to identify lessons learned for future redesigns.

- If open-plan offices or agile workspaces are being designed, then considerable attention should be devoted to mitigating the primary detractors of such workspaces—limited opportunities for privacy and concentration and reduced ability to control colleague interactions.

- Design teams should recognize that physical redesign may not necessarily be the answer to achieve identified objectives and shape employee behavior (e.g., increased collaboration). Non-physical solutions that address company culture, policies, and practices may be more successful and more cost effective.

- The impacts of factors such as cost, square footage, and overall footprint should be evaluated and weighed against other short-term and long-term factors that affect employee performance and satisfaction. Costs incurred by degradations in employee productivity, increased attrition, and sickness absences are far more substantial than the costs of the physical workplace itself.

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