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REVIEW

Sounds in nursing homes and their effect on health in dementia: a systematic review

Sarah I. M. Janus,[1] Janouk Kosters,[1] Kirsten A. van den Bosch,[2] Tjeerd C. Andringa,[1,3] Sytse U. Zuidema,[1] and Hendrika J. Luijendijk[1]

[1]*Department of General Practice & Elderly Care Medicine, University of Groningen, University Medical Centre Groningen, Groningen, the Netherlands*
[2]*Department of Youth Studies, University of Groningen, Groningen, the Netherlands*
[3]*University College Groningen, University of Groningen, Groningen, the Netherlands*

ABSTRACT

Objectives: Nursing home residents with dementia are sensitive to detrimental auditory environments. This paper presents the first literature review of empirical research investigating (1) the (perceived) intensity and sources of sounds in nursing homes, and (2) the influence of sounds on health of residents with dementia and staff.

Design: A systematic review was conducted in PubMed, Web of Science and Scopus. Study quality was assessed with the Mixed Methods Appraisal Tool. We used a narrative approach to present the results.

Results: We included 35 studies. Nine studies investigated sound intensity and reported high noise intensity with an average of 55–68 dB(A) (during daytime). In four studies about sound sources, human voices and electronic devices were the most dominant sources. Five cross-sectional studies focused on music interventions and reported positives effects on agitated behaviors. Four randomized controlled trials tested noise reduction as part of an intervention. In two studies, high-intensity sounds were associated with decreased nighttime sleep and increased agitation. The third study found an association between music and less agitation compared to other stimuli. The fourth study did not find an effect of noise on agitation. Two studies reported that a noisy environment had negative effects on staff.

Conclusions: The need for appropriate auditory environments that are responsive to residents' cognitive abilities and functioning is not yet recognized widely. Future research needs to place greater emphasis on intervention-based and longitudinal study design.

Key words: nursing homes, behavioral and psychological symptoms of dementia (BPSD)

Introduction

In recent decades, research has highlighted strong relationships between the auditory environment and human health (Monti *et al.*, 2012). Sound exceeding 50 dB(A) is known to cause annoyance, disturbed sleep, delirium, elevations in blood pressure and tachycardia and is possibly linked to ischemic heart disease in healthy populations (Choiniere, 2010; Morrison *et al.*, 2003). Auditory environments are made up by the whole of audible sounds in any certain place and time. Loud and unwanted sounds are usually regarded as noise.

Correspondence should be addressed to: Sarah Janus, Department of General Practice & Elderly Care Medicine, University Medical Centre Groningen, Internal post FA21, Postbox 196, 9700 AD Groningen, the Netherlands. Email: s.i.m.janus@umcg.nl. Received 14 Aug 2019; revision requested 21 Oct 2019; revised version received 28 Apr 2020; accepted 14 May 2020.

In nursing homes, staff, household appliances and other residents shape the auditory environment. Staff may produce unexpected, repetitive, loud and droning sounds, which residents can experience as unpleasant, disturbing and even unsafe (van den Bosch *et al.*, 2016). Furthermore, staff members tolerate (unconsciously) more and louder sounds since the nursing home is their workplace. As a result, staff might (unintentionally) contribute to an auditory environment that influences the mood and quality of life of the residents adversely (Sloane *et al.*, 2003).

Residents with dementia, which make up the majority of nursing home population, are highly sensitive to detrimental sounds (Jao and Algase, 2016; van Hoof *et al.*, 2010). This increased sensitivity might arise from a reduced ability to consciously value sensory experiences (van Hoof *et al.*, 2010). Research has found associations between noise and increased agitation and apathy, fewer social interactions, and sleep disturbance in nursing home residents (Garre-Olmo *et al.*, 2012; Joosse, 2012; Meyer *et al.*, 1992; Schnelle *et al.*, 1998; Southwell and Wistow, 1995). On the other hand, natural sounds have been associated with a decrease in agitation and aggression (Whall *et al.*, 1997).

In addition, nursing home residents are often unable to adjust their situation to personal needs due to limited cognitive, sensory and verbal abilities. Residents with dementia depend on caregivers to acknowledge and satisfy their daily needs, shape their environment and make them feel secure. As suggested by Cadieux *et al.* (2013), there is a need to create the notion of home for this population. The auditory environment, however, does not only influence the well-being of the residents, but also affects the staff members who spend a considerable amount of time in these (work) environments (Aletta *et al.*, 2018a).

Sound perception and the effects of sounds on health vary across individuals and situations. This variance can be researched with the acoustical approach, which focuses on the physical aspects of sound (e.g. intensity), or the soundscape approach, which focuses on the meaning people attribute to sounds. Both types of research have been performed in nursing homes. However, no previous review has examined the evidence on sounds in nursing homes and their influence of sounds on residents or caregivers. Furthermore, as the literature field is not yet densely populated with relevant studies, a review is required to guide future research in this area. The aim of this literature review was (1) to explore the (perceived) intensity and sources of sounds in nursing homes, and (2) to investigate the influence of sounds on health of residents (including behavioral problems in dementia) and staff.

Methods

Search strategy

The search was carried out according to guidelines of the Centre for Reviews and Dissemination for systematic reviews (Tacconelli, 2010). We used the following sources: PubMed (covering Embase and Medline), Scopus, Web of Science and trial registers (clinicaltrials.gov, controlledtrials.gov, trialregister.nl). The search was last updated in January 2019. The following text words were used: (sound* OR noise OR acoustic OR auditory OR music) AND (nursing home OR long-term care). The search strategy is shown in Table S1 as supplementary material online attached to the electronic version of this paper. The search was limited to studies published after January 1990, because prior reviews about sounds in hospitals show that the first sound studies were published in the 1990s (Iyendo, 2016). The review protocol was registered in the International Prospective Register of Systematic Reviews, PROSPERO (CRD42018117962).

Two authors independently screened the titles and abstracts yielded by the search. Full reports were obtained for titles that appeared to meet the inclusion criteria and abstracts that could not be excluded definitively at that point. The reference management software Mendeley was used to de-duplicate references and share documents.

Study selection criteria

Two authors screened the full-text reports and decided whether these met the inclusion and exclusion criteria. Studies performed in nursing homes were included. Criteria for exclusion were a focus on hearing problems or music therapy, and poster abstracts. Studies using music interventions to improve the auditory environment, such as live music, would have been included but were not found. Disagreement was resolved through discussion.

Data extraction

Two authors extracted the data of each eligible study independently into the pre-created data extraction form. The general study characteristics included the number of residents, if applicable, setting, and study design. For observational studies, the sound intensity in dB(A) and descriptions of sound sources were extracted. For intervention studies, the design, description of the (sound) intervention and primary and secondary outcomes, as well as results, were extracted.

Two authors assessed study quality using the revised Mixed Methods Appraisal Tool for qualitative and quantitative research (Pace *et al.*, 2012; Pluye and Hong, 2014). The criteria used for appraisal can be found in Table S2 as Supplementary material online attached to the electronic version of this paper. Discrepancies were resolved by discussion. The results of the quality assessment process were taken into consideration during data interpretation.

Data analysis

Meta-analyses could not be executed due to the heterogeneity in characteristics of the interventions, health-care settings, outcome measures and residents. Therefore, we present the study characteristics and findings in descriptive tables and summarize the results in the text.

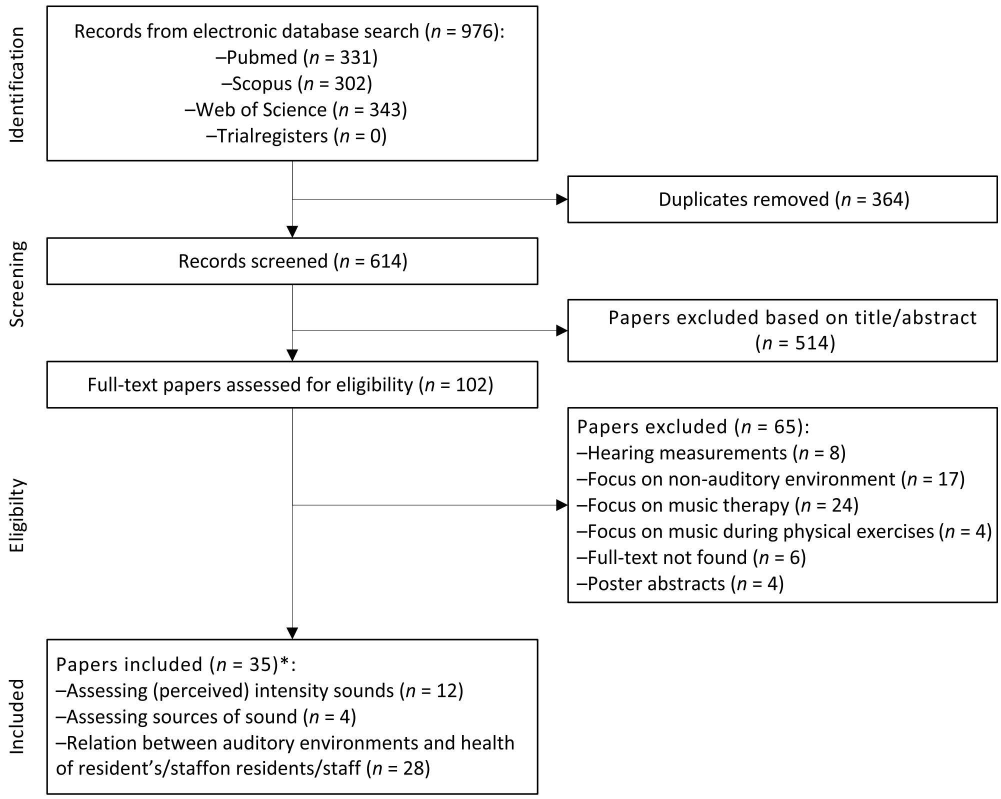

Figure 1. Flowchart of the selection process of paper; *some studies investigated >1 topic.

Results

Search results

We identified 976 potentially relevant studies in electronic databases. We retrieved the full-text papers of 102 potentially eligible studies based on title and abstract. We identified 35 eligible studies. Figure 1 provides the results of the literature search. Of the included studies, 12 studies assessed the (perceived) intensity of sounds, 4 studies investigated sound sources and 28 studies determined the influence of sound on patient and staff behavior. Eight studies investigated more than one topic.

General study characteristics are summarized in Table 1. We found 4 randomized trials, 5 non-randomized trials, 20 quantitative descriptive studies and 7 qualitative studies. The majority of studies ($n = 20$) were conducted in the U.S.A. Five papers had been published by the same research group (Alessi *et al.*, 2005; Cruise *et al.*, 1998; Ouslander *et al.*, 2006; Schnelle *et al.*, 1993, 1999). Nine studies conducted sound intensity measurements. In 22 studies, the participants were residents ($n = 8$–267) and in 5 studies, the participants were nurse(-assistant)s ($n = 17$–214).

Quality assessment

The four randomized trials were of low quality (see Supplementary material S2) (Alessi *et al.*, 1999, 2005; Cohen-Mansfield *et al.*, 2012; Cohen-Mansfield *et al.*, 2010). The randomization procedure was unclear in all studies and only one study had comparable groups at baseline. The number of staff involved in the behavior modification program was not reported. No trial used blinded outcome assessors.

All five non-randomized prospective studies were of low quality too (Meyer *et al.*, 1992; Oppikofe and Geschwindner, 2014; Ouslander *et al.*, 2006; Schnelle *et al.*, 1999; Tabloski *et al.*, 2006). No study reported sufficient information about the participants' representativeness to the target population. In two studies, the sample sizes were small ($n = 11$–27). Three studies did not use appropriate measurements (e.g. no blinding, intervention only reported if effective), and four studies had incomplete outcome data. Lastly, two studies did not take confounders into account in the analysis.

Four of the 19 quantitative descriptive cross-sectional studies fulfilled all of the identified

Table 1. General study characteristics

STUDY	COUNTRY	STUDY DESIGN	METHOD USED	PARTICIPANTS (*n*)	NUMBER OF NH
Sound intensity					
Aletta *et al.*, 2018	Belgium	Cross-sectional	Questionnaire	214 caregivers	NR
Jao *et al.*, 2015	U.S.A.	Cross-sectional	Sound measurement	40 residents#	22 NH
van Hout *et al.*, 2014	Netherlands	Cross-sectional	Sound measurement	NA	5 NH^
Garre-Olmo *et al.*, 2012	Spain	Cross-sectional	Sound measurement	160 residents*	8 NH
Joosse, 2011	U.S.A.	Cross-sectional	Sound measurement	NA	4 NH
Bharathan *et al.*, 2007	U.S.A.	Cross-sectional	Sound measurement	NA	1 NH
Hicks-Moore, 2005	Canada	Repeated measurements	Sound measurement	30 residents*	1 NH
Webber *et al.*, 2004	U.S.A.	Cross-sectional	Observations	NA	1 NH
McClaugherty *et al.*, 2000	U.S.A.	Cross-sectional	Sound measurement and questionnaire	135 caregivers	13 NH
Ragneskog *et al.*, 1996b	Sweden	Cross-sectional	Sound measurement	20 residents*	1 NH
Goddaer and Abraham, 1994	Belgium	Repeated measurements	Sound measurement	29 residents*	2 NH
Schnelle *et al.*, 1993	U.S.A.	Cross-sectional	Sound measurement	118 residents	4 NH
Sources of sound					
Aletta *et al.*, 2018	Belgium	Cross-sectional	Questionnaire	214 caregivers	NR
Joosse, 2011	U.S.A.	Cross-sectional	Sound measurement	8 residents	4 NH
Webber *et al.*, 2004	U.S.A.	Cross-sectional	Observations	NA	1 NH
McClaugherty *et al.*, 2000	U.S.A.	Cross-sectional	Sound measurement and questionnaire	135 caregivers	13 NH
Relation between auditory environments and health of residents and staff					
Bautrant *et al.*, 2018	France	Pre/post design	Behavior measurement	19 residents*	1 NH
Van Vracem *et al.*, 2016	Netherlands	Cross-sectional	Observations and interviews	46 caregivers	8 NH
Jao *et al.*, 2015	U.S.A.	Cross-sectional	Sound measurement	40 residents#	22 NH
Wong *et al.*, 2014	Hong Kong	Cross-sectional	Focus groups	36 caregivers	4 NH
Oppikofer and Geschwindner, 2014	Switzerland	Pre/post design	Behavior measurement	67 residents	3 NH
Joosse, 2012	U.S.A.	Cross-sectional	Sound measurement	53 residents*	8 NH
Cohen-Mansfield *et al.*, 2012	U.S.A.	Randomized Cross-sectional	Behavior measurements and environment stimuli	193 residents	7 NH
Ho *et al.*, 2011	Taiwan	Pre/post design	Behavior measurement	22 residents*	1 NH
Cohen-Mansfield *et al.*, 2010	U.S.A.	Randomized Cross-sectional	Behavior measurements and environment stimuli	111 residents*	7 NH
Algase *et al.*, 2010	U.S.A.	Cross-sectional	Observations (videos)	122 residents	22 NH
Götell *et al.*, 2009	Sweden	Cross-sectional	Observations	9 residents* 5 caregivers	1 NH
van der Geer *et al.*, 2009	Netherlands	Cross-sectional	Interviews	17 NH physicians 20 NH care providers	20 NH

Table 1. Continued

STUDY	COUNTRY	STUDY DESIGN	METHOD USED	PARTICIPANTS (*n*)	NUMBER OF NH
Ouslander *et al.*, 2006	U.S.A.	Non-randomized trial with parallel control group	Sleep and behavior measurement	160 residents	8 NH
Tabloski *et al.*, 2006	U.S.A.	Within subjects design	Sleep measurement	27 residents	NR
Alessi *et al.*, 2005	U.S.A.	Randomized prospective trial	Sleep measurement	118 residents	4 NH
Hicks-Moore, 2005	Canada	Repeated measurements	Behavior measurement	30 residents*	1 NH
Remington, 2002	U.S.A.	Four-group repeated measurements	Behavior measurement	68 residents*	4 NH
McClaugherty *et al.*, 2000	U.S.A.	Cross-sectional	Sound measurement	135 caregivers	13 NH
Alessi *et al.*, 1999	U.S.A.	Randomized prospective trial	Physical activities and sleep measurement	29 residents	1 NH
Schnelle *et al.*, 1999	U.S.A.	Non-randomized trial with parallel control group	Sound and Behavior measurement	267 residents (with incontinence)	2 NH
Cruise *et al.*, 1998	U.S.A.	Cross-sectional	Sound and sleep measurement	225 residents	10 NH
Ragneskog *et al.*, 1998	Sweden	Cross-sectional	Interviews	17 caregivers	5 NH
Gentili *et al.*, 1997	U.S.A.	Cross-sectional	Interviews	48 residents	2 NH
Ragneskog *et al.*, 1996b	Sweden	Cross-sectional	Observations	5 residents*	1 NH
Ragneskog *et al.*, 1996a	Sweden	Cross-sectional	Behavior + food measurements	20 residents*	1 NH
Tabloski *et al.*, 1995	U.S.A.	Quasi-experimental, (subject is his own control)	Behavior measurement*	20 residents	2 NH
Goddaer and Abraham, 1994	Belgium	Repeated measurements	Behavior measurement	29 residents*	2 NH
Meyer *et al.*, 1992	U.S.A.	Pre/post design	Behavior observation, Interviews	11 residents *	1 NH

NA = not applicable, NH = nursing home, NR = not reported; * with dementia; # 3 videos per patient; ^5 common rooms and 5 bedrooms.

methodological criteria (Garre-Olmo *et al.*, 2012; Remington, 2002; Gentili *et al.*; 1997; Schnelle *et al.*, 1993), but the other 15 studies were of varying quality (Algase *et al.*, 2010; Aletta *et al.*, 2018b; Bautrant *et al.*, 2018; Bharathan *et al.*, 2007; Cruise *et al.*, 1998; Goddaer and Abraham, 1994; Ho *et al.*, 2011; Hicks-Moore, 2005; Jao *et al.*, 2015; Joosse, 2011, 2012; McClaugherty *et al.*, 2000; Ragneskog *et al.*, 1996b; Tabloski *et al.*, 1995; van Hout *et al.*, 2014; Webber *et al.*, 2004). A recurrent problem was a small and unrepresentative sample. Five studies did not report the number or location of the sound measurements clearly.

All six included qualitative studies were of good quality (Ragneskog *et al.*, 1996a; Ragneskog *et al.*, 1998; Götell *et al.*, 2009; van der Geer *et al.*, 2009; Van Vracem *et al.*, 2016; Wong *et al.*, 2014). Two met all quality criteria. One study did not provide sufficient data for the interpretation of results.

(Perceived) intensity of sounds

Twelve studies investigated sound intensity nursing homes, either using a digital sound level meter (n = 10; see Table 2) or rater observations (n = 2). Three studies conducted measurements during the night. One study reported an average of 32 noises per night per resident's bedroom at the level of loud speech or above (60 dB) (Schnelle *et al.*, 1993). The other study took measurements in five common rooms and five sleeping rooms and measured averaged intensity of 32.1 dB(A) as well as maximum peak intensity of 97.8 dB(A) (van Hout *et al.*, 2014). In the third study, a rater observed the noises during two consecutive nights in one nursing home, and reported 784 noises (sounds sufficiently loud enough to disrupt sleep as rated by the observers) at the patient bedside (46.8/hour) (Webber *et al.*, 2004).

Ten studies performed measurements during the day (one study conducted measurements during the day and night). One study, in 13 nursing homes, conducted sound measurements spanning 12-hour intervals and reported sound intensity as high as 70–101 dB(A) (McClaugherty *et al.*, 2000). One research group recorded sound intensity four times per day at the nurses' stations and in the doorways of residents' rooms of one nursing home and reported an average sound intensity of 57.3 ± 2.1 dB(A) (Bharathan *et al.*, 2007). The third and fourth study conducted sound measurements 8 and 10 times per day, respectively, in different rooms of 4 and 8 nursing homes respectively (Joosse, 2011; Garre-Olmo *et al.*, 2012). The average morning sound intensity was the quietest and the average evening sound levels the loudest (Joosse, 2011). The bedroom space was the quietest space observed and the dining room was the loudest (Joosse, 2011). The mean sound intensity of all rooms was 48.5 ± 6.1 dB(A) (Garre-Olmo *et al.*, 2012). The fifth study was based on measurements in the common rooms of five nursing homes (van Hout *et al.*, 2014). The mean daytime sound intensity was 55.3 dB(A) with a maximum of 115.0 dB(A). In the sixth study, three videos of each participating nursing homes resident (n = 40) were made. The sound intensity was measured at the same time and the average sound intensity was 68 dB(A) and the range of 51–124 dB(A) (Jao *et al.*, 2015). Another three studies measured sound intensity during lunch and dinner time in the eating areas (Goddaer and Abraham, 1994; Ragneskog, 1996b; Hicks-Moore, 2005). They measured sound intensities between 61.4 dB(A) and 65 dB(A). The final study used an online survey for staff exploring the personal experience of sound in the work environments (Aletta *et al.*, 2018b). Nursing staff was rather positive about the auditory environment (M = 6.42, SD = not reported, 10-point rating scale, not at all completely). Bedside staff scored the items "uneventful" more negative than management staff, and the items "safe" and "familiar" lower than the head nurses.

Sources of sound

Four studies investigated sources of sound with measurements and surveys (see Table 2). One study first made sound recordings and analyzed the sources afterwards as mixed (44%), equipment related (26%), human (26%, staff talking to each other; 3%, staff talking near or directly to residents) and maintenance facility related (1%) (Joosse, 2011). In the second study, raters reported that 31% of the sounds were environmental (e.g. doors slamming and telephones ringing), 34% were staff-generated (e.g. nurses talking and staff pushing carts) and 35% were resident-generated (e.g. residents calling out) (Webber *et al.*, 2004). In the third study, the nurses reported that the primary sources of noise were alarms, vacuums and steam cleaners, but measurements indicated that a band, cleaning equipment and phones were the loudest (McClaugherty *et al.*, 2000). Additionally, an online survey among staff found that human vocal and nonvocal sounds as well as electronic sounds were reported to be the most noticeable and dominant (Aletta *et al.*, 2018b).

Associations between sounds and health of residents and staff

Thirteen studies investigated the association between the auditory environment and the health of residents with dementia using observations or interviews (see Table 3). Three studies specifically looked at sleeping problems. One of these studies

Table 2. Results of studies measuring the (perceived) intensity and sources of sounds

STUDY	SOUND INTENSITY		SOURCES OF SOUNDS
	Place of measurement	*Mean sound intensity*‡	
Aletta *et al.*, 2018	Not specified	– Overall sound quality rated as 6.4* – Item *uneventful* was scored lower by bedside staff than management staff (M = 2.78*, SD = 2.36 vs. 3.86, SD = 2.07, p = .033) – Item *safe* was scored lower by bedside staff than head nurse staff (M = 5.81* (SD = 2.28) vs. M = 6.70* (SD = 1.90), p = .016) – Item *familiar* was scored lower by bedside staff than head nurse staff ((M = 4.91* (SD = 2.75) vs. M = 6.01* (SD = 2.39), p = .016) – Bedrooms were perceived as calmer and living rooms as more eventful (M = 3.69*, SD = 2.34 vs. M = 5.38*, SD= 2.18); $t(210) = 4.553$, $p < .001$)	– perceived dominance of the sources of noise were human vocal sounds, human sounds nonvocal and electronic sounds
Jao *et al.*, 2015†	Dining room, patient staff interaction, random chosen	Day: 68.0 dB(A) (SD 11.0)	
van Hout *et al.*, 2014	Shared spaces, bedroom	Night: 32.1 dB(A) (max 97.8); day: 55.3 dB(A) (max 115.0)	
Garre-Olmo *et al.*, 2012	Bedroom	Morning: 36.2 dB(A) (30.6 – 71.7), afternoon: 39.2 dB(A) (30.3 – 68.8),	
	Dining room	Morning: 48.0 dB(A) (31.7 – 70.1), afternoon: 54.8 dB(A) (32.7 – 64.8),	
	Living room	Morning: 54.8 dB(A) (39.1 – 69.1), afternoon: 56.3 dB(A) (34.9 – 68.3)	
Joosse, 2011	Not specified	Morning: 55.6 dB(A) (SD 10.78); afternoon: 57.0 dB(A) (SD 10.67); evening: 58 dB(A) (SD 13.97)	– equipment (26%) – mixed (44%) – human (26%)
	Bedroom	51.8 dB(A) (SD 6.88)	
	Dining room	60.4 dB(A) (SD 4.14)	
	Shared spaces	58.9 dB(A) (SD 4.27)	
Bharathan *et al.*, 2007†	Nurses' stations	Day: 57.3 dB(A) (SD 2.1)	
Hicks-Moore, 2005	Dining room	62.1 dB(A)	
Webber *et al.*, 2004	Bedroom	Night: 784 (46.8/hour) noises (sounds sufficiently loud enough to disrupt sleep as rated by the observers) heard at the patient bedside; 44.1% of staff-generated and 41.2% of equipment related noises were at the level of normal talking or louder	– equipment (31.5%) – staff (33.5%) – resident (35.0%)
McClaugherty *et al.*, 2000†	Not specified	maximum 70–101 dB(A)	Cleaning equipment, phones, door buzzes, yelling by staff, intercom
Ragneskog *et al.*, 1996b	Dining room	Dinner time: 65 dB(A)	
Goddaer and Abraham, 1994	Dining room	Lunch time: 62.1 dB(A) and 61.4 dB(A)	
Schnelle *et al.*, 1993	Bedroom	Night: 16.5 changes in noise levels between consecutive 2-minute intervals at ≥ 10 dB(A); average of 32 noises per night per resident at the level of ≥ 60 dB(A)	

*Scored on a 10-point rating scale, very bad to very good; †studies reported results in dB, however, we assumed that results were measured in dB(A); ‡ points of reference: 0 dB(A) softest sound a person can hear, 30 dB(A) dB(A) soft whisper, 60 dB(A) normal conversation, 110 dB(A) shouting in ear (Center for Hearing and Communication, n.d.).

Table 3. Results of studies measuring the relation between auditory environments and health of residents/staff

STUDY	INTERVENTION (I) OR DETERMINANT (D)	OUTCOME	RESULTS
Bautrant *et al.*, 2018	I: Environmental changes to the ward (skylike ceiling tiles together with soothing streaming music, reinforcement of the illuminance during the day, and night team clothes color (dark blue) different from that of the day team (sky blue))	NPS (agitation/physical aggression, wandering, screaming as defined by Neuropsychiatric Inventory Questionnaire, Cummings *et al.*, 1994)	• The number of residents showing agitation/physical aggression or screaming over 24 hours or during late hours was not statistically different between Phases 1 and 2 • The number of residents showing wandering was significantly lower during Phase 2 over 24 hours (12 vs. 5) • The number (8.42 vs. 1.36) but not the mean duration (34.0 vs. 52.2 minutes) of agitation/physical aggression and screaming and both the number (4.10 vs. 1.26) and mean duration (112 vs. 39.2 minutes) of wandering episodes were significantly decreased over 24 hours following environmental rearrangements • A significant reduction of the number (3.16 vs. 1.10) and mean duration (106.6 vs. 33.7) of wandering was noticed during the late hours
Van Vracem *et al.*, 2016	D: Light and noise (not further defined)	Sleep problems* (observed by the researcher)	• Wandering and screaming seem to be the most prevalent nighttime agitated behaviors • Observations highlighted that “a lot of light and noise” is prominent and this might be causing nighttime restlessness
Jao *et al.*, 2015	D: Ambiance (measured on Ambiance Scale), crowding, staff familiarity, light (lux), sounds	Apathy† * (Person-Environment Apathy Rating-Environment subscale, Jao *et al.*, 2013)	• Ambiance, crowding, staff familiarity, light and sounds did not show significant effects on apathy • In a clear and strong environmental stimulation as measured with the Person-Environment Apathy Rating-Environment subscale (Jao *et al.*, 2013), residents with dementia show significantly less apathy
Wong *et al.*, 2014	D: Indoor environmental factors (e.g. acoustic environment, lighting and thermal environment)	Well-being† (as defined by researcher)	• Residents with dementia are sensitive to mechanical noise (TV, air conditioners, renovation)
Oppikofer and Geschwindner, 2014	I: Nursing interventions (i.e. avoiding noise)	Agitation* (measured with the Cohen–Mansfield Agitation Inventory (CMAI), Cohen-Mansfield *et al.*,1989a)	• Less agitation was experienced when noise was avoided; person was accompanied to the toilet, communication/validation, walking about/movement and administering beverages
Joosse, 2012	D: Sound (dB(A)), space (m^2)	Agitation† (measured with the Wisconsin Agitation Inventory, Kovach *et al.*, 2004)	• Sound exposure was a significant predictor of agitation • The accumulation of sound predicted agitated behavior and explained 16% of the variance, $F(5, 47) = 4.520$, $p < .002$, and adjusted $R^2 = .253$

Table 3. Continued

STUDY	INTERVENTION (I) OR DETERMINANT (D)	OUTCOME	RESULTS
Cohen-Mansfield *et al.*, 2012	I: 25 stimuli presentation to each participant during 3 weeks (4 stimuli per day, stimulus was presented twice)	Agitation* (measured with Agitation Behavior Mapping Inventory (ABMI), Cohen-Mansfield *et al.*, 1989b)	• Background noise did not reach significance on agitation
Ho *et al.*, 2011	I: Relaxing music intervention at mealtimes twice a day	Agitation† (measured with the CMAI, Cohen-Mansfield *et al.*,1989a)	• Global agitation scores and subscores decreased after the 4-week music intervention (all $p < .001$, mean score before 60.64 vs. 42.99 after)
Algase *et al.*, 2010	D: Sound intensity	Wandering* (based on rate and duration of the video observations)	• Wandering was more likely in locations in which variation in sound intensity was greater (OR = 1.03, 95% CI 1.02–1.08, $p < .003$)
Cohen-Mansfield *et al.*, 2010	I: 25 stimuli presentation to each participant during 3 weeks (4 stimuli per day, stimulus was presented twice)	Agitation* (measured with ABMI, Cohen-Mansfield, *et al.*, 1989b)	• Music and self-identity stimuli were associated with less agitation than simulated social (e.g. doll) and manipulative stimuli (e.g. squeeze ball)
Götell *et al.*, 2009	I: A care routine with recorded music playing in the background, or caregiver singing to and/or with the patient versus no music or singing	Vocally expressed emotions and mood during "usual" care routines	• Compared to no music, the presence of background music and caregiver singing improved the mutuality of the communication between caregiver and resident, creating a joint sense of vitality • Positive emotions were enhanced, and aggressiveness was diminished
van der Geer *et al.*, 2009	D: The kinds of music (genre) and the frequency of music provided during all care activities	Life of the resident as reported in by the physician or health-care professional	• 38 of the 51 (75%) selected residents enjoyed listening to music. • While the music supply was relatively limited during patient centered morning and evening care activities, as well as during meals, music was offered to the residents almost daily during the midmorning coffee and the afternoon tea.
Ouslander *et al.*, 2006	I: Nursing interventions and strategies to reduce nighttime noise	Nighttime sleep quality * (duration, awakenings, percentage asleep using actigraphy), Daytime sleep (duration, awakenings, percentage asleep using actigraphy), NPS (as defined by Neuropsychiatric Inventory Questionnaire, Cummings *et al.*, 1994)	• Intervention did not lead to differences in sleep quality • Intervention led to reduction in daytime sleep (not clinically)
Tabloski *et al.*, 2006	I: Calming music at bedtime, strategies to reduce noise/light	Total sleep time*, sleep latency*, daytime agitation* (not further defined)	• Both music and noise/ sound reduction program reduced sleep latency
Alessi *et al.*, 2005	I: Strategies to reduce daytime in-bed time and to decrease nighttime noise/light	Daytime sleep (measured in minutes), nighttime sleep (measures in minutes), agitation (as defined by Cohen-Mansfield *et al.*,1989a), and participation in activities*	• Intervention led to a decrease in daytime sleeping • Intervention led to an increase in social/physical activities and social conversation

Table 3. Continued

STUDY	INTERVENTION (I) OR DETERMINANT (D)	OUTCOME	RESULTS
Hicks-Moore, 2005	I: Relaxing music during dinner time	Agitation† (measured with the CMAI, Cohen-Mansfield *et al.*,1989a)	• In the weeks with music, there were days without any aggressive behaviors being displayed, which was not the case in the weeks without music. During the weeks with music, in all but one day, three or fewer incidences of physically nonaggressive behaviors were recorded • Out of the five possible verbally agitated behaviors, in the weeks with music the incidences were seen less frequently, with the maximum recorded incidences on any one day being two compared to a maximum of four incidences seen in the weeks without music
Remington, 2002	I: (1) Calming music, (2) hand massage, (3) calming music and hand massage simultaneously or (4) control	Agitation † (measured with the CMAI, Cohen-Mansfield *et al.*,1989a)	• Residents who received either intervention, alone or in combination, exhibited significantly less agitation than the control group up to 1 hour after intervention (Fcons 6.47, *p* .01 and follow-up comparisons using Tukey's Honest Significant Difference procedure with a level of significance of .05)
McClaugherty *et al.*, 2000	D: Noise (as reported by participants)	Reported psychological– physiological effects on nursing staff	• Loud noises as experienced by the nurses had negative psychological effects on nurses
Alessi *et al.*, 1999	I: Strategies to improve physical activity and reduce nighttime noise and sleep-disruptive nursing care practices	Nighttime sleep (measured in minutes), agitation (as defined by Cohen-Mansfield *et al.*,1989a) daytime sleep* (measured in minutes)	• Intervention did not lead to changes in physical functioning • Intervention led to an increase in nighttime sleep (from 51.7% to 62.5% in intervention group compared to 67.0–66.3% in controls) • Intervention led to a decrease in daytime in-bed time (32% decrease in observations in intervention group, no change in control) • Intervention led to a decrease in agitation (7 out of 15 showed decrease in agitation in intervention group, 1 out of 14 in control group)
Schnelle *et al.*, 1999	I: Behavioral intervention (feedback to staff about noise intensity, strategies to reduce noise and to improve individual nighttime incontinence care)	Bedside noise and light changes, Sleep (in minutes), day in-bed time (in minutes), wrist actigraphy to estimate nighttime sleep*	• Noise was reduced significantly (from 83 intervals per night to 58 intervals) • 27% awakenings associated with just sounds
Cruise *et al.*, 1998	D: noise (dB(A)),	Nighttime sleep* (in minutes)	• Noise was associated with sleep disruption
Ragneskog *et al.*, 1998	D: Probable reasons for agitation	Agitation* (as defined by researchers)	• Probable reasons: discomfort, wish to be served immediately, conflict between residents or staff, re-actions to environmental noises, invasion of personal space

Table 3. Continued

STUDY	INTERVENTION (I) OR DETERMINANT (D)	OUTCOME	RESULTS
Gentili *et al.*, 1997	D: Noise, light amongst others (as reported)	Factors associated with poor sleep* (as reported)	• Factors that disturbed the residents' sleep were nocturnia (71%), environment-related noise or light (38%), pain (33%), feeling too hot (6%) and leg cramps (6%)
Ragneskog *et al.*, 1996b	I: Three different types of music with three different types of music (soothing, pop from the 20s and pop from the 80s)	Time spent with dinner (measured in minutes)	• Four of five residents spent more time with dinner during the three musical periods in comparison with the control period. The longest time they spent with dinner was during the playing of soothing music • Patients ate by themselves more often during music intervention
Ragneskog *et al.*, 1996a	I: Three different types of music during dinner (soothing, pop from the 20s and pop from the 80s)	NPS during dinner, food intake (measured with the Multi-Dimensional Dementia Assessment Scale, Sandman, Norberg and Adolfsson, 1988)	• During the music intervention, the NPS ratings indicated significant improvements in irritability, fear-panic and depressed mood compared to the control period ($p < .05$). The difference was most pronounced when soothing music was played • The residents ate more when music was played, but the difference was particularly significant for the dessert ($p < .01$). The increase in food intake was most marked when pop music was played
Tabloski *et al.*, 1995	I: Calming music (15 minutes)	Agitation† (measured with the Agitated Behavior Scale, Corrigan, 1989)	• Results indicate that a reduction in agitated behavior occurred both during ($p < .01$) and after the musical intervention ($p < .05$). The mean pre, during and post scores were significantly different ($F = 33.45$; $df = 2$; $p < .001$; mean scores pre = 24.15; during = 18.45; 15 minutes after = 19.92)
Goddaer and Abraham, 1994	I: Relaxing music during dinner	Agitation† (measured with the CMAI, Cohen-Mansfield *et al.*,1989a)	• A significant change over the 4-week period was observed on the cumulative incidence of agitated behaviors ($F(3,78) = 8.52$, $p < .0001$) • The total reduction in agitation over the 4-week period was 63.4%
Meyer *et al.*, 1992	I: "Quiet Time"	Agitation† (as defined by researchers)	• Intervention led to a decrease in frantic/violent behavior observations (from 38 to 19)

*In residents, †in residents with dementia; NPS stands for neuropsychiatric symptoms.

found that 27% of waking episodes were associated with noise alone (Schnelle *et al.*, 1999). In another study, of the 48 nursing home residents 17 (35%) reported that their sleep was disturbed by noise made by other residents (n = 5), by the nurses (n = 4) or both (n = 8) (Gentili *et al.*, 1997). Caregivers identified many possible causes in the third study (Van Vracem *et al.*, 2016). Even though a "lot of light and noise" was prominent in the nursing homes, noise was rarely mentioned spontaneously, or identified as a cause for nighttime restlessness (Van Vracem *et al.*, 2016).

Six studies looked at the association between noise and behavioral problems other than sleeping disorders. Two research groups analyzed videotapes of nursing home residents with dementia to identify the most probable antecedents to agitation and apathy (Jao *et al.*, 2015; Cohen-Mansfield *et al.*, 2012). Reactions to environmental noises or sound tend to influence expressed agitation but not apathy (Jao *et al.*, 2015). In addition, two studies examined the relationship between sound intensity, personal space and agitation by observing residents (Algase *et al.*, 2010; Joosse, 2012). The accumulation of sound predicted agitated behavior and explained 16% of the variance (n = 53) (Joosse, 2012). By analyzing 20-minute observations (n = 122), another study also reported that the sound was significantly, yet not greatly, associated with wandering (Algase *et al.*, 2010). In the fifth study, focus groups with caregivers and nurses indicated that the auditory environment, thermal comfort and indoor air quality are considered the most important factors influencing behavioral problems (Wong *et al.*, 2014). Sounds generated by electronic devices, such TV, air conditioners and announcement speakers, were thought to trigger behavioral problems in the residents. The final study investigated staff perceptions of noise and its physiological and psychological effects on themselves (McClaugherty *et al.*, 2000). In a noisy environment, nurses felt irritable (67%), felt anxious (53%), had difficulties concentrating (64%) and were more likely to make errors (70%). The authors hypothesized that noise might cause workers to take out their frustrations on residents and other staff (McClaugherty *et al.*, 2000).

Four studies specifically looked at the association between music and behavioral problems. One study looked at the moods of residents with severe dementia in the communication between caregivers during morning care sessions using qualitative content analysis. Compared to no music, the presence of background music and caregiver singing enhanced the presence of positive emotions and diminished aggressiveness (Götell *et al.*, 2009). Van der Geer *et al.* (2009) investigated the type of music being offered and the degree to which it corresponds to the preferences of residents with both dementia and agitation. Interviews with nursing home physicians ($n = 17$) and other nursing home care providers ($n = 20$) revealed that music was offered mostly in the communal living room during the mid-morning coffee and the afternoon tea. However, this music was not tailored to the preferences of the residents. Two studies by Ragneskog *et al.* (1996a,b) investigated the influence of three different types of music (soothing music, Swedish music from the 1920/30s and pop music) played during dinner on time spent on dinner, food intake and neuropsychiatric symptoms. Video recordings showed that patients spent more time on dinner and food intake was higher and food intake was higher when music was played. In addition, irritability, fear, panic and depressed mood scores decreased compared to the control period ($p < .05$). The difference was most pronounced when soothing music was played.

Effects of sounds on health of residents

Eleven studies studied the effect of sound improving interventions on the environment and problem behavior prospectively but did not have a control group (see Table 3). One study focused specifically on noise reduction (Meyer *et al.*, 1992), and in the other studies, noise reduction was part of a multicomponent intervention.

Three of the 11 studies investigated the effect on sleeping problems. One intervention consisted of providing feedback to the staff about noise intensity, and research staff implementing procedures to both abate noise (e.g. turn off unwatched TVs) and individualizing nighttime incontinence care routines, to make them less disruptive to sleep (Schnelle *et al.*, 1999). Even though the intervention resulted in less noise, it did not lead to significant improvements in night or day sleep. Educating staff about improving sleep including strategies to reduce nighttime noise did not lead to differences in sleep quality either (Ouslander *et al.*, 2006). The third study used calming music at bedtime together with staff education about strategies to reduce noise and light (Tabloski *et al.*, 2006). Post-measurements showed a reduction in sleep latency. Agitation was also measured, but background noise was not associated with it in the multivariate model.

Three non-controlled studies investigated noise and agitation in nursing home residents. One study implemented a "quiet week" in which nurses were obliged to lower their voices and reduce fast movements, the public entrance was relocated to a side door and residents were not allowed to watch television or play piano (Meyer *et al.*, 1992). The intervention influenced the agitation levels of some but not all residents, and there was a decrease in agitated behaviors from 38 to 19 frantic/violent behaviors in the total sampled hourly behaviors. However, at the end of the week, some residents seemed to become more agitated than they usually were. In the other study, the frequency and circumstances of agitation before and after introducing a nursing intervention focused on person-centered care and activation were documented in diaries (Oppikofe and Geschwindner, 2014). The most successful of 433 recorded care interventions were communication/validation related (25%), individualized care (17%) and avoiding noise (9%). The third study implemented environmental changes to the ward such as skylike ceiling tiles together with soothing music and compared neuropsychiatric symptoms before and after the intervention (Bautrant *et al.*; 2018). No change in the number of residents showing agitation or physical aggression or the duration of this behavior was found, but the number of episodes (8.42 vs. 1.36) of agitation/physical decreased.

Two studies studied the effect of calming music on agitation. The results of the within subject design used by Tabloski *et al.* (1995) indicated that a reduction in agitated behavior occurred both during and after the musical intervention. Remingtion (2002) compared 4 groups: a) calming music intervention, b) hand massage, c) calming music and hand massage simultaneously and d) control group. Residents who received either intervention, alone or in combination, exhibited significantly less agitation than the control group up to 1 hour after intervention.

Three studies investigated the effect of relaxing music played during dinnertime on the residents' behavior (Goddaer *et al.*, 1994; Hicks-Moore, 2005; Ho *et al.*, 2011). All found a reduction on agitation during the intervention period in comparison with the baseline measurements.

Four studies used a randomized parallel-group design to study the effect of interventions improving the environment on behavioral problems in dementia (see Table 3). Again, noise was only one part of the multicomponent intervention in all studies. One study focused on sleeping problems. During the intervention period, staff was educated about how to reduce daytime in-bed time and to decrease nighttime noise and light, which led to a decrease in daytime sleeping and an increase in social/physical activities and social conversation (Alessi *et al.*, 2005). Another study tested an intervention to improve physical activity in residents with dementia. Additionally, after the 14-weeks activity period, the researchers taught nursing staff strategies to reduce nighttime noise and sleep-disruptive nursing care practices, which were applied to the intervention and control groups (Alessi *et al.*, 1999). The combination of activity stimulation and noise reduction led to an increase in nighttime sleep (52–63%) compared to noise reduction only (67–66%, $F = 4.42$, $p = .045$, $df = 27$), to a decrease in daytime in-bed time (32% decrease vs. no change, $F = 51$, $p = .029$, $df = 27$) and to a decrease in agitation (7 out of 15 residents vs. 1 out of 14 residents, $F = 7.86$, $p = .009$, $df = 27$). The third study looked at the impact of environmental, personal and stimulus attributes on agitation and examined whether engagement to stimuli influenced levels of agitation (Cohen-Mansfield *et al.*, 2010). During the stimuli presentation, of which the order was randomized per participant, environmental attributes and direct observations of agitation were recorded. Live social stimuli (e.g. live dog) were associated with less agitation than music, self-identity (e.g. hobbies), work (e.g. folding towels, sorting envelopes), simulated social (e.g. doll) and manipulative stimulus (e.g. squeeze ball) categories. Music and self-identity stimuli were associated with less agitation than simulated social and manipulative stimuli. The fourth study used the same method (Cohen-Mansfield *et al.*, 2012). During the stimuli presentation, of which the order was randomized per participant, environmental attributes and direct observations of agitation were recorded. Background noise was, however, not associated with agitation.

Discussion and conclusions

We performed a literature review on sounds in nursing homes and their effect on health of residents and staff in nursing homes. Twelve studies investigating sound intensity reported high daytime and nighttime sound intensity. Four studies investigating sound sources reported human vocal and electronic sounds to be the most dominant. In addition, 13 cross-sectional, 11 interventional non-controlled and 4 randomized studies investigated the association between sounds and the health of nursing home residents and staff. Five studies focused on music interventions and reported positives effects on agitated behaviors. Three randomized controlled trials used noise reduction as part of the intervention. Methodological quality of the randomized controlled studies was low. Two studies reported positive effects on nighttime sleep and agitation, but the third study did not find an effect of noise on agitation. One randomized controlled trial used music as part of the intervention. Live social stimuli (e.g. live dog) were associated with less agitation than musical, recreational (e.g. hobbies) and work-related activities (e.g. folding towels and sorting envelopes) (Cohen-Mansfield *et al.*, 2010).

The studies reporting daytime sound intensity found average levels between 55–68 dB(A) and additional peaks of 70–110 dB(A) (Jao *et al.*, 2015; McClaugherty *et al.*, 2000; van Hout *et al.*, 2014). The international standards for sound intensity in hospital rooms range between 35 and 45 dB(A) for daytime hours and 20 and 35 dB(A) for nighttime hours (Berglund *et al.*, 1999; EPA, 1974). The sound intensity values found in nursing homes are higher than those recommended and could have a detrimental effect on persons with dementia. Even in healthy populations, sound exceeding 50 dB(A) is known to cause annoyance, disturbed sleep, delirium, elevations in blood pressure and tachycardia and is possibly linked to ischemic heart disease (Choiniere *et al.*, 2010; Morrison *et al.*, 2003).

We found three studies focusing on background music during dinnertime. Those studies reported positive effects of music, especially relaxing/soothing music. Less agitated behaviors and more food intake were measured (Goddaer *et al.*, 1994; Hicks-Moore, 2005; Ho *et al.*, 2011). We found one study that focused specifically on the effect of noise reduction on nursing home residents' behavior (Meyer *et al.*, 1992). Observations before and after the changes showed a decrease in frantic and violent behaviors. However, the study results are limited by several factors. A pre-post design was used instead of an experimental study design. Also, the sample size ($n = 11$) was too small for elaborate analysis and generalization of the results. In addition, the intervention itself was designed to reduce stimulation, but also prohibited pleasant activities, such as playing the piano. This might not be seen as patient-centered care and might have led to understimulation in a few residents that exhibited an increase in "non-calm" behaviors. Therefore, generalization of the results is not possible and more studies investigating the impact of noise on patient behavior are needed.

Three experimental studies showed that educational noise reduction programs for staff might be helpful for reducing noise (Alessi *et al.*, 1999, 2005; Cohen-Mansfield *et al.*, 2012). However, since noise sources in nursing homes varied widely, there can be no single solution to reduce sound intensity. Therefore, it is important that different noise reduction techniques are applied including behavior modification, reconstruction of units and reducing volume of TVs, telephones and doorbells.

Nursing staff was an important source of sound in nursing homes. However, the nurses themselves did not always report themselves as source. In the study by Van Vracem *et al.* (2016), the nurses only reported mechanical noises. Communication between nursing staff and residents is an essential part of the work of a nurse and might therefore not be experienced as a sound source.

Our search revealed 13 studies specifically focusing on residents with dementia and 3 studies using health-care professionals as dementia proxies. Noise might be especially disturbing for people with cognitive impairment. Some researchers have claimed that auditory information contributes to forming a "sense of place" (van den Bosch *et al.*, 2016). Sounds provide information about the location and activities to come, so that one can prepare for them. The absence of information can lead to uncertainty and it becomes difficult to respond situationally. The studies in our review showed that most sounds in nursing homes were related to staff activities, staff talking and electronics. Residents with dementia might have difficulties understanding those sounds since they are often unrelated to their own activities. The exposure of individuals with dementia to ambivalent sound sources is likely to increase confusion and trigger negative feelings. Observed reactions to noise were often neuropsychiatric symptoms (e.g. agitation, apathy and nighttime restlessness), which are common in people with dementia (Cruise *et al.*, 1998; Jao *et al.*, 2015; Joosse, 2012). According to the person-centered model of care, these reactions could be a form of communication to a non-adapted environment, such as sensory overload (Garre-Olmo *et al.*, 2012).

We found that sounds might influence not only residents but also staff members. A noisy environment seemed to have negative psychological effects on staff, which is likely to negatively affect the quality of care. Research in the hospital setting has shown that noise-induced stress correlates with predictors of burnout (Basner *et al.*, 2014). In the health-care environment, noise is evaluated as a potential contributor to medical errors and poor staff retention, which underlines the importance of a good auditory environment.

While sounds experienced as noise have been studied in nursing homes, positive auditory environments have received less attention. We found fives studies using music interventions to improve the auditory environment. However, these interventions are applied to all residents living on the ward. Residents in care facilities might be stimulated even more through technologies and "active" tools that are more person-centered. An example is the use of a parametric speaker, a high-directional loudspeaker transmitting sound in a narrow acoustic space, to create personal space in a common room (Nishiura *et al.*, 2018). Actively designing soundscapes, for instance, using the residents' sensitivity and preference, might be another valuable approach. However, raising more awareness about the potential role of sound in nursing homes would be the first necessary step toward healthy and stimulating auditory environments that can promote better living and working conditions.

To our knowledge, this is the first review summarizing the so far accumulated knowledge regarding sound, noises and music in nursing homes and their effects on the residents. The strengths of this paper include a rigorous search strategy and study quality assessment of the included studies.

A limitation of this review is the small number of interventional studies. In addition, the studies had limitations themselves such as small sample sizes and a moderate quality of design. The studies investigating sound intensity varied in measurement of sound intensity with respect to locations, measurement moments and number of measurements (1× day vs. 8× per hour for a period of 12 hours). Some studies collected data for only one day, thus providing insufficient data for rigorous conclusions. The studies investigating the effect of sound on residents' health and behavior used varying determinants and outcomes. Therefore, comparisons between different studies were difficult. Meta-analyses could not be executed; thus, overall estimates of effects could not be given. In many of the studies, the designs of the studies were often not reported completely, which means that those studies cannot easily be replicated. In addition, during the last two decades, a shift took place from shared rooms to single rooms. Nowadays, in newer small-scaled nursing homes, residents might be less likely to experience noise. Hence, the inclusion of studies conducted before the shift in the 1990s might have influenced the results.

This review shows that sound intensity in nursing homes are high during daytime and nighttime. Furthermore, there is a lack of intervention studies focusing specifically on noise reduction. As suggested in other recently published papers in *International Psychogeriatrics* (Buist *et al.*, 2018; Jao *et al.*, 2019), more studies investigating the relation between (auditory) environments are needed. Some nonexperimental studies suggested that music played during dinner had a positive effect on food intake. This might be easily applicable in clinical practice. However, we would first advocate the conduction of experimental studies exploring effects of sounds.

Conflict of interest

None.

Description of authors' roles

S. Janus, J. Kosters and H. Luijendijk were responsible for study concept and design. S. Janus, J. Kosters and H. Luijendijk collected the data, and interpreted them. Drafting of the manuscript was done by S. Janus and J. Kosters. Critical revision of the manuscript for important intellectual content was done by H. Luijendijk, K. van den Bosch, T. Andringa and S. Zuidema.

Supplementary material

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