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Improving sleep by fostering social connection for dementia patients in long-term care: Commentary on "*Effects on sleep from group-activity with a robotic seal for nursing home residents with dementia: a cluster randomized controlled trial" by* Jøranson *et al*.

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Sleep disturbances increase risk for reduced cognitive functioning and dementia in older adults (Xu *et al*., 2019) and are highly prevalent (~40%) among persons with dementia living in nursing homes (NH) (Webster *et al*., 2020). Poor sleep quality is also associated with elevated behavioral and psychological symptoms of dementia (BPSD), such as agitation and depression, which decrease quality of life (QoL) and present serious challenges for caregivers that may hasten institutionalization and mortality (Chen *et al*., 2018). Furthermore, sleep problems in dementia are also associated with increased use of psychotropic medications, which carry substantial risks, including falls, strokes, and complications due to polypharmacy.

Although assessment, diagnosis, and treatment of primary sleep disorders, such as obstructive sleep apnea, are critical, there is limited evidence supporting interventions, whether pharmacologic or non-pharmacologic, to improve subclinical sleep disturbances in dementia (Kinnunen, Vikhanova and Livingston, 2017). This may be due to the heterogeneous etiology of poor sleep in dementia (e.g., circadian dysregulation, neurodegenerative lesions, hyperarousal), as well as ineffectiveness of or contraindications for conventional treatment strategies, such as cognitive behavioral therapy. Evidence is accumulating, however, for the effectiveness of multicomponent, psychosocial interventions for both patients and caregivers to improve BPSD (reviewed in Livingston *et al*., 2020), which may also translate into improved sleep. For example, the DREAMS-START study for dementia caregivers incorporates various activities, such as exercise, light therapy, and relaxation, and may improve sleep by targeting multiple etiologic pathways (e.g., metabolic, circadian, immune, stress physiology). Other types of multicomponent, psychosocial interventions, known collectively as highly individualized social activity interventions (ISAI), have also demonstrated positive effects on sleep quality. These studies suggest that increasing social engagement may be a promising strategy for improving sleep disturbances in dementia.

Social isolation and loneliness are independently associated with poorer sleep among older adults with dementia, and are of particular concern for those within NH, where up to 83% of their time is spent without social interaction and loneliness is twice as prevalent as in their community-dwelling peers (Prieto-Flores *et al.*, 2011). Like many interventions within NH, ISAIs may be difficult to implement due to costs, caregiver burden, and logistical challenges. An emerging strategy to improve sleep in older adults with dementia in NH is the use of social robots (i.e., robopets), robotic animals that mimic living animals and respond to human interaction. A recent systematic, mixed-methods review of 19 studies of robopets in NH (Abbott *et al.*, 2019) found significant decreases in agitation (n=3 studies; std. mean diff = −0.32 [−0.61, −0.04]) and non-significant improvements in loneliness (n=2 studies; std. mean diff. = −0.51 [−1.24, 0.22]); but neither of the two studies that assessed sleep reported improvements after 6 weeks or 10 weeks compared to a live animal or non-robotic soft toys. Notably, patients in these two studies were left to interact alone with the robopet, whereas interactions in other studies contained within the review were facilitated by staff. While robopet interventions are a promising tool for mitigating BPSD and loneliness in NH, whether they can be used to improve sleep disturbances, and the mechanisms by which improvements occur, remains unclear.

In their study, Jøranson et al. (2020) implemented an innovative, robopet-assisted group intervention in NH aimed to improve sleep among residents with dementia. Participants (n=60) were over the age of 65, had either a dementia diagnosis or meeting criteria for cognitive impairment based on a Mini-Mental State Examination (MMSE) score below 25/30, and resided in 10 different nursing home special care units in Eastern Norway. The intervention consisted of twice-weekly 30-minute group sessions over 12 weeks in which participants (n=6 maximum per group) sat with Paro, a robotic seal used to treat BPSD and improve QoL, placed on their lap for an equal period of time before being passed to the next person. The intervention was intended to stimulate activity between participants and Paro, among participants, and/or between participants and the activity leader, who facilitated the interactions. Sleep was assessed using wrist actigraphy over a 1-week pre- and post-intervention period by comparing sleep efficiency (%SE), wake after sleep onset (WASO, total duration of overnight awakenings), number of awakenings greater than 5 min, and total sleep time for individuals in the intervention versus control group (i.e., treatment as usual) across the two testing periods. The two groups did not differ at baseline by psychotropic medication use, light exposure, activity level, age, sex, or clinical dementia rating scale. A mixed-effects model was used to determine that the Paro intervention group modestly improved on all four sleep measures from the pre- to post-test period, compared to the control group, for whom sleep worsened somewhat across the testing period.

Overall, these findings raise several important issues in treating sleep disturbances in NH residents with dementia or with serious mental illnesses (SMI) who present with disrupted sleep, such as schizophrenia. As mentioned above, the etiology of poor sleep in dementia is heterogeneous. However, recent longitudinal data support bidirectional relationships between sleep disturbance and loneliness in aging (Griffin, Williams, *et al.*, 2020). Although neither loneliness nor social isolation were assessed by Jøranson and colleagues, by design the intervention increased participant social activity beyond their regular schedules by 1-hour per week across the 12-week study period. As the authors point out, it is therefore

possible that increased socialization with peers and NH staff during the group sessions, rather than interactions with Paro per se, mediated improved sleep by serving as a catalyst for social engagement. Whether social activity or engagement outside of the formal group sessions increased among participants is unknown, but quantifying social activity is an important direction for future robopet trials.

Measuring social activity, sleep, and other psychosocial factors in this population presents a unique challenge, but as Jøranson *et al.* demonstrate, can be accomplished by the use of passive sensing via wearables and other non-wearable technologies, such as motion-sensing devices. Although the actigraphy-based sleep measurements used by Jøranson *et al.* have certain limitations, such as detecting daytime sleepiness or differentiating when individuals are awake but not moving, objective measures can be uniquely useful when self-report is unreliable or unattainable. For example, intermittently-recorded speech has been used in conjunction with natural language processing to accurately predict subjective loneliness in older adults (Badal *et al.*, 2020). Such tools generate continuous data on behavioral patterns and can in theory be leveraged to facilitate earlier detection of BPSD and guide more precise therapies (reviewed in Husebo *et al.*, 2020). Individualized, multimodal datasets could be further translated into predictive algorithms to minimize risk of adverse events (Graham *et al.*, 2020) or to more quickly identify patients who are responding well (or not) to a new intervention. Furthermore, remote data collection and monitoring, as well as technology-based interventions, are of particular interest in light of the COVID-19 pandemic. High risk for viral transmission and morbidity have restricted visitation to NH facilities, and as a consequence, isolation from peers and family have acutely increased loneliness among residents. Given the links between loneliness, sleep disturbances, and BSPD, sensing technologies present exciting opportunities within this context.

The underlying neurologic mechanisms linking dementia and poor sleep, as well as loneliness, are not well understood. Interestingly, brain functional changes are related to acute sleep loss in younger adults, specifically within social approach and Theory of Mind networks (Ben Simon and Walker, 2018). These regions, which include the temporoparietal junction, precuneus, and dorsal intraparietal sulcus, likely mediate sleep loss-related increases in loneliness and social withdrawal, as well as are affected in neurodegenerative diseases including Alzheimer's dementia (Strikwerda-Brown, Ramanan and Irish, 2019) as well as in schizophrenia (Ioakeimidis *et al.*, 2020). Thus, insights into these brain-behavioral relationships in NH populations with dementia and SMI may offer targets for future therapeutic interventions.

One potential unifying biological process between sleep and loneliness in older adults is inflammation. Aging is associated with higher risk of sleep disorders (Xu *et al.*, 2019) loneliness, and inflammation (Franceschi and Campisi, 2014). In the general population, lonely older adults have higher levels of pro-inflammatory biomarkers, such as C-reactive protein (Vingeliene *et al.*, 2019). Meta-analyses have reported small-moderate sized associations between sleep disturbance and inflammation (Irwin, Olmstead and Carroll, 2016), which may, in turn, drive Alzheimer's disease pathogenesis and dementia (Irwin and Vitiello, 2019). Remission of insomnia has been shown to induce decreases in systemic, cellular and genomic markers of inflammation (Irwin *et al.*, 2015). While few studies

have explicitly examined the links between sleep, loneliness, and inflammation, sleep disturbances have been shown to mediate the link between loneliness and poor health among older adults (Griffin, Mladen, *et al.*, 2020).

In conclusion, addressing sleep disturbances, BPSD, loneliness, and social isolation among older adults with dementia or SMI in NH is a critical concern, and robopet ISAIs may address the unique psychosocial care needs of this underserved population. Future work is warranted to better understand how interventions for loneliness and social isolation could improve sleep and other daily behaviors using targeted approaches that examine the underlying biological processes.

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