WHITE PAPER

HOW FLOORING MATERIALS IMPACT NOISE

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Abstract

Of all the finishes in the built environment, flooring is the one that has the most significant impact on noise and occupant comfort. A recent study of the relationship between environmental stressors and their effect on occupant experience found that carpet tile was better at mitigating noise and discomfort when compared to terrazzo and rubber flooring [1]. Specifically, carpet tile decreased sound levels and improved occupant satisfaction with their environment, speech privacy and decreased distraction from noise. Additionally, employees indicated that carpet tile was more comfortable underfoot, reduced glare, improved air quality, and was more aesthetically appealing.

Increasing and maintaining building occupant satisfaction is tied to many factors related to the quality of the indoor space, including acoustics, aesthetics, privacy, cleanliness, and level of control over the interior environment [2]. In the workplace, building occupant satisfaction is important because it has been correlated with job performance [3], absenteeism, and potential to quit work [4]. Environmental stressors, such as noise, prolonged standing or walking, and heavy lifting can have a negative impact on both employees (fatigue, injury, and decreased efficiency and productivity) and on the organization (costs associated with absenteeism, retention, and recruitment).

Noise is the most frequent complaint of office workers. Open-office designs intended to increase teamwork, communication and productivity have been shown to increase the level of noise, adding difficulty to verbal communication and the completion of complex mental tasks [5]. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) recommends sound levels in workplace environments not to exceed 58 decibels, with office workers preferring sound levels between 48 and 52 decibels [6].

In education, noise may interfere with students' learning, behavior, and academic achievement. Adverse health effects on children linked to noise include noise induced hearing loss, impaired cognition, physiological and psychological effects [8]. Adverse health effects on teachers include noise induced hearing loss, strain on the vocal chords, stress and fatigue [8]. The findings of a study that evaluated the effect of school design on student outcomes showed that students in carpeted classrooms scored higher on standardized tests than students in rooms with smooth flooring. The overall noise levels were lower in the carpeted rooms [9].

Noise interferes with communication, causes distractions, affects occupants' cognitive performance and concentration, contributes to stress and fatigue, [10] and sleep deprivation [11]. Research has shown that decreasing noise levels has a noticeable effect on building occupants. In a study that compared a before scenario with poor acoustics to an after scenario with improved acoustics, workers reported decreased noise levels, better speech intelligibility; and feeling less pressured, more relaxed, and less irritable [12]. Addressing noise can also have a substantial impact on occupants' physical health by decreasing blood pressure, heart rate, and stress [10].

Flooring Research: The Sound and Comfort Study

In an independent study funded by Mohawk Group that took place in a hospital

unit corridor over a 42 week period, researchers compared three flooring types (terrazzo, rubber, and carpet tiles) for their effect on occupant experience, as it relates to their perceptions of sound and ergonomic factors [1]. Phase 1 assessed the existing terrazzo floor covering; phases 2 and 3 evaluated sheet rubber and carpet tile, respectively. Each flooring condition was studied over approximately 3-month intervals.

Surveys were used to evaluate healthcare workers' health and well-being (i.e., stress, fatigue, and pain) and their perception of the quality of the indoor environment (i.e., air quality, glare, comfort, aesthetics, noise, and flooring preference) at each phase of the study. Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) scores were used to determine how the three flooring conditions influenced patients' satisfaction levels, specifically as it related to noise levels. HCAHPS is a patient-satisfaction survey used to measure patient experience. Sound meters were installed in three locations on the unit to record noise levels in 60 second increments continuously through all three phases.

With the implementation of The Patient Protection and Affordable Care Act (ACA), hospital reimbursable rates are directly tied to patient satisfaction. Based in part on these scores, hospitals Medicare payments may change plus or minus 1.5% in fiscal year 2015 and up to 2% of reimbursement dollars by fiscal year 2017 [13]. Therefore, it is critical to a hospital's financial health to explore ways in which it can improve patient satisfaction and outcomes during their stay.

In general, noise levels fluctuate widely over time. Continuous sound levels can be described as the average of the high and low sounds during a specified period. Results from the sound meters indicated that there was a scientifically significant difference between the flooring types when it came to noise levels. When compared to terrazzo and rubber, carpet tile showed the lowest continuous noise levels, which was in line with its greater sound absorbing qualities. Moreover, employee perceptions mirrored the objective sound level data. Employees consistently perceived loudness as lowest with carpet tile. Workers also reported that with carpet tiles on the floor:

- the air seemed healthier;
- reflected glare was lower;
- there was enough speech privacy;
- the floor was more comfortable underfoot; and
- the floor was more aesthetically appealing.

Patient HCAHPS scores regarding noise were also consistent with the sound meter results and employees' perceptions about improved noise levels with carpet tiles. There was an increase in patients who agreed that the area around their room was always quiet when the sound levels were reduced. Table 1 shows comments made by participants after being exposed to each flooring type. Notice how perceptions around sound and comfort improved during the three phases.

Table 1: Participant Perceptions about Terrazzo, Rubber, and Carpet Tile Floors

	Phase 1	**Phase 2**	**Phase 3**
Category	Terrazzo	Rubber vs. Terrazzo	Carpet Tiles vs. Rubber & Terrazzo
Sound	"noisy" "loud"	"less noise" "seems quiet"	"quiet" "quiet, soothing, calming, professional" "comfortable and quiet" "sound is decreased"

Comfort	"hard on my hips, feet and legs" "not comfortable to stand or walk on" "the surface is hard - it makes my feet, back and knees hurt"	"my legs and feet did not hurt as bad as on the old flooring" "….the sound and stress on my feet are decreased"	"…provides extra cushioning for employees who are standing or walking constantly" "feels nice to walk on all day"

Interestingly, when terrazzo was the floor covering, participants preferred rubber flooring. When rubber was the floor finish, participants preferred terrazzo. When carpet tile was on the floor, there was a sharp 26% increase in participant preference for carpet tile making it the overall preferred flooring material (Figure 1). Once exposed to working on carpet tiles, employees preferred it over terrazzo and rubber flooring. Carpet tiles are easy to maintain and, if a tile is soiled and cannot be cleaned on site, then it can be quickly removed and replaced with a new tile [14].

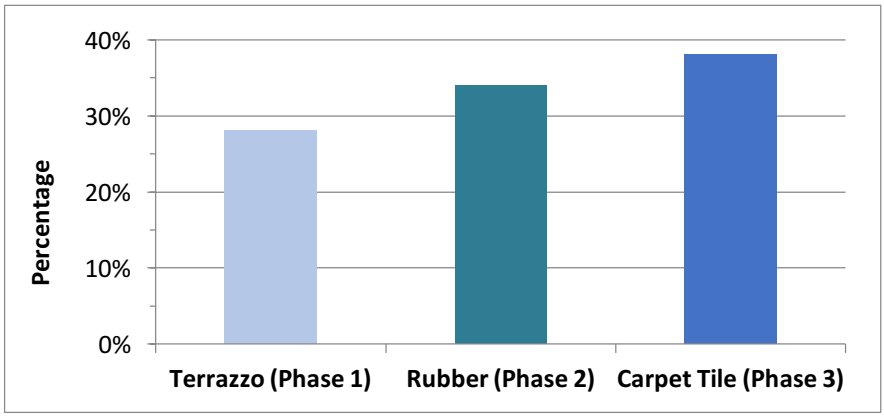

Figure 1. Overall preference, shown by percentages, for terrazzo, rubber, and carpet tile flooring.

Choosing Flooring

Choosing the right flooring for any given space requires attention to a number of factors including budget, foot traffic, care and maintenance requirements, as well as concern for the needs of employees, clients, patients, visitors, students, and teachers who occupy the space.

Hard surfaces made from natural or synthetic rigid materials, like terrazzo, stone, and ceramic tile, are durable and have a long service life and may be disinfected. However, hard surfaces are reflective and reverberates sound rather than absorbing it [15]. In addition, a hard surface floor may contribute to fatigue and joint pain for employees on their feet for a sustained amount of time [16].

Many hard surfaces require a sealant that may require it be stripped and reapplied over time, potentially increasing the long-term cost of ownership. The sealer contributes to reflectance levels making glare a potential detractor.

Resilient surface flooring such as rubber, luxury vinyl tile, and sheet vinyl, is named for its ability to recover from impact. Resilient floors provide some underfoot comfort compared to hard surface flooring and may reduce fatigue associated with standing long hours, for instance in surgery, the classroom, and other areas where employees may be on their feet for a sustained amount of time. Smooth resilient surfaces are excellent for roll-ability of equipment. Resilient surfaces are slip-resistant and provide striking sound-reducing properties. Resilient flooring has strong performance characteristics, including durability, underfoot comfort, and sound insulation. Additionally, some resilient products offer the low-maintenance option of a non-wax surface, reducing the maintenance requirements.

Carpet may be ideal for businesses and schools that need an increased level of acoustic

performance creating an improved environment for clear communication, less distraction, and the ability to remain focused on the task at hand. Carpet provides flexibility with style and pattern options conducive to branding and aesthetics, but also allows practicality with respect to maintenance. A benefit specific to carpet tile is the ability to remove and replace soiled tiles quickly and individually, causing little disruption. Facility managers may also benefit from carpet tiles' low overall costs compared to other flooring types. In a life-cycle cost analysis conducted to determine the long-term cost of flooring ownership including initial, maintenance, and replacement costs, soft flooring, which included carpet tiles, was shown to cost 50%-66% less to install and about six times less to maintain [17].

Hospital staff members initially felt resistant to using carpet tiles in a hospital setting due to preconceived ideas about its appropriateness. Some reported concerns are that carpet tiles are "unsanitary" and "able to harbor germs and infection" [1] as well as reduced rolling mobility. Though flooring may have infectious organisms on them, these surfaces are not primarily associated with the direct transmission of infection to patients and staff [14]. The primary culprit of hospital transmitted infections results from poor hand washing practices of healthcare staff [18]. In the hospital patient unit study, once hospital staff members were exposed to working on carpet tiles, their perceptions and preferences for this flooring option changed markedly [1]. Educating staff members about the appropriateness, cost effectiveness, along with noise and comfort benefits of carpet tiles on the hospital unit may be the key to overcoming concerns about this flooring choice.

Flooring selection is complex – often a range of flooring choices may seem to be equally appropriate for any given area. The key to selecting the best flooring for the application is understanding the client's requirements for the space, any concerns they may be working to overcome, or goals they wish to achieve, and then finding the proper flooring solution based on their needs. Products may be compared based on aesthetics, appropriateness to the space, cost effectiveness, and other attributes such as noise absorption and comfort.

The Cost of Noise

Elevated noise levels make environments not only uncomfortable for occupants, but also unsafe. Work exposure to high noise levels can lead to a host of health hazards including hearing loss, hearing impairment, and elevated blood pressure [19]. In the hospital setting it leads to unsatisfied patients. According to HCAHPS scores taken from across the U.S., 'quietness of the hospital environment' routinely receives one of the lowest scores [20]. Unsatisfied patients directly affect revenue for hospitals.

Occupant comfort is directly tied to the quality of the indoor environment which includes lighting, air quality, temperature control, and acoustics. In a survey of 33,285 occupants of 181 office buildings across the U.S., Canada, and Finland, of those who expressed dissatisfied with the acoustical environment [21], the top complaints were related to a lack of speech privacy and distractions from other people's conversations. Distractions cost money. In a survey of 1,000 high-level knowledge workers, interruptions accounted for over two hours of the work day costing employers and the U.S. economy an estimated $588 billion per year [22]. While it is unrealistic and even detrimental to collaborative efforts to provide every occupant with a private office, these results suggest that there is need for innovative strategies to provide quiet and privacy when required.

Specific building features related to occupant comfort such as climate control, indoor air quality, lighting, and acoustical control have been shown to negatively affect student achievement [23]. Chronic noise in the classroom is detrimental to both students and teachers. For teachers, it has been shown to

cause a host of negative outcomes including vocal cord strain, increased cognitive fatigue, low job satisfaction, lack of energy, interest in leaving the job [24], lack of motivation, and sleepiness [25]. School renovations are expensive, but strategic improvements and design features that address student and teacher comfort extend far beyond the academic walls and should not be underestimated. The cost of status quo education in the U.S. is remarkably high. For example, in 2008, it was estimated that if the educational gap between America's low- and high-performing states was narrowed, the gross domestic product (GDP) would have been $425 billion to $700 billion higher, or 3 to 5 percent of GDP [26].

Conclusion

Addressing noise and comfort in the built environment has far reaching implications. Environmental stressors may have an adverse impact on occupants' physical and mental well-being that can, in turn, negatively affect an organization's bottom line. Flooring choices may have a substantial impact on noise and comfort. Carpet tile has the potential to cost-effectively improve acoustical challenges, while simultaneously providing comfort.

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