# Team 4A: LumiSafe

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**Objective** Night-light intervention for prevention of slips and falls in MCI Patients within In-Patient Settings

## Introduction

### What is MCI?

Cognitive decline greater than that expected for an individual's age and education level ((Frank et al., 2006; Langa & Levine, 2014; Paradise et al., 2014; Petersen, 2011)) People experience a decline in cognitive function with age, this decline is comparatively worse in the case of people with mild cognitive impairment (MCI), and worst in the case of individuals with Dementia (PwD). Family members, care partners, and friends can easily identify these cognitive changes however they do not affect the patient's ability to perform everyday activities. (Alzheimers-Association, 2020)

Mild cognitive impairment (MCI) is a condition in which individuals demonstrate cognitive decline with minimal impairment of instrumental activities of daily living (IADL) (Petersen et al., 2018). Instrumental activities of daily living (IADL) are activities that allow an individual to live independently. These activities are not necessary for an individual to be functional, however, the ability to do IADLs are signifiers for a good quality of life. Individuals with mild cognitive impairment (MCI), see a noticeable decline in cognitive abilities that don't necessarily come in the way of activities of daily living (ADLs) but are at increased risk of developing Alzheimer's disease (AD) or other dementias. (Albert et al., 2011)

Since MCI is a new fairly topic of research and based on the progression statistics of MCI to Dementia, it might be useful to investigate some challenges faced by People with Dementia (PwD).

### How does Sleep Disorder lead to slips and falls in older adults and MCI fellows?

A sound sleep needs to cover a range of aspects like duration, satisfaction, timing, and efficiency. (Buysse, 2014) As people get older, sleep decline seems to become very common. Research has shown that with increasing sleep disorder, specific cognitive functioning also further declines. Moreover, Sleep disturbances lead to issues of nightly wandering, daytime sleepiness, and daytime napping. All these factors contribute to concerns of slips and falls in patients living with Dementia and AD which in turn cause loss in autonomy and independence hence may be a concern for those living with MCI and their care partners.

In a cross-sectional analysis study of a Korean community health survey data which studied association between sleep duration and injury from falling in older adults, it was proven that reduction in sleep duration and sleep quality, are both factors that increase the frequency

and severity in falling among the sample population.(Noh et al., 2017) Therefore, for people living with MCI, who are often seniors with issues in their sleep cycle, risk of injuries due to falling is worrisome.

**Common Intervention: Biodynamic Lighting**

A common intervention or solution used in prevention of sleep cycle disturbance is Biodynamic Lighting. Lighting in general has visual and non-visual aspects which helps in the synchronization in the physiological and behavioral rhythms of the human body and influences our sleep-wake cycle. (Ramkisoensing & Meijer, 2015)

In particular, the effect of biodynamic lighting with varying intensity and color resembling a daylight curve has been researched and proven to induce sleep in Dementia patients within in-patient settings. (van Lieshout-van Dal, Snaphaan, & Bongers, 2019) Biodynamic lighting (Figure 1) refers to a system where the color and intensity of lighting fixtures are adjusted in a timely fashion with bright blue light in the mornings of about 6500K is switched on at about 6am to wake the patients up to daylight and become alert. Throughout the morning, the color and intensity of the light is adjusted to whiter and cleaner temperatures of 5000-4000K, at noon the light is adjusted to a warmer temperature of 3000-3500K. By evening the color is warmest at about 7pm ambient temperature of 2700K is maintained. Finally, the lighting is turned off at 9pm to help the patients fall asleep with no disturbance caused by any bright light.

Though switching the biodynamic lights off and making the room dark helps the patients in falling asleep during night times, it leads to increasing chances of them slipping and falling in the dark. They may also feel very unsecure to get out of the bed and leads to a loss of autonomy increasing the concern of care givers and care partners. Hence there is a need for a night lighting system to address these concerns within the inpatient setting.

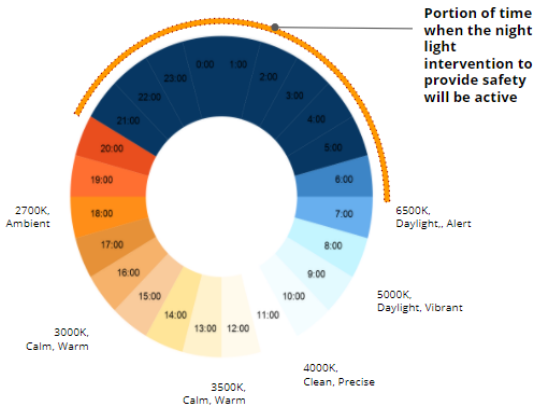


Figure 1. Biodynamic lighting represented through a chart with color temperatures for particular hours of the day.

**Existing Interventions to prevent slips and falls in hospitalized patients**

Falls and slips among hospitalized patients are significant problems to patient safety (Gillespie et al., 2010; LeLaurin & Shorr, 2019). About 2% of hospitalized patients fall at least once during their hospitalization and it has been shown that this can lengthen approximately 2% of hospital stays (Agostini, Baker, & Bogardus Jr, 2001; Bouldin et al., 2013; Rubenstein & Josephson, 2002). Inpatient falls can result in significant physical and economic burdens to patients as approximately one in four falls result in injury with about 10% in serious injury (Rubenstein & Josephson, 2002). There are many risk factors that are associated with falling, including intrinsic risk factors

such as age, mental status, illness severity, and extrinsic risk factors such as poor lighting and lack of grab bars in the bath or toilet (Table 1). These may differ across unit type and contribute to differences in fall rates. In particular, age is one of the most important factors that can lead to severe injuries because older people tend to have weaker body, poor vision, and difficulties with balance. In addition to this risk factor, dementia-related cognitive impairment is known to increase the chance of falls, and falls have been shown to lead to rapid cognitive decline in some extreme cases (Tchalla et al., 2013).

Recently, various interventions have been researched and implemented to reduce the risks mentioned above. These included improvements of surrounding environment including decreasing ward or room obstacles, adding additional lightings, guide rails to the bathroom, and lowering bedrails and bed height. Some interventions included physical restraints, bed alarms as the patient tries to leave the bed, and special flooring such as placing anti-slip mats to prevent patients from severe injuries when they fall. Also, improving personal safety by providing better footwear (e.g. non-skid socks).

**Table 1**
Examples of risk factors associated with falls.

| Intrinsic risk factors in order of high to low risk | Additional intrinsic risk factors | Extrinsic risk factors |
|---|---|---|
| Lower extremity weakness | Chronic illness | Lack of grab bars in the bath or toilet |
| History of falls | Orthostatic hypotension | Poor lighting |
| Gait/Balance deficits | Postural hypotension | Height of bed or chairs |
| Use of assistive devices | Urinary incontinence | Improper use of assistive devices |
| Vision deficit | Mental/Cognitive deficit | Inadequate assistive devices |
| Arthritis | Medication/Polypharmacy | Poor condition of flooring surfaces |
| Impaired ADLs | • Antidepressants | Improper footwear |
| Depression | • Antipsychotics: zolpidem | |
| | • Benzodiazapine | |
| | • Calcium channel antagonists | |
| | • Diuretics | |
| | • Hypoglycemics | |
| | • Laxatives | |
| | • Nonsteroidal anti-inflammatory agents | |
| | • Sedatives/hypnotics | |

Table 1. Examples of intrinsic and extrinsic risk factors that contribute to falls (Gu, Balcaen, Ni, Ampe, & Goffin, 2016)

## Problem Statement

People with MCI or Alzheimer's disease often have Sleep cycle disruptions lead to problems in the sleeping pattern with symptoms such as nightly wandering, daytime sleepiness, and daytime napping. (Cooke & Ancoli-Israel, 2011) Along with these symptoms a major problem is that of injuries due to slips and falls. A common intervention to address issues of sleep cycle is the use of biodynamic lighting designs, which are implemented within in-patient settings. (van Lieshout-van Dal et al., 2019) These lights are turned off during the night to allow the patient to sleep and not disturb them. However, despite the enhancement in sleep, there is an increasing risk of slips and falls when the patients try to ambulate to the bathroom etc. during the night times when the lights are turned off (Figure 2). Therefore, there is a need to address this issue with a comprehensive night lighting solution that gives the patient's their lost autonomy, while also helping care partners and nurses by reducing their burden.

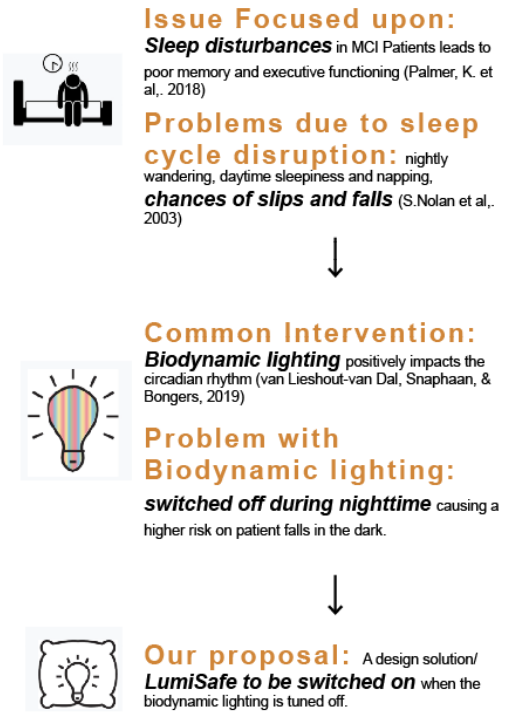


Figure 2. Design Topic and Problem statement breakdown

## Aim and Purpose:

### Project Value Statement

The purpose of LumiSafe is to develop a night lighting and motion sensor system that will be incorporated in an inpatient setting with biodynamic lighting already in place to help the MCI Patients regulate their sleep cycle. The aim of this prototype is to make the inpatient setting safe for patients to ambulate at night when the biodynamic lights are turned off, while also helping the nurses to monitor the patient's sleep cycle and notifying the care partners about the patient's whereabouts.

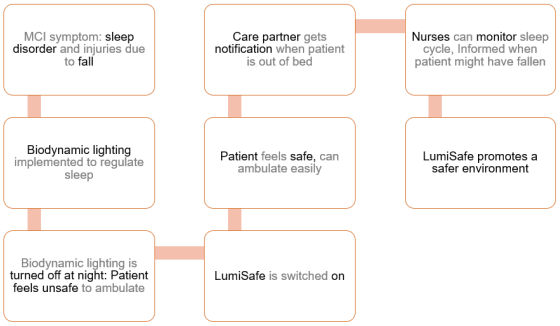


Figure 3. Process of empowerment

## Method

LumiSafe has been informed by the process of learning we went through with our assignments this semester. Assignment 1: Understanding Healthcare Design Problem helped us in defining MCI, understanding symptoms and impacts of MCI on patients and their care partners and exploring some of the design interventions and strategies. Assignment 2: Understanding Healthcare Experience facilitated us in learning more from the evidence base about MCI. We also made Journey Maps (Figure 4) to explain the MCI experience and System Maps (Figure 5) to explore design opportunities to enhance sleep and other needs within the inpatient setting. Assignment 3: Analyzing evidence-based design opportunities to improve health introduced us to sleep issues in specific and we went through case studies in this subject to build an evidence based table to understand more about sleep disorder and lighting interventions. This introduced us to Biodynamic lighting, and we found a gap in literature with regards to patient safety during night times to be a concern that we wished to address in the Assignment 4: Proposing design solution to improve health outcomes.

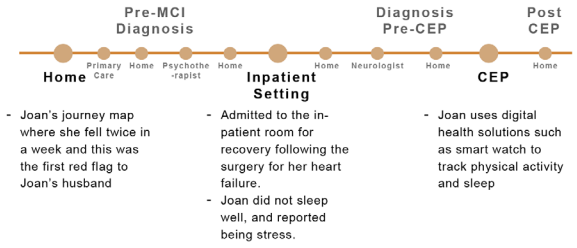


Figure 4. simplified Journey Map developed from the Vignette Exercise, highlighting the aspects we considered when designing LumiSafe.

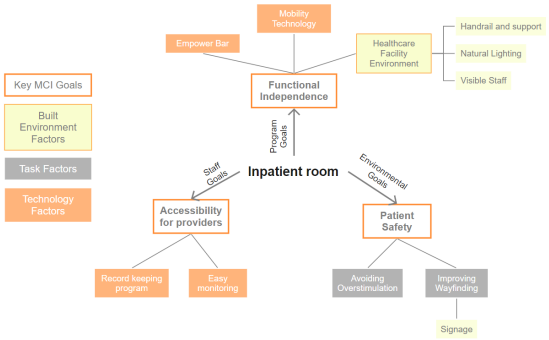


Figure 5. System Map focusing on outcomes of patient safety, functional independence, and accessibility for providers within the inpatient setting.

## Design Concept

During the initial prototyping of the lighting intervention LumiSafe, we wanted to address aspects of increasing sleep, safety and autonomy with different strategies like wayfinding arrows that would light up the path to the washroom, actigraphy wearables that could also

function as a method to call nurses when the patients were in need. However, we thought that focusing on specific aspect of increasing safety would allow for a more in-depth research on the topic and concerned issue and allow a broader development of the prototype that we wished to design.

For the final system we therefore focused on providing autonomy and control to the patients while reducing care giver and care partner stress and burden. The following are the design guidelines we implemented and opportunities we identified:

**Design Guidelines**

**Safety:** Ensure safety of the patients by providing enough lighting for them to see the edge of the bed and the floor

**Autonomy:** Give autonomy to patients by allowing them to control the lights, its intensity and color

**Design Opportunities**

**Monitoring:** Motion and sleep monitor (actigraphy) sensors to detect changes in the patients' circadian rhythm and their activeness

**Lighting:** Lights on the rail of the bed, underneath the bed, and on the mat that turn on/off in response to sensors and set to specific brightness/intensity

**Notifying:** Notifications sent to caregivers when patients are more active, awake, or leaves the bed

## Current Prototype

### Experience map

We would like to introduce our design through the journey map of Susan, who is a single, 70 years old woman with a diagnosis of MCI and has a high risk of fall. She has been admitted to the hospital for heart failure and is now in the inpatient setting. She has a daughter, Rachel, who only gets to visit Susan in the mornings and has to work during the night. She is constantly worried about her mother.

*Sleep problem*

Susan is staying in the in-patient room and has been facing issues with her sleep cycle. She sleeps mostly during the day and is active during the night. To prevent her from falling, there is an ordinary slip mat placed on the floor. Even during the night, caregivers need to frequently check on her for various measurements and for giving prescriptions. Because Susan has not been getting a quality sleep, she is noticeably more irritable and is not in good mood for her daughter who can only visit her during the day.

*Biodynamic light intervention*

To intervene her situation, the hospital has activated biodynamic lights to help her regulate her sleep cycle. Bright blue light wakes her up at 6 a.m. every morning. During the day, lighting levels and color correlated temperature is regulated. Towards the end of the day, the lighting is dimmer and dimmest after sunset to induce sleep. During nights, the lighting is switched off completely.

*Effects of biodynamic light intervention during night*

Susan feels unsafe to ambulate to the toilet at night because the room is completely dark. The caregivers struggle to check up on the patients as well. One night, while trying to reach the bathroom, Susan falls down. After a lot of effort, she gets back to bed on her own, while the

caregivers are unaware of what has happened.

*LumiSafe implementation*

LumiSafe has been implemented to help Susan be more aware of the surroundings and to prevent her from falling. It is a comprehensive night lighting system with controllable wall lights to fit the need of the patients at different lighting levels and motion sensors to detect when patients are getting out of the bed and to activate various lightings installed around the patients' bed. Lights are also turned on when caregivers are near the bed which helps them check up on Susan easily. Notifications are sent to caregivers and Rachel to notify Susan has left the bed and to inform the duration she has been away.

*Effects of LumiSafe intervention*

Because of LumiSafe, Susan feels safer to get out of the bed and is more empowered. This has reduced burden on the caregivers, and Rachel is less worried about Susan.

**Prototype features**

LumiSafe is a comprehensive night lighting system that integrates several lighting components with motion sensors (Figure 6). On the wall, there is a controllable wall light that allows patients to turn on the lights at night if they need. On walls near both sides of the bed, there are passive infrared (PIR) motion sensors similar to the commercially available sensor (Figure 7) will be installed. PIR is not visible and can automatically detect the body in dark environments. When a patient leaves the bed, the light under the bed and anti-slip mat is activated and caregivers are immediately notified. The lights will be sent to be 3000K warm light. When motion sensor detects that the patient has left the bed, notifications will be sent to caregivers and care partners not only to inform them that they have left the bed but also the duration that patients are away (Figure 8). Anti-slip mat is completely flat and sticks to the floor to prevent trip and fall, and the lighting turns on due to the PIR motion sensor. It is made from memory foam to prevent patients from severe injuries when they fall, and has pressure sensor so when the patients actually fall, the pressure sensor detects the body weight i.e. force being applied to a much region in the mat and notifies the caregivers and care partners.

In addition, LED lighting along the bed handrail is be activated based on the patients' sleep pattern. This is because lights activated by motion sensors will only be turned on when the patient moves out of the bed, so even before the patient tries to get out of the bed, extra lighting on the handrail will help the patient be more aware of the surrounding. Non-wearable sleep monitor sensor such as Apple sleep monitor sensor is placed underneath the patient's pillow or on the side of the bed to monitor the patient's circadian rhythm. This sensor will be connected to an app on phone for a monitoring sleep patterns, and based on these patterns, when the patient is in the awake state, the lights on the handrail will be activated (Figure 9).


Figure 6. LumiSafe prototype with lighting components identified

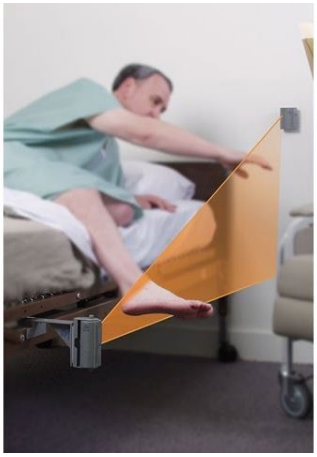

Figure 7. Commercially available Passive Infrared (PIR) motion sensor (AliMed®, 2019)

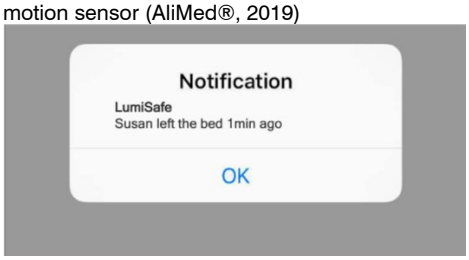


Figure 8. Phone notifications sent to caregivers and care partners.

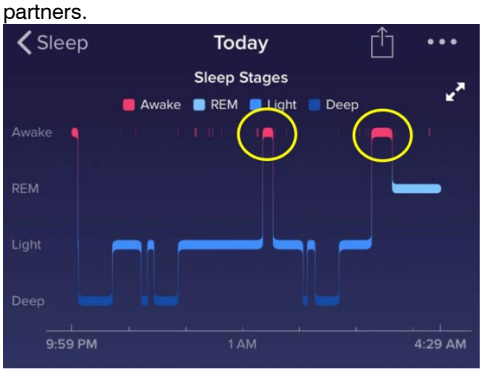


Figure 9. Sleep pattern detected by non-wearable sleep monitor device. Yellow circle indicates when the patient is awake and when the lights on the handrail is turned on.

## Testing and Evaluation

For 30 days after the implementation, testing and evaluation will be done to quantitatively measure the effectiveness of a comprehensive system, test the effectiveness and reliability of the lighting individually or in various combinations, and to measure the satisfaction levels from patients, caregivers, and care partners. The effectiveness of LumiSafe night light intervention will be reported by the number of falls and slips recorded by the sensors. Anti-slip mat with pressure sensors and motion sensors on the side of the bed will be used for this report. The intervention will be considered effective when the incidence rate is reduced by more than 50% after the intervention.

To test the effectiveness and reliability of the each component of the lighting individually or in combinations, the patients will perform standardized sit-to-stand (STS) test in in-patient settings (Figueiro et al., 2008). During STS test, patients are asked to sit on blocks with their feet on two force plates (Figure 10). Then, they are instructed to rise from the blocks as if they are usually standing up from a chair. The force plates measures sway velocity, which is a velocity measured as the body sways as measures of patients' stability because the visual differences in different scenarios will affect their stability. Three STS trials are conducted for every scenario. Five different scenarios for testing the light component individually will be tested using STS test and combinations of these scenarios will be tested as well (Figure 11).

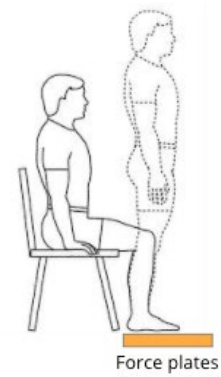


Figure 10. Standardized STS test in in-patient setting to see how stable patients are when exposed to different lighting conditions

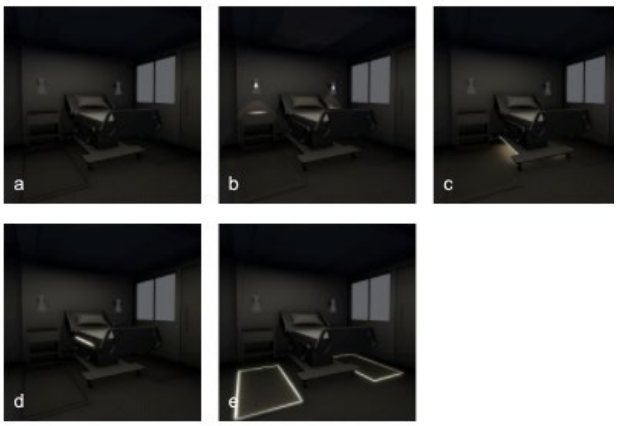


Figure 11. Five scenarios for testing the light component individually and as combinations using STS test. (a) without any LumiSafe interventions, complete darkness; (b) only controllable wall lamp turned on; (c) only motion sensor LED lighting under the bed activated; (d) only LED light along the bed rail activated; (e) only lights on anti-pressure mat activate

Lastly, surveys are conducted to measure how caregivers and patients feel about LumiSafe. This will be conducted after 30 days of the implementation along with other evaluation methods mentioned above and also after the final prototype implementation as an on-going evaluation and improvement strategy. These surveys will be collected by nurses, and improvements will be made based on this survey. In a 5-point scale from 1 being strongly disagree and 5 being strongly agree, the patients, caregivers, and care partners will be asked to answer questions similar to the following question.

Q1. I like the motion sensor feature on the lighting under the bed. (5-point scale; 5 strongly agree, 1 strongly disagree)

## Big Show Feedback

The Big Show was a great way to receive feedbacks from industry professionals. They were very interested our prototype as well as our testing and evaluation strategies. Some said that they would want to see this in in-patient rooms and that it can be implemented in any in-patient rooms in the nation, which highlights the flexibility of our idea. In terms of constructive feedbacks, it was recommended that we consider how to better guide the patient when one is coming back from the bathroom. This was something that we have not considered. It was recommended that by setting a timer or by having an additional motion sensor by the bathroom, the lights can be stayed on or again turned on. Another recommendation was to use anti-slip mats to track other events that are relevant for MCI hospitalized patients. He suggested that because cords can be a hazard for the patient, these anti-slip mats can be self-powered using new technologies such as by pressure.

## Conclusion and Future Goals

In conclusion, LumiSafe achieves the outcomes of not only reducing patient stress and caregiver burden but also empowering MCI patients by increasing their safety and providing them autonomy. For the future, LumiSafe wishes to use the results from the evaluation and testing phase to further enhance the design prototype. Using the information, we gain from the surveys and testing combination of different

lighting scenarios we will be able to make the design as cost effective as possible. Secondly after the implementation of the prototype within the in-patient setting, the sensors may be able to collect data on not only the sleeping patterns, but also time the patient takes to return to bed and keep the lights switched on for that duration and eventually dim the lights after the patient is in a sleeping position. Through this feedback mechanism system, we will be able to provide more autonomy to the patients, making LumiSafe a stronger and more successful prototype.

## References


Agostini, J. V., Baker, D. I., & Bogardus Jr, R. S. T. (2001). Prevention of falls in hospitalized and institutionalized older people. *Making health care safer: A critical analysis of patient safety practices, 43*, 281-299.

Albert, M. S., DeKosky, S. T., Dickson, D., Dubois, B., Feldman, H. H., Fox, N. C., . . . Phelps, C. H. (2011). The diagnosis of mild cognitive impairment due to Alzheimer's disease: recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimers Dement, 7*(3), 270-279. doi:10.1016/j.jalz.2011.03.008

Alzheimers-Association. (2020). Mild Cognitive Impairment (MCI). Retrieved from https://www.alz.org/alzheimers-dementia/what-is-dementia/related_conditions/mild-cognitive-impairment

Bouldin, E. D., Andresen, E. M., Dunton, N. E., Simon, M., Waters, T. M., Liu, M., . . . Shorr, R. I. (2013). Falls among adult patients hospitalized in the United States: prevalence and trends. *Journal of patient safety, 9*(1), 13.

Buysse, D. J. (2014). Sleep Health: Can We Define It? Does It Matter? *Sleep, 37*(1), 9-17. doi:10.5665/sleep.3298

Cooke, J. R., & Ancoli-Israel, S. (2011). Normal and abnormal sleep in the elderly. *Handbook of clinical neurology, 98*, 653-665. doi:10.1016/B978-0-444-52006-7.00041-1

Figueiro, M., Gras, L., Qi, R., Rizzo, P., Rea, M., & Rea, M. (2008). A novel night lighting system for postural control and stability in seniors. *Lighting Research & Technology, 40*(2), 111-126.

Frank, L., Lloyd, A., Flynn, J. A., Kleinman, L., Matza, L. S., Margolis, M. K., . . . Bullock, R. (2006). Impact of cognitive impairment on mild dementia patients and mild cognitive impairment patients and their informants. *International Psychogeriatrics, 18*(1), 151.

Gillespie, L., Robertson, M., Gillespie, W., Lamb, S., Gates, S., & Cumming, R. (2010). Interventions for preventing falls in older people in nursing care facilities and hospitals. *Cochrane database Syst rev, 12*.

Gu, Y.-Y., Balcaen, K., Ni, Y., Ampe, J., & Goffin, J. (2016). Review on prevention of falls in hospital settings. *Chinese nursing research, 3*(1), 7-10.

Langa, K. M., & Levine, D. A. (2014). The diagnosis and management of mild cognitive impairment: a clinical review. *JAMA, 312*(23), 2551-2561. doi:10.1001/jama.2014.13806

LeLaurin, J. H., & Shorr, R. I. (2019). Preventing falls in hospitalized patients: state of the science. *Clinics in geriatric medicine, 35*(2), 273.

Noh, J. W., Kim, K. B., Lee, J. H., Lee, Y., Lee, B. H., & Kwon, Y. D. (2017). Association between Sleep Duration and Injury from Falling among Older Adults: A Cross-Sectional Analysis of Korean Community Health Survey Data. *Yonsei medical journal, 58*(6), 1222-1228. doi:10.3349/ymj.2017.58.6.1222

Paradise, M., McCade, D., Hickie, I., Diamond, K., Lewis, S., & Naismith, S. (2014). Caregiver burden in mild cognitive impairment. *Aging & Mental Health, 19*, 1-7. doi:10.1080/13607863.2014.915922

Petersen, R. C. (2011). Clinical practice. Mild cognitive impairment. *N Engl J Med, 364*(23), 2227-2234. doi:10.1056/NEJMcp0910237

Petersen, R. C., Lopez, O., Armstrong, M. J., Getchius, T. S. D., Ganguli, M., Gloss, D., . . . Rae-Grant, A. (2018). Practice guideline update summary: Mild cognitive impairment: Report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. *Neurology, 90*(3), 126-135. doi:10.1212/wnl.0000000000004826

Ramkisoensing, A., & Meijer, J. H. (2015). Synchronization of Biological Clock Neurons by Light and Peripheral Feedback Systems Promotes Circadian Rhythms and Health. *Frontiers in neurology, 6*, 128-128. doi:10.3389/fneur.2015.00128

Rubenstein, L. Z., & Josephson, K. R. (2002). The epidemiology of falls and syncope. *Clinics in geriatric medicine, 18*(2), 141-158.

Tchalla, A. E., Lachal, F., Cardinaud, N., Saulnier, I., Rialle, V., Preux, P.-M., & Dantoine, T. (2013). Preventing and managing indoor falls with home-based technologies in mild and moderate Alzheimer's disease patients: pilot study in a community dwelling. *Dementia and geriatric cognitive disorders, 36*(3-4), 251-261.

van Lieshout-van Dal, E., Snaphaan, L., & Bongers, I. (2019). Biodynamic lighting effects on the sleep pattern of people with dementia. *Building and Environment, 150*, 245-253. doi:https://doi.org/10.1016/j.buildenv.2019.01.010