



 THE CENTER FOR HEALTH DESIGN®

SUMMARY OF LITERATURE REVIEW
**RESIDENT SAFETY RISK
ASSESSMENT**

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By

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The Center for Health Design



The Center for Health Design (CHD) is a nonprofit organization that engages and supports professionals and organizations in the healthcare, construction, and design industry to improve the quality of healthcare facilities and create new environments for healthy aging. CHD's mission is to transform healthcare environments for a healthier, safer world through design research, education, and advocacy.



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I. SUMMARY OF LITERATURE REVIEW

Abstract

The purpose of the literature review was to create a framework for evaluating key environmental design features that impact resident safety in various residential care settings—skilled nursing facilities, assisted living, and memory-care facilities. The review focused on the existing empirical research studies about the relationships between environmental design and safety outcomes in residential care settings. After a process of searching, sorting, and screening over 100 publications, a total of 55 research articles were identified and classified into six major outcome categories. A framework was then created to present the environmental features impacting each outcome category, key research findings, strength of evidence, and the relevant reference information as well as evidence-based design recommendations.

The existing body of research evidence indicates that various environmental features significantly impact safety outcomes in six categories:

- Resident falls
- Resident elopement/unsafe exiting
- Sleep disorders
- Aggressions/disruptive behaviors
- Medical errors, and
- Healthcare-associated infections

Several environmental features are especially important because each of them influences multiple resident safety outcomes:

- Room occupancy (single-bed rooms)
- Lighting (high lighting level, sunlight)
- Outdoor nature/wander garden

- Acoustics (noise reduction, music, nature sounds)
- Ambience (soothing environment, positive distractions).

The literature review also identified several gaps in knowledge base that need more research. Rigorous research is needed to verify whether evidence from other similar healthcare settings including other residential care settings is also applicable in specific residential care settings and to address specific problems found in residential care.



II. PURPOSE

The purpose of the literature review was to create a framework/matrix that outlines the safety issues that should be considered in the design of various long-term care (LTC) settings (skilled nursing homes, assisted living, and dementia/Alzheimer's care facilities). This matrix will help to guide the development of the Resident Safety Risk Assessment (RSRA) to be submitted as a proposal for the *2014 Guidelines for Design and Construction of Health Care Facilities*.

The objective was that the RSRA matrix would serve as a broad evaluation framework for the key design areas (e.g., noise, light levels, design of outdoor spaces) that impact resident safety in various residential care settings—skilled nursing facilities, assisted living, and memory-care facilities. Serving as the basis for the RSRA, the literature review was conducted to identify existing research studies that empirically examined the relationship between design and safety outcomes in LTC settings. In addition, the literature review was to identify areas in the RSRA where additional research may be needed to strengthen guidelines language for future revision cycles.



III. METHODOLOGY

A literature search was conducted on The Center for Health Design (CHD) database of evidence based design literature, PubMed, EBSCO, and other databases such as Google Scholar. Additional literature was also obtained from several existing literature reviews on relevant topics (e.g., Chang et al., 2004; Day, Carreon, & Stump, 2000; Joseph, 2006) and the reference lists of the identified publications. In the second step, the more than 100 publications found in the first step were sorted, screened, and narrowed down to about 55 publications that empirically supported the connection between the physical environment and resident safety outcomes in LTC. The vast majority of the identified research was conducted in LTC settings. However, relevant research conducted in homes of seniors as well as other similar healthcare settings was also included for certain topics lacking empirical research in LTC settings.

In the third step, the identified literature was first sorted according to the outcome categories (e.g., resident falls). Then the environmental features (e.g., wander garden) impacting each safety outcome category were identified. Information regarding the relationships between safety outcomes and environmental factors was extracted from the literature. A RSRA matrix (see attached) was established based on the literature review. Each row of the matrix presents the relevant information, including research settings, key research findings, strength of evidence, and literature reference information, for the relationship between one outcome and one environmental feature (e.g., resident falls—wander garden).

Design recommendations based on the research evidence were also provided. The strength of evidence was rated as 1 or 2: 1 meaning that the relationship was supported by only one or two studies with a weak study design/measurement tool or only nonsignificant tendencies were found in the research; 2 meaning that the relationship was supported by multiple studies with a strong study design/measurement tool and significant results from statistical analyses.



IV. RESULTS

The review identified six categories of safety outcomes (i.e., resident falls, resident elopement/unsafe exiting, sleep disorders, aggressions/disruptive behaviors, medical errors, and healthcare-associated infections) that were impacted by various environmental features. This section summarizes key findings in these six outcome categories. (See the RSRA matrix on page 7 for details.)

Resident Falls

Environmental design can effectively reduce resident fall risk by increasing ambient lighting levels (Creditor, 1993; McMurdo, Millar, & Daly, 2000; Vu, Weintraub, & Rubenstein, 2004), reducing light glare (Bicket et al., 2010), reducing the use of physical restraints including bedrails (Capezuti, Strumpf, Evans, Grisso, & Maislin, 1998; Hoffman, Powell-Cope, MacClellan, & Bero, 2003; Si, Neufeld, & Dunbar, 1999), positioning beds to prevent resident falling from bed (Hofmann, Bankes, Javed, & Selhat, 2003), selecting low-height beds or chairs (Scandura, 1995), and selecting soft (e.g., wooden) subfloor and flooring with small motifs and lowest contrast (Perritt, McCune, & McCune, 2005; Simpson, Lamb, Roberts, Gardner, & Evans, 2004). In addition, a wander garden may reduce the frequency and severity of falls of demented residents (Detweiler, Murphy, Kim, Myers, & Ashai, 2009). Research conducted in homes of seniors suggests that optimizing configuration of grab bars near bath/toilet may reduce falls related to the use of bathtubs and toilets (Runyan et al., 2005; Sanford, Arch, & Megrew, 1995; Sveistrup, Lockett, Edwards, & Aminzadeh, 2006). More research is needed to examine the effects of bathroom locations and grab bars in LTC settings.

Resident Elopement/Unsafe Exiting

Unsafe exiting is a special problem in LTC, especially for residents with dementia. Research found that nursing home residents exhibited fewer unsafe exiting behaviors in an environment that is soothing and provides appropriate sensory stimulation such as nature scene artwork, plants, nature sounds, music, and aroma (Algase, Beattie, Antonakos, Beel-Bates, & Yao, 2010; Cohen-Mansfield & Werner, 1998a).

Another effective environmental measure in reducing unsafe exiting or exit-seeking behaviors is the use of visual barriers to reduce the visibility of exit doors and doorknobs. The visual barriers can be cloth panels covering doorknobs, window blinds blocking views of outside, wall mural painted over exit doors, and full-length mirrors in front of doors (Dickinson & McLain-Kark, 1996; Dickinson, McLain-Kark, & Marshall-Baker, 1995; Kincaid & Peacock, 2003; Mayer & Darby, 1991).

Research also shows that wander gardens help to reduce aggressive behavior among dementia residents (Detweiler, Murphy, Myers, & Kim, 2008). Providing safe exits and transitions from residential areas to wander gardens might help to reduce exit-seeking behavior or provide a safe outlet to do so.

Sleep Disorders

Sleep disorders are a frequently seen problem in LTC settings that may lead to falls, delirium, morbidity, and mortality. Higher lighting levels during daytime, bright light exposure, and sunlight exposure can significantly improve nighttime sleep (decreased awakenings) and reduce daytime sleep (Alessi et al., 2005; Fetveit & Bjorvatn, 2004; Satlin, Volicer, Ross, Herz, & Campbell, 1992; Shochat, Martin, Marler, & Ancoli-Israel, 2000; Sloane et al., 2005; Van Someren, Kessler, Mirmiran, & Swaab, 1997; Wallace-Guy et al., 2002).

Another effective measure is the reduction of environmental disturbances during nighttime such as noise and variation of lighting levels (Schnelle et al., 1998; Schnelle, Alessi, al-Samarrai, Fricker, & Ouslander, 1999; Webber, Martin, Alessi, Josephson, & Harker, 2004). Disruption from roommates is a significant source of sleep disturbance. Single-bed rooms may lead to better sleep and less need for sleep medications (Koch, Haesler, Tiziani, & Wilson, 2006; Morgan & Stewart, 1998a). Access to outdoors may increase the exposure to bright light and natural elements, therefore, can improve sleep of nursing home residents with dementia (Calkins, Szmerekovsky, & Biddle, 2007).

Aggressive/Disruptive Behaviors

Resident agitation and aggressive behaviors may result in harm to residents themselves, other residents, and staff members. Bright light exposure, increased environmental lighting, and heightened color contrast have been found to reduce

level of agitation and aggression (Koss & Gilmore, 1998; Lovell, Ancoli-Israel, & Gevirtz, 1995; Sloane et al., 1998). Blocking afternoon sunlight together with maintaining constant lighting levels may help reduce disruptive behaviors in individuals with Alzheimer's disease at senior adult day-care centers (La Garce, 2002; La Garce, 2004).

Agitation and aggression can also be reduced by decreasing spatial and social density (fewer residents per unit, larger space per resident) and separating residents by single rooms (Morgan & Stewart, 1998b; Low, Draper, & Brodaty, 2004; Pekkarinen, Sinervo, Perala, & Elovainio, 2004). Positive distractions (e.g., visual, audio, and olfactory stimuli of nature or home/people contents, small-scale homelike environment with features such as residential kitchen and wander gardens) may help soothe residents, thus reduce psychiatric difficulties and disruptive behaviors (Burgio, Scilley, Hardin, Hsu, & Yancey, 1996; Cohen-Mansfield & Werner, 1998a; Cohen-Mansfield & Werner, 1998b; Detweiler et al., 2008; Kane, Lum, Cutler, Degenholtz, & Yu, 2007; McGonagle & Allan, 2002; McMinn & Hinton, 2000; Mooney & Nicell, 1992; Murphy, Miyazaki, Detweiler, & Kim, 2010; Namazi & Johnson, 1992; Nelson, 1995; Whall et al., 1997).

Medical Errors

The literature search did not find environmental research on medical errors that was conducted in LTC settings. However, research evidence from acute care settings may shed some light on how environmental design may impact medical errors in LTC. Especially relevant environmental measures include the increase of lighting levels and the reduction of environmental distractions and interruptions (unexpected sounds, unrelated traffic).

These two measures have been found to significantly reduce medication-dispensing errors (Buchanan, Barker, Gibson, Jiang, & Pearson, 1991; Flynn, Barker, Gibson, Pearson, Berger, & Smith, 1999; Westbrook et al., 2010). Rigorous research is needed to verify whether knowledge from other healthcare settings is also applicable in LTC and address the specific problems in LTC.

Healthcare-Associated Infections

Research conducted in nursing homes indicated that residents in single-bed rooms were less likely to contract infections with urinary bacteria (Fryklund, Haeggman, & Burman, 1997), influenza A (Drinka, Krause, Nest, Goodman, & Gravenstein, 2003), and nonbacterial gastroenteritis (Pegues & Woernle, 1993). In one study, ratings of the quality of ambient environment (e.g., cleanliness, homelikeness, odors, and noise) in nursing homes were related to lower risk of hospitalization for infection (Zimmerman, Gruber-Baldini, Hebel, Sloane, & Magaziner, 2002). Research is needed to examine the effects of other design strategies (e.g., air filtration, easy-to-clean materials) on infection control in LTC settings.

One finding of the literature review was that most published environmental research on resident safety in LTC was conducted in nursing homes or on demented residents; research on relatively healthier residents in assisted living environments was very limited. This is consistent with the observation of other researchers (Bicket et al., 2010). Although it is reasonable to assume that most findings from research in other LTC settings could be similarly applied to assisted living facilities, research evidence is needed to directly address special safety issues in assisted living settings.

RESIDENT SAFETY RISK ASSESSMENT MATRIX

Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
Resident Safety Outcomes	Visual environment (lighting levels, contrast sensitivity)	x	x	x	<ul style="list-style-type: none"> - Ambient lighting level. A falls risk factor assessment/modification program including the improvement of ambient lighting level led to an decrease in fall risk (nonsignificant) (McMurdo et al., 2000). Higher lighting level was related to lower fall risk (Vu et al., 2004). Light glare was related to higher risk of fall (Bicket et al., 2010). 	<ul style="list-style-type: none"> - Bicket, M. C., Samus, Q. M., McNabney, M., Onyike, C. U., Mayer, L.S., Brandt, J., et al. (2010). The physical environment influences neuropsychiatric symptoms and other outcomes in assisted living residents. <i>International Journal of Geriatric Psychiatry</i>, 25(10), 1044–1054. - McMurdo, M. E., Millar, A. M., & Daly, F. (2000). A randomized controlled trial of fall prevention strategies in old peoples' homes. <i>Gerontology</i>, 46(2), 83–87. - Vu, M. Q., Weintraub, N., & Rubenstein, L. Z. (2004). Falls in the nursing home: Are they preventable? <i>Journal of the American Medical Directors Association</i>, 5(6), 401–406. 	1	Light glare should be avoided. Ambient lighting level should be above the recommended values for residential buildings.
	Bed rails/physical restraints	x		x	<ul style="list-style-type: none"> - Physical restraints. Physical restraints were associated with higher fall rates and injury rates (Capezuti et al., 1998). - Bedrails. After a bedrail-use reduction program, including alternatives to bedrail, such as floor mat next to bed and full-length body pillow, bedrail use decreased as well as the frequencies of falls and fall-related injuries (nonsignificant) (Hoffman et al., 2003). Bedrails can be safely removed from most short-stay nursing home rehabilitation residents (Si et al., 1999). 	<ul style="list-style-type: none"> - Capezuti, E., Strumpf, N. E., Evans, L. K., Grisso, J. A., & Maislin, G. (1998). The relationship between physical restraint removal and falls and injuries among nursing home residents. <i>Journals of Gerontology Series A: Biological Sciences and Medical Sciences</i>, 53(1), M47–52. - Chang, J. T., Morton, S. C., Rubenstein, L. Z., Mojica, W. A., Maglione, M., Suttrop, M. J., et al. (2004). Interventions for the prevention of falls in older adults: Systematic review and meta-analysis of randomized clinical trials. <i>British Medical Journal</i>, 328(7441), 680–687. - Hoffman, S., Powell-Cope, G., MacClellan, L., & Bero, K. (2003). BedSAFE: A bed safety project for frail older adults. <i>Journal of Gerontological Nursing</i>, 29(11), 34–42. - Si, M., Neufeld, R. R., & Dunbar, J. (1999). Removal of bedrails on a short-term nursing home rehabilitation unit. <i>The Gerontologist</i>, 39(5), 611–614. 	2	Remove bedrails from skilled nursing beds unless required.
Resident Falls	Location and design of furniture	x			<ul style="list-style-type: none"> - Furniture (e.g., bed) locations. Repositioning beds with one side to the wall and repositioning furniture to allow more room for maneuvering, together with staffing changes and restorative recreational programs, significantly reduced resident falls and fractures related to falls (Hofmann et al., 2003). - Furniture selection. Furniture that put residents closer to the ground (i.e., futons, bean bag chairs, mattresses directly on floor) resulted in reduction of falls (Scandura, 1995). 	<ul style="list-style-type: none"> - Malone, E. B. & Dellinger, B. A. (2011). <i>Furniture design features and healthcare outcomes</i>. Concord, CA: The Center for Health Design. - Gulwadi, G. B. & Calkins, M. P. (2008). <i>The impact of healthcare environmental design on patient falls</i>. Concord, CA: The Center for Health Design. - Hofmann, M. T., Bankes, P. F., Javed, A., & Selhat, M. (2003). Decreasing the incidence of falls in the nursing home in a cost-conscious environment: A pilot study. <i>Journal of American Medical Directors Association</i>, 4(2), 95–97. - Scandura, D. A. (1995). Freedom and safety. <i>A Colorado center cares for Alzheimer's patients</i>. <i>Health Progress</i>, 76(3), 44–46. 	1	The arrangement of furniture should allow more room for resident maneuvering and to prevent falls. The ergonomics of furniture (e.g., lower bed height) should help reduce the likelihood of fall and injury.

RESIDENT SAFETY RISK ASSESSMENT MATRIX

Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
Resident Safety Outcomes	Handrails and grab bars	x			<p>- Bath/toilet grab-bar configuration. One bar should be mounted on the head of faucet wall to assist entering/exiting bathtub; a vertical bar for entering/exiting; the second horizontal or angled bar to assist in sitting/standing from the bottom of the tub should be located on the back wall of the tub; nonslip surfaces on the back wall of the tub; nonslip back rims (Sveistrup et al., 2006). Some grab-bar configurations that were not code-compliant were preferred and were used more often (Sanford et al., 1995).</p>	<p>No empirical research in LTC. - Rulyan, C. W., Perkis, D., Marshall, S. W., Johnson, R. M., Coyne-Beasley, T., Waller, A. E., et al. (2005). Unintentional injuries in the home in the United States: Part II: Morbidity. <i>American Journal of Preventive Medicine</i>, 28(1), 80–87. - Sanford, J., Arch, M., & Megrew, M. (1995). An evaluation of grab bars to meet the needs of elderly people. <i>Assistive Technology</i>, 7(1), 36–47. - Sveistrup, H., Lockett, D., Edwards, N., & Aminzadeh, F. (2006). Evaluation of bath grab bar placement for older adults. <i>Technology & Disability</i>, 18(2), 45–55.</p>	2	<p>One bar should be mounted on the head of faucet wall of bathtub; a second horizontal or angled bar should be located on the back wall of the tub; nonslip surfaces should be on the bath front and back rims.</p>
	Resident Falls	Flooring/ flooring design Flooring thresholds	x	x		<p>- Carpet texture. Carpet pile texture was associated with slower walking time (Perritt et al., 2005). - Carpet pattern. Carpet patterns that had smallest motifs and lowest contrast were associated with shortest walking time and lowest number of incidents (Perritt et al., 2005). - Subfloor. Compared to wooden subfloor, concrete subfloor was related to a higher risk of hip fracture in a fall (Simpson et al., 2004).</p>	<p>- Perritt, M. R., McCune, E. D., & McCune, S. L. (2005). Research informs design: Empirical findings suggest recommendations for carpet pattern and texture. <i>Alzheimer's Care Today</i>, 6(4), 300–305. - Simpson, A. H., Lamb, S., Roberts, P. J., Gardner, T. N., & Evans, J. G.</p>	2
	Wander gardens			x	<p>- Wander garden. After the opening of a wander garden in a dementia unit, significant reduction was observed in resident fall frequency and fall severity scores (Detweiler et al., 2009).</p>	<p>- Detweiler, M. B., Murphy, P. F., Kim, K. Y., Myers, L., & Ashai, A. (2009). Scheduled medications and falls in dementia patients utilizing a wander garden. <i>American Journal of Alzheimer's Disease & Other Dementias</i>, 24(4), 322–332.</p>	2	<p>Provide wander garden for dementia patients.</p>

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Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
	Ambience	x		x	<p>- Positive distractions. Positive distractions in corridors included nature scene wall murals and posters of forests, valleys, and others; artificial plants and trees; nature sounds; smell of forests; home/people scene (b/w photos of family scenes); wall posters of familiar persons; music, citrus aroma; armchair, coffee table, and benches. Nursing home residents exhibited fewer exit-seeking and trespassing behaviors when positive distractions were added to the corridors (nonsignificant) (Cohen-Mansfield & Werner, 1998a).</p> <p>- Soothing environment. Higher ratings of soothing ambience was associated with lower level of wandering. Brighter lighting, greater variation in sound levels, proximity of others, and an engaging atmosphere were associated with higher level of wandering (Algase et al., 2010).</p>	<p>- Algase, D., Beattie, E., Antonakos, C., Beel-Bates, C., & Yao, L. (2010). Wandering and the physical environment. <i>American Journal of Alzheimer's Disease & Other Dementias</i>, 25(4), 340–346.</p> <p>- Cohen-Mansfield, J., & Werner, P. (1998a). The effects of an enhanced environment on nursing home residents who pace. <i>The Gerontologist</i>, 38(2), 199–208.</p>	1	Provide soothing, calming, positive distractions such as nature pictures, nature sounds, smells of forests, home scenes, and music inside the facility.
Resident Elopement/ Unsafe Exiting	Design of exit doors	x		x	<p>- Visual barriers. Camouflage of exit doors using masking tapes or cloth panels to conceal doorknobs might deter unsafe exiting of dementia wanderers (Dickinson & McLain-Kark, 1996). Both miniblinds on the exit door that blocked the view to outside and cloth panels that concealed doorknobs effectively reduced exiting due to wandering (Dickinson et al., 1995). A wall mural designed to fit into the existing colors and designs and painted over exit doors significantly reduced the door-testing behaviors of residents with dementia (Kincaid & Peacock, 2003). A full-length mirror placed in front of exit door significantly reduced residents' exiting attempts (Mayer & Darby, 1991).</p>	<p>- Dickinson, J. I., & McLain-Kark, J. (1996). Wandering behavior associated with Alzheimer's disease and related dementias: Implications for designers. <i>Journal of Interior Design</i>, 22(1), 32–38.</p> <p>- Dickinson, J. I., McLain-Kark, J., & Marshall-Baker, A. (1995). The effects of visual barriers on exiting behavior in a dementia care unit. <i>The Gerontologist</i>, 35(1), 127.</p> <p>- Kincaid, C., & Peacock, J. R. (2003). The effect of a wall mural on decreasing four types of door-testing behaviors. <i>Journal of Applied Gerontology</i>, 22(1), 76–88.</p> <p>- Mayer, R., & Darby, S. J. (1991). Does a mirror deter wandering in demented older people? <i>International Journal of Geriatric Psychiatry</i>, 6(8), 607–609.</p>	2	Use visual barriers such as masking tapes, cloth panels, and/or wall mural design to camouflage the exit doors and doorknobs. Block the views to outside around exit doors.
	Access to safe outdoor areas	x		x	<p>- Access to outdoors. The use of exterior environments reduced aggressive behaviors of demented residents (Mooney & Nicell, 1992). After opening a wander garden at a dementia facility, residents' agitation level (measured by a standard rating scale) and the use of as-needed medications decreased (Detweiler et al., 2008).</p>	<p>- Detweiler, M. B., Murphy, P. F., Myers, L., & Kim, K. Y. (2008). Does a wander garden influence inappropriate behaviors in dementia residents? <i>American Journal of Alzheimer's Disease & Other Dementias</i>, 23(1), 31–45.</p> <p>- Mooney, P., & Nicell, P. (1992). The importance of exterior environments for Alzheimer's residents: Effective care and risk management. <i>Healthcare Management Forum</i>, 5(2), 23–29.</p>	2	If possible, provide safe outdoor areas that can be accessed from exit doors. Provide safe transitions between indoor and outdoor areas.

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Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
	Sunlight exposure	x		x	<p>- Sunlight. Thirty minutes or more of daily sunlight exposure (together with other interventions, e.g., increased physical activity, efforts to decrease nighttime noise and lighting) resulted in decrease in the duration of nighttime awakenings and decrease in daytime sleep (Alessi et al., 2005).</p>	<p>- Alessi, C. A., Martin, J. L., Webber, A. P., Kim, E. C., Harker, J. O., & Josephson, K. R. (2005). Randomized, controlled trial of a nonpharmacological intervention to improve abnormal sleep/wake patterns in nursing home residents. <i>Journal of the American Geriatrics Society</i>, 53(5), 803–810.</p> <p>- Sloane, P. D., Noell-Waggoner, E., Hickman, S., Mitchell, C. M., Williams, C. S., Preisser, J. S., et al. (2005). Implementing a lighting intervention in public areas of long-term care facilities: Lessons learned. <i>Alzheimer's Care Quarterly</i>, 6(4), 280–293.</p>	1	Provide ample sunlight exposure in and around the building.
Sleep Disorders	Exposure to artificial bright light	x		x	<p>- Bright light. Two-hour exposure of 1,500–2,000 lux bright light between 7 and 9 p.m. decreased sleep-wakefulness of dementia patients as rated by staff (Satlin et al., 1992). Two-hour bright light (6,000–8,000 lux) between 8 and 11 a.m. led to improved sleep at night; sleep efficiency (% sleep of total bedtime) increased from 73% to 86%, and total nocturnal wake decreased by 2 hours as measured by Actiwatch worn on wrist (Fetveit & Bjorvatn, 2004).</p>	<p>- Fetveit, A., & Bjorvatn, B. (2004). The effects of bright-light therapy on actigraphical measured sleep last for several weeks post-treatment. A study in a nursing home population. <i>Journal of Sleep Research</i>, 13(2), 153–158.</p> <p>- Satlin, A., Volicer, L., Ross, V., Herz, L., & Campbell, S. (1992). Bright light treatment of behavioral and sleep disturbances. <i>The American Journal of Psychiatry</i>, 149(8), 1028.</p>	2	Provide artificial bright light exposure (>1,500 lux).
	Illumination level	x		x	<p>- Environmental lighting level. The increase of lighting levels (from average 436 lux to 1,136 lux) in patient living rooms resulted in more stable rest-activity rhythms among demented patients as measured by Actiwatch (Van Someren et al., 1997). Higher lighting levels during daytime (7 a.m. to 7 p.m.) was associated with fewer awakenings in nursing home residents at night (Shochat et al., 2000). Greater 24-hour illumination amount was associated with shorter sleep latencies (from lights out to the first sleep) and reduced wake within sleep (home residents, Wallace-Guy et al., 2002).</p>	<p>- Shochat, T., Martin, J., Marler, M., & Ancoli-Israel, S. (2000). Illumination levels in nursing home patients: Effects on sleep and activity rhythms. <i>Journal of Sleep Research</i>, 9(4), 373–379.</p> <p>- Van Someren, E. J. W., Kessler, A., Mirmiran, M., & Swaab, D. F. (1997). Indirect bright light improves circadian rest-activity rhythm disturbances in demented patients. <i>Biological Psychiatry</i>, 41(9), 955–963.</p> <p>- Wallace-Guy, G., Kripke, D., Jean-Louis, G., Langer, R., Elliott, J., & Tuunainen, A. (2002). Evening light exposure: Implications for sleep and depression. <i>Journal of the American Geriatrics Society</i>, 50(4), 738–739.</p>	2	Design the ambient lighting so that the illumination level is high.

RESIDENT SAFETY RISK ASSESSMENT MATRIX

Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
	Reduced nighttime noise and disturbance	x			<p>Light change. Reduction of peak noise level and light changes at nighttime was associated with reduced number of awakenings and improved sleep efficiency % of time spent in sleep) (Schnelle et al., 1999). Nighttime sleep of nursing home residents was adversely affected by noise and light (Schnelle et al., 1998). External factors causing sleep difficulties included noise, light, and disruption from roommates (Koch et al., 2006).</p> <p>Environmental noise. Environmental noise (e.g., phone ring) and staff-generated noise accounted for significant portion of nighttime noise; half of the noises were loud enough to disrupt sleep (Webber et al., 2004). Noise was the most common factor causing sleep disturbance as reported by nursing home residents and the elderly in rehabilitation ward (Ersser et al., 1999).</p>	<p>- Ersser, S., Wiles, A., Taylor, H., Wade, S., Wals, R., & Bentley, T. (1999). The sleep of older people in hospital and nursing homes. <i>Journal of Clinical Nursing</i>, 8(4), 360–368.</p> <p>- Koch, S., Haesler, E., Tiziani, A., & Wilson, J. (2006). Effectiveness of sleep management strategies for residents of aged care facilities: Findings of a systematic review. <i>Journal of Clinical Nursing</i>, 15(10), 1267–1275.</p> <p>- Ouslander, J. G., Connell, B. R., Bliwise, D. L., Endeshaw, Y., Griffiths, P., & Schnelle, J. F. (2006). A nonpharmacological intervention to improve sleep in nursing home patients: Results of a controlled clinical trial. <i>Journal of The American Geriatrics Society</i>, 54(1), 38–47.</p> <p>- Schnelle, J. F., Alessi, C. A., al-Samarrai, N. R., Fricker, R. D., Jr., & Ouslander, J. G. (1999). The nursing home at night: Effects of an intervention on noise, light, and sleep. <i>Journal of American Geriatrics Society</i>, 47(4), 430–438.</p> <p>- Schnelle, J. F., Cruise, P. A., Alessi, C. A., Ludlow, K., al-Samarrai, N. R., & Ouslander, J. G. (1998). Sleep hygiene in physically dependent nursing home residents: Behavioral and environmental intervention implications. <i>Sleep</i>, 21(5), 515–523.</p> <p>- Webber, A., Martin, J., Alessi, C., Josephson, K., & Harker, J. (2004). Nighttime noise in the post-acute rehabilitation nursing home setting. <i>The Gerontologist</i>, 44(1), 38.</p>	2	Reduce or eliminate environmental factors causing sleep disturbance such as noise, light changes, and disruption from roommates.
Sleep Disorders	Room occupancy			x	<p>Single room. Moving from multibed rooms to single rooms resulted in better sleep and fewer interventions (e.g., medications) to promote sleep at night in demented residents (Morgan & Stewart, 1998a). Disruption from roommates was one of the external factors causing sleep difficulties (Koch et al., 2006).</p>	<p>- Koch, S., Haesler, E., Tiziani, A., & Wilson, J. (2006). Effectiveness of sleep management strategies for residents of aged care facilities: Findings of a systematic review. <i>Journal of Clinical Nursing</i>, 15(10), 1267–1275.</p> <p>- Morgan, D. G., & Stewart, N. J. (1998a). Multiple occupancy versus private rooms on dementia care units. <i>Environment & Behavior</i>, 30(4), 487–503.</p>	1-2	Provide single rooms.
	Illumination level	x		x	<p>Access to outdoors. Access to outdoors provided exposure to bright light and natural elements and helped improve the sleep of nursing home residents with dementia (Calkins et al., 2007).</p>	<p>- Calkins, M., Szmerekovsky, J. G., & Biddle, S. (2007). Effect of increased time spent outdoors on individuals with dementia residing in nursing homes. <i>Journal of Housing for the Elderly</i>, 21(3/4), 211–228.</p>	1-2	Provide access to outdoors for nursing home residents with dementia.

RESIDENT SAFETY RISK ASSESSMENT MATRIX

Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Evidence Strength of	Design Recommendations
Aggression and Disruptive Behavior	Unit size	x		x	- Unit size. Large unit size was associated with higher level of agitation in demented residents (Sloane et al., 1998). Large unit size was correlated with high level of time pressure among staff and low levels of quality of life in residents at long-term care facilities (Pekkarinen et al., 2004). Demented residents had improvements in disruptive behaviors when they moved from a 69-bed unit to two 20-bed subunits with more space for each patient (38 vs. 17 m2/resident) (Morgan & Stewart, 1998b).	<ul style="list-style-type: none"> - Morgan, D.G., & Stewart, N. J. (1998b). High versus low density special care units: Impact on the behavior of elderly residents with dementia. <i>Canadian Journal on Aging</i>, 17(2), 143–165. - Pekkarinen, L., Sinvervo, T., Perala, M.-L., & Elovainio, M. (2004). Work stressors and the quality of life in long-term care units. <i>The Gerontologist</i>, 44(5), 633–643. - Sloane, P. D., Mitchell, C. M., Preisser, J., Phillips, C., Commander, C., & Burke, E. (1998). Environmental correlates of resident agitation in Alzheimer's disease special care units. <i>Journal of the American Geriatrics Society</i>, 46(7), 862–869. 	1-2	Reduce unit size (< 20 residents per unit).
	Ambiance	x	x	x	<ul style="list-style-type: none"> - Positive distractions in corridors (nature scene, home/people scene, including visual, audio, and olfactory stimuli). Nursing home residents exhibited fewer agitated and aggressive behaviors when positive distractions were added to the corridors (nonsignificant) (Cohen-Mansfield & Werner, 1998a). - Aesthetics and amenities. Homelike environment, cleanliness and maintenance of environment, nonglare and nonslip floors, public kitchen for activities were factors associated with lower levels of agitation in demented residents (Sloane et al., 1998). After the renovations of chronic mental units (e.g., lowered ceiling, shaded lights, light-colored tiles, vinyl walls with calm colors and sylvan designs in dayroom; furniture regrouped for different activities; full carpeting; noninstitutional clocks; ornamental ceramic tiles, full-length mirrors, vanity-style sinks, and wood-covered cabinets in bathrooms with private dressing rooms), patient violence significantly decreased (almost 50%), and patient satisfaction increased (Christenfeld, Wagner, Pastva, & Acrish, 1989). Facility maintenance, handrails, call buttons, room autonomy (independent control of heating, AC, and door), telephone, privacy (private patient room, toilet, bathroom) were environmental elements related to lower frequency/severity of neuropsychiatric symptoms (Bicket et al., 2010). - House-like small unit. Patients in purpose-built bungalows (each of which was occupied by four patients and designed to reflect a "house" [single bedroom, kitchen, lounge, garden]) experienced significantly lower levels of psychiatric difficulty than patients in traditional long-term psychiatric units (McGonagle & Allan, 2002). Green House (small scale, private rooms and bathrooms, residential kitchen, dining, and hearth; certified nursing assistants; visiting clinical support team) was associated with lower level of depression (Kane et al., 2007). 	<ul style="list-style-type: none"> - Bicket, M.C., Samus, Q.M., McNabney, M., Onyike, C.U., Mayer, L.S., Brandt, J., et al. (2010). The physical environment influences neuropsychiatric symptoms and other outcomes in assisted living residents. <i>International Journal of Geriatric Psychiatry</i>, 25(10), 1044–1054. - Christenfeld, R., Wagner, J., Pastva, G., & Acrish, W. P. (1989). How physical settings affect chronic mental patients. <i>Psychiatric Quarterly</i>, 60(3), 253–264. - Cohen-Mansfield, J., & Werner, P. (1998a). The effects of an enhanced environment on nursing home residents who pace. <i>The Gerontologist</i>, 38(2), 199–208. - Kane, R. A., Lum, T. Y., Cutler, L. J., Degenholtz, H. B., & Yu, T.-C. (2007). Resident outcomes in small-house nursing homes: A longitudinal evaluation of the initial Green House program. <i>Journal of American Geriatrics Society</i>, 55(6), 832–839. - McGonagle, I. M., & Allan, S. (2002). A comparison of behaviour in two differing psychiatric long-stay rehabilitation environments. <i>Journal of Psychiatric & Mental Health Nursing</i>, 9(4), 493–499. - Sloane, P. D., Mitchell, C. M., Preisser, J., Phillips, C., Commander, C., & Burke, E. (1998). Environmental correlates of resident agitation in Alzheimer's disease special care units. <i>Journal of the American Geriatrics Society</i>, 46(7), 862–869. 	2	Provide positive distractions such as nature scenes, sounds, and smells, home scenes, and music in the corridors. Integrate homelike elements in the environment design such as private rooms, private bathrooms, shaded lights, lowered ceiling, full carpet, and noninstitutional furniture.

RESIDENT SAFETY RISK ASSESSMENT MATRIX

Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
	Room occupancy	x		x	<p>- Single room. Moving from a unit with multibed rooms to another unit with all single rooms resulted in improvements in demented residents' behaviors (increased nondisruptive behavior and decreased disruptive behavior) (Morgan & Stewart, 1998b). Being in a shared room was a significant predictor of "uncooperativeness" of nursing home residents (e.g., refusing to follow staff request, verbal abuse) (Low et al., 2004).</p>	<p>- Low, L.-F., Draper, B., & Brodaty, H. (2004). The relationship between self-destructive behaviour and nursing home environment. <i>Aging & Mental Health</i>, 8(1), 29–33.</p> <p>- Morgan, D. G., & Stewart, N. J. (1998b). High versus low density special care units: Impact on the behaviour of elderly residents with dementia. <i>Canadian Journal on Aging</i>, 17(2), 143–165.</p>	1-2	Provide single rooms.
	Music/nature sounds/noise	x		x	<p>- Nature sounds. When the audiotapes of two types of nature sounds (mountain stream and gentle ocean) were played, nursing home residents exhibited lower level of verbal agitation than when the audiotapes were turned off (Burgio et al., 1996).</p> <p>- Noise. Loud noises (e.g., loud talking, singing, and clapping) were related to agitation and disruptive behaviors (Nelson, 1995).</p>	<p>- Burgio, L., Scille, K., Hardin, M., Hsu, C., & Yancey, J. (1996). Environmental "white noise": An intervention for verbally agitated nursing home residents. <i>The Journals of Gerontology</i>, 51B(6), P364–P373.</p> <p>- Nelson, J. (1995). The influence of environmental factors in incidents of disruptive behavior. <i>Journal of Gerontological Nursing</i>, 21(5), 19–24.</p>	2	Provide access to nature sounds. Reduce loud noises.
Aggression and Disruptive Behavior	Light levels/bright light	x			<p>- Environmental lighting level. Low intensity of environmental lighting was associated with increased agitation in demented residents (Sloane et al., 1998). Demented residents exhibited less agitation when dining environment incorporated brighter light and heightened color contrast (Koss & Gilmore, 1998).</p> <p>- Bright light. Bright light exposure in morning (3 hr, 2,500 lux) resulted in significant reduction of agitation behaviors of residents (manual manipulation, escape restraints, searching and wandering, tapping and banging, vocalization) (Lovell et al., 1995).</p> <p>- Blocking afternoon sunlight. A lighting intervention—blocking direct afternoon sunlight by the microslatted glazed windows and maintaining a constant light level during afternoon by a lighting system including a photo sensor and luminaries with full-spectrum lamps—significantly reduced disruptive behaviors in individuals with Alzheimer's disease at senior adult day-care center (La Garce, 2002; La Garce, 2004).</p>	<p>- Koss, E., & Gilmore, G. C. (1998). Environmental interventions and functional ability of AD patients. In B. Vellas, J. Fitten, & G. Frisoni (Eds.), <i>Research and practice in Alzheimer's disease 1998</i> (pp. 185–193). New York: Springer.</p> <p>- La Garce, M. (2002). Lighting affects behavior of Alzheimer's patients. <i>Journal of Interior Design</i>, 28(2), 15–25.</p> <p>- La Garce, M. (2004). Daylight interventions and Alzheimer's behaviors—A twelve-month study. <i>Journal of Architectural and Planning Research</i>, 23(3), 257–269.</p> <p>- Lovell, B. B., Ancoli-Israel, S., & Gevirtz, R. (1995). Effect of bright light treatment on agitated behavior in institutionalized elderly subjects. <i>Psychiatry Research</i>, 57(1), 7–12.</p> <p>- Sloane, P. D., Mitchell, C. M., Preisser, J., Phillips, C., Commander, C., & Burke, E. (1998). Environmental correlates of resident agitation in Alzheimer's disease special care units. <i>Journal of the American Geriatrics Society</i>, 46(7), 862–869.</p>	2	<p>Increase the illumination level of ambient lighting. Block afternoon sunlight from entering patient rooms, keep lighting level constant during afternoon.</p>

RESIDENT SAFETY RISK ASSESSMENT MATRIX

Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
Aggression and Disruptive Behavior	Access to nature/outdoors	x		x	<p>- Access to <i>outdoors (wander garden)</i>. The use of exterior environments reduced aggressive behaviors of demented residents (Mooney & Nicell, 1992). The number of garden visits was significantly associated with the agitation level of dementia patients (Murphy et al., 2010). After opening a wander garden at a dementia facility, residents' agitation level (measured by a standard rating scale) and the use of as-needed medications decreased (Detweiler et al., 2008). Dementia residents exhibited fewer agitated behaviors (e.g., agitated pacing, agitated walking, restlessness) when the exit doors to outdoor terrace/garden area were unlocked than when the doors were locked (Namazi & Johnson, 1992). Visits to an outdoor garden helped decrease agitation behaviors (e.g., trespassing, exiting) in nursing home residents with dementia (Cohen-Mansfield & Werner, 1998b). Access to outdoors resulted in decreases of verbal and physical aggression in patients with dementia in an acute psychogeriatric admission unit (McMinn & Hinton, 2000).</p> <p>- Access to <i>nature elements</i>. The use of natural elements (recorded sounds of birds, babbling brooks, and other small animals; large bright pictures coordinated with the audio tapes) together with other distractions including foods (such as banana pudding and soda) during showers/baths resulted in significant reduction of dementia patients' agitation and aggression and more positive affective responses (Whall et al., 1997).</p>	<p>- Cohen-Mansfield, J., & Werner, P. (1998b). Visits to an outdoor garden: Impact on behavior and mood of nursing home residents who pace. In B. Vellas, J. Fitten, & G. Frisoni (Eds.), <i>Research and practice in Alzheimer's disease</i> (pp. 419-436). New York: Springer.</p> <p>- Detweiler, M. B., Murphy, P. F., Myers, L., & Kim, K. Y. (2008). Does a wander garden influence inappropriate behaviors in dementia residents? <i>American Journal of Alzheimer's Disease & Other Dementias</i>, 23(1), 31-45.</p> <p>- McMinn, B. G., & Hinton, L. (2000). Confined to barracks: The effects of indoor confinement on aggressive behavior among inpatients of an acute psychogeriatric unit. <i>American Journal of Alzheimer's Disease and Other Dementias</i>, 15(1), 36-41.</p> <p>- Mooney, P., & Nicell, P. (1992). The importance of exterior environments for Alzheimer's residents: Effective care and risk management. <i>Healthcare Management Forum</i>, 5(2), 23-29.</p> <p>- Murphy, P. F., Miyazaki, Y., Detweiler, M. B., & Kim, K. Y. (2010). Longitudinal analysis of differential effects on agitation of a therapeutic wander garden on dementia patients based on ambulation ability. <i>Dementia</i>, 9(3), 355-373.</p> <p>- Namazi, K. H., & Johnson, B. (1992). Pertinent autonomy for residents with dementias: Modification of the physical environment to enhance independence. <i>American Journal of Alzheimer's Disease and Related Disorders and Research</i>, 7(1), 16-21.</p> <p>- Whall, A. L., Black, M. E., Groh, C. J., Yankou, D. J., Kupferschmid, B. J., & Foster, N. L. (1997). The effect of natural environments upon agitation and aggression in late stage dementia patients. <i>American Journal of Alzheimer's Disease & Other Dementias</i>, 12(5), 216-220.</p>	2	Provide wander gardens and convenient access to natural elements.

RESIDENT SAFETY RISK ASSESSMENT MATRIX

Resident Safety Outcomes	Design Features	Skilled Nursing	Assisted Living	Dementia/ Alzheimer's Care	Key Findings	References	Strength of Evidence	Design Recommendations
	Light levels				- Light level. Pharmacists made significant fewer errors in dispensing prescriptions when illumination level was higher (Buchanan et al., 1991).	Buchanan, T. L., Barker, K. N., Gibson, J. T., Jiang, B. C., & Pearson, R. E. (1991). Illumination and errors in dispensing. <i>American Journal of Hospital Pharmacy</i> , 48(10), 2137–2145.	1-2	Improve illumination level in pharmacy dispensing area.
Medical Errors	Unit design to reduce interruptions				- Interruptions. The number of interruptions and distractions per half-hour was positively related to the number of dispensing errors per half-hour (Flynn et al., 1999). The rates of procedural failures and medication errors as well as error severity were positively related to the number of interruptions per medication administration (Westbrook et al., 2010).	- Flynn, E. A., Barker, K. N., Gibson, J. T., Pearson, R. E., Berger, B. A., & Smith, L. A. (1999). Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. <i>American Journal of Health Systems Pharmacy</i> , 56(13), 1319–1325. - Westbrook, J. I., Woods, A., Rob, M. I., Dunsmuir, W. T. M., & Day, R. O. (2010). Association of interruptions with an increased risk and severity of medication administration errors. <i>Archives of Internal Medicine</i> , 170(8), 683–690.	1-2	Reduce or eliminate distractions or interruptions (such as noise, other unrelated activities); separate pharmacy dispensing area from other activities.
Healthcare-Associated Infections (HAIs)	Room occupancy	x			- Single room. Nursing home residents with indwelling urinary catheters were three times more likely to contract urinary bacteria than residents in single rooms (Fryklund et al., 1997). Nursing home residents whose roommates were infected with influenza A had higher risks of infection than residents in single rooms (Drinka et al., 2003). Among nursing home residents who developed acute nonbacterial gastroenteritis during an outbreak, 84% lived in shared rooms, only 16% lived in single rooms (Pegues & Woernle, 1993).	- Drinka, P., Krause, P., Nest, L., Goodman, B., & Gravenstein, S. (2003). Risk of acquiring influenza A in a nursing home from a culture-positive roommate. <i>Infection Control and Hospital Epidemiology</i> , 24(11), 872–874. - Fryklund, B., Haeggman, S., & Burman, L. G. (1997). Transmission of urinary bacterial strains between patients with indwelling catheters—nursing in the same room and in separate rooms compared. <i>The Journal of Hospital Infection</i> , 36(2), 147–153. - Pegues, D., & Woernle, C. (1993). An outbreak of acute nonbacterial gastroenteritis in a nursing home. <i>Infection Control and Hospital Epidemiology</i> , 14(2), 87–94.	2	Provide single rooms.
	Cleanliness and ambience	x			- Physical environment. Cleanliness, odors, noises, homelikeness, and environmental quality (ratings on Therapeutic Environment Screening Survey for Nursing Homes) were factors associated with lower risk of hospitalization for infection (Zimmerman et al., 2002).	- Zimmerman, S., Gruber-Baldini, A. L., Hebel, J. R., Sloane, P. D., & Magaziner, J. (2002). Nursing home facility risk factors for infection and hospitalization: Importance of registered nurse turnover, administration, and social factors. <i>Journal of the American Geriatrics Society</i> , 50(12), 1987–1995.	1	Improve the quality of ambient environment (cleanliness, homelikeness, odors, noises, etc.).

Note. Some outcomes included in this matrix are not resident safety outcomes by themselves. However these outcomes strongly impact resident safety. Sleep disorders may lead to increased falls, delirium, morbidity, and mortality. Aggression and disruptive behaviors may lead to harm to self, other residents, and staff. The strength of evidence is indicated by two numbers: 1- some evidence (there are only one or two studies with weak study design/measurement tool and/or nonsignificant tendency); and 2- Strong evidence (there are multiple studies with strong study design/measurement tool and significant results)



V. CONCLUSION

The built environment of LTC settings plays a significant role in providing safe care to residents. Several of the environmental features mentioned in this paper are especially important since each of them influences multiple resident safety outcomes.

- **Room occupancy:** Single-bed rooms are related to better sleep, lower levels of agitation, and reduced risk of healthcare-associated infections.
- **Lighting:** High lighting level is related to better outcomes—lower fall risk, lower agitation, and fewer medication errors. Bright light or sunlight exposure at appropriate times helps reduce sleep disorders and disruptive behaviors. Blocking afternoon sunlight together with a constant light level can lead to reduction of disruptive behaviors.
- **Outdoor nature/wander garden:** An outdoor nature/wander gardens contributes to the reduction of resident falls, agitation, and aggressive behaviors and the improvement of sleep.
- **Acoustics:** Sleep disorders and agitation/aggression can be reduced by alleviating noise and providing music or nature sounds.
- **Ambience:** A soothing, homelike, aesthetic interior environment that provides positive distractions (e.g., nature artworks) may reduce agitation, aggression, and unsafe exiting.

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As a research associate for The Center for Health Design (CHD), Xiaobo Quan works closely with the director of research to collaborate with Pebble Project partners, planners, designers, and other researchers on Pebble Project research efforts. He examines the impact of the built environment on human behaviors and healthcare outcomes, evaluates the effects of evidence based design innovations, and disseminates research findings through presentations and publications.

Quan has been actively engaged in healthcare environment research and has published widely on topics of healthcare associated infection prevention, medication

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