ASSESSMENT OF INDOOR VISUAL ENVIRONMENTS USING DEMENTIA-FRIENDLY DESIGN CRITERIA IN DAY CARE CENTRES

María Carmen Carballeira Rodríguez[1] and Neveen Hamza[2]
[1]MSc Sustainable Buildings and Environments, Newcastle University, UK
[2]Senior lecturer in Architecture, Newcastle University, UK

ABSTRACT

This research assesses whether the indoor visual environment in three day care centres in Galicia (Spain) for people with Alzheimer's disease and other dementia (ADOD), complies with a set of dementia-friendly design criteria and principles of environmental psychology. Qualitative evaluations, combined with measurements of indoor lighting parameters (i.e. horizontal and vertical illuminances - E_H, E_V; correlated colour temperature - CCT), are conducted to assess the indoor visual conditions. Building Performance Simulation (BPS) is used to evaluate the indoor daylight availability. The study highlights that indoor visual aids and lighting levels for task undertaking and circadian entrainment are insufficient. Altough BPS can underpin daylight contribution from the design stage, further research regarding daylight metrics is needed to include non-visual effects of light within the BPS capabilities.

INTRODUCTION

Dementia is one of the main causes of disability and dependency among the world population aged over 60 years. Alzheimer's disease (AD) is the most common type (WHO & ADI, 2012) and in Spain, 1.5 million people are expected to suffer from AD by 2050 (SSN, 2012). Galicia, the region with a higher rate of disability and the third higher rate of visual impairment (INE, 2008), holds the Galician Network of social day care centres for people with ADOD to support patients (maximising remaining autonomy and postponing institutionalisation) and caregivers.

Reduced dexterity caused by the ageing process, along with neurological and cognitive decline tied to dementia, worsens the persons' restricted adaptability to changing surroundings (van Hoof & Kort, 2009). Since pharmacological treatments may have negative side effects, a non-pharmacological approach through dementia-friendly design is widely proposed as a first intervention, particularly of light and visual conditions due to its higher impact on daily functioning and health among indoor factors (ibid). No studies of the visual ambience have been found regarding ADOD facilities in Galicia, so this research aims to evaluate if the indoor visual environments of the day care centres assessed follow dementia-design criteria to ultimately raise awareness of its benefits.

LIGHT AND DEMENTIA

Visible light stimulates retino-neural connections differently for both the visual and non-visual systems (Rea et al., 2002). Thus, the ageing process and eye diseases affect vision and photobiological processes.

Age-related visual deterioration and diseases

1. Age-related visual decline, caused by different eye alterations (e.g. stiffness, increased thickness and yellowing of the lens; reduction of colour preceptors), leads to functional changes such as slower adaptation to light levels changes, declined contrast sensitivity (identifying object's boundaries) and reduced colour discrimination, (particularly of bluish colours) (Jones & van der Eerden, 2008). This functional deterioration is worse in AD individuals (Butter et al., 1996 cited in Torrington & Tregenza, 2007).
2. Main age-related eye conditions are cataracts, macular degeneration, glaucoma and reduced visual field (McNair et al., 2013).

Visual effects of light

Age-related visual decline is tied to both physical and cognitive-related outcomes (Shikder et al., 2012). The loss of "spatial orientation" abilities (i.e. initial signs of dementia) is linked to a potential increase in dependency (Marquardt, 2011); and age-related visual decline is among the main factors of falling hazard (Torrington & Tregenza, 2007). Visuo-perceptual abilities, affected by ageing vision and brain damage from dementia, may lead to environmental mistakes: illusions, misperceptions and misidentifications (AS, 2013). Thus, dementia-friendly design of the indoor visual environment aims to reduce visuo-perceptual distortions, minimise behavioural issues by removing environmental triggers (Bidewell & Chang, 2011) and support physical performance by lessening the falling hazard, facilitating wayfinding and aiding task performance (DSDC, 2011; McNair et al., 2013).

Non-visual effects of light

Living organisms' biological processes are adjusted by daily exogenous patterns linked to their circadian clock (being the light/dark cycle the main regulator); particularly, mammalians' physiological functions such as melatonin secretion, the endogenous regulator of biological functions. Its production and release is regulated by the suprachiasmatic nuclei (SCN) responding to blue photosensitive retinal ganglion cells stimuli (melanopsin) that are activated by short-wavelength light (Berson et al., 2002). Pineal melatonin secretion occurs at night, between 02.00 and 04.00 in circadian regulated individuals (Pauley, 2004), but age-related alterations have been found in both seniors (Dick, 2013) and AD patients (Skene & Swaab, 2003). Partly because of less short-wavelength light reaching the retina (Herljevic et al., 2005) and reduced SCN functioning (Mishima et al., 1999) and partly due to indoor environments where E_V is not enough to entrain the circadian clock (Boyce, 2010), particularly in seniors' homes and residential care settings (Aarts & Westerlaken, 2005). Moreover, circadian disruptions have been reported in seniors with AD when compared to healthy older adults (Figueiro & Rea, 2011).

Daylight

Light therapy may assist the entrainment of circadian rhythms subject to light levels, light spectrum and exposure duration (Skene & Swaab, 2003; Figueiro, 2008). Daylight exposure may regulate the circadian cycle (its spectrum stimulates retinal visual receptors and melanopsin) while enhancing colour rendition (Altomonte, 2008). Due to the temporary availability and indoor variation of daylight, a supplement of artificial lighting is required (Figueiro, 2008) and setbacks of daylight (e.g. glare) need to be tackled from design (Leslie, 2003).

Dementia-friendly guidelines recommend a daylight factor (DF) above the threshold of 5% if the space only relies on daylight (McNair et al., 2013). DF is a static metric calculated under CIE overcast sky, considering neither sunlight nor dynamic parameters (i.e. place, orientation and time of day) (Mardaljevic et al., 2009). Therefore, is a useful metric to study daylight availability (Reinhart, 2011) but it does not support a climate-based approach to design. The use of dynamic metrics (i.e. daylight autonomy - DA and useful daylight illuminance - UDI), incorporates sunlight contribution and orientation (ibid) into the design, being the key factors to tackle glare, reflections, shadows and summer overheating issues (Leslie, 2003) from the design stage.

RESEARCH METHODOLOGY

This research was based on the literature review, fieldwork and BPS. The on-site assessments used a qualitative approach to indoor visual environments (i.e. colour contrast and patterns) and a quantitative technique to evaluate lighting parameters (i.e. E_H, E_V and CCT). BPS was conducted to evaluate daylight availability. The study, focused on the Ártabra urban region (Galicia, Spain), assesses social and public day care centres for people with ADOD. Only detached facilities recently purposed-refurbished were considered: two in A Coruña and one in Ferrol. Although the window layouts differ, double-glazing with indoor blinds is a shared solution; only centre 1 has outdoor louvres. Four of the six common rooms have a one-sided external facade, but rooms 2.1 and 3.1 have two outer facades. The window-to-wall ratio (WWR) varies from 0.29 to 0.99 (Table 2).

The field study was completed in July to evaluate the lighting conditions during the whole working day. Although daylight contribution is higher in summer, it is also the most feasible time to assess the mix of daylight and artificial lighting during afternoon hours. As the aim of the research was to evaluate the indoor environment as used, measurements were made without changing the lighting scheme.

Permission was obtained from each centre manager after being informed of both research objectives and methodology. Assessments of occupied rooms were conducted in the presence of one member of staff without disturbing the users. Managed care premises were dismissed due to ethical and medical reasons.

Indoor visual environment assessment

A qualitative study of the indoor visual layout was conducted in common rooms, corridors and toilets, using a checklist compiled from the literature review (Table 1). Results were analysed using descriptive statistics for comparisons between the three centres.

Table 1 Number of criteria for the qualitative study

Space	Sample number	DSDC 2011		Other literature
		Essential	Recommended	
Common rooms	n = 6	3	10	9
Corridors	n = 3	2	9	10
Toilets	n = 4	10	8	9

Indoor lighting assessment

Measuring points, selected according to each room's layout, followed the criteria of assessing three points of a central line perpendicular to the facade. In centre 1, the duplicity of common rooms allowed to measure every metre in the room less time occupied.

1. E_H at working plane (WP) height (0.80 m) was analysed from a visual- performance perspective, with the lux meter parallel to the ceiling.
2. E_V was assessed at standard eye height (1.25 m) using a photobiological approach, with the lux meter parallel to the window to consider angle and direction of viewing (Bellia et al., 2011).

Table 2 Common rooms studied and measurement details

Day care centre	Common room studied			Measurement period		
	Room code	Window orientation	WWR	Date	Times	Weather conditions
1	1.1	West	0.29	17th July 2014	10.00 to 13.30 16.00 to 19.30	Sunny sky: 10.00 to 12.25 Overcast sky: 12.25 to 18.00 Sunny sky: 18.00 to 19.30
	1.2	East	0.29			
2	2.1	South + West	0.90	18th July 2014	10.00 to 19.30	Overcast sky
	2.2	West	0.49			
3	3.1	South + West	0.99	21st July 2014	10.00 to 19.30	Sunny sky
	3.2	West	0.99			

3. CCT, assessed like E_V, was included due to its link to the light wavelength.

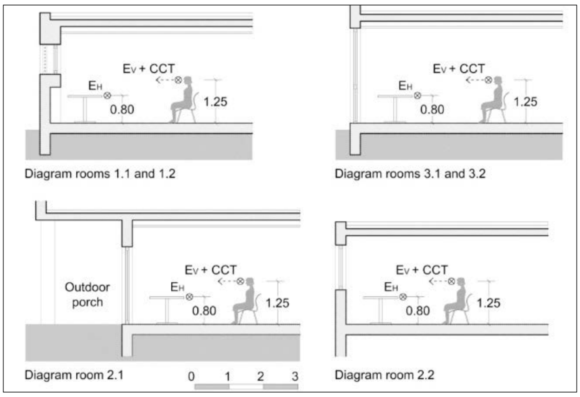

Figure 1 Measurement heights and gaze direction

E_H and E_V were measured using a Hagner Digital Luxmeter, model E2 (0.1 – 199.9 lux; accuracy: ±3% for all usual light sources within a temperature range from -5 ºC to +55 ºC). CCT was determined through digital imaging (RAW file from a Canon EOS 600D camera; 2,500 - 10,000 K, ±50 K) and computer processing (Camera Raw 8.4 plug-in for Adobe Photoshop CS6). E_H, E_V and CCT values were plotted against metrics thresholds (Table 3) using descriptive statistics to compare the six common rooms.

Table 3 Thresholds of E_H, E_V and CCT

E_H (lux)	≥ 300 lux	≥ 500 lux	≥ 700 lux	≥ 1000 lux
E_V (lux)	≥ 400 lux	≥ 1000 lux	≥ 3000 lux	
CCT (K)	≥ 5000 lux	≥ 6500 lux		

Daylight

BPS was conducted with IESve 2014 student version, using RadianceIES to obtain E_H values (Table 4), due to its simulation accuracy (Ibarra & Reinhart, 2009). To validate the models, survey settings were defined and the degree of similarity between BPS and field values was graphically and quantitatively evaluated.

Table 4 RadianceIES calculation settings

Ambient bounces	Ambient accuracy	Ambient resolution	Ambient divisions	Ambient super samples
7	0.1	521	1024	512
Iversen et al. (2013)	IESve default settings for maximum image quality calculations			

Table 5 IESve Dynamic simulation (beta) parameters

SPATIAL DAYLIGHT AUTONOMY (sDA)				
Analysis period	Target			
08:00 to 18:00	> 500 lux during more than 50 % of the year			
USEFUL DAYLIGHT ILLUMINANCE (UDI)				
Analysis period	Thresholds			
	Fell-short	Supplementary	Autonomous	Exceeded
Year	<500 lx	500-1000 lx	1000–2500 lx	>2500 lx

DF at the WP level was calculated at noon on three days of the year (vernal equinox; winter and summer solstices), using the illuminance WP data option (0.50 x 0.50 m grid at 0.80 m) under CIE standard overcast sky. DF results were analysed using descriptive statistics to compare the six common rooms.

Finally, room 1.2 (lower daylight performance) was assessed to investigate how BPS can underpin the daylight design in dementia-friendly environments, using sDA and UDI (Table 5).

INDOOR VISUAL ENVIRONMENT

Methodological limitations

Qualitative answers regarding daylight conditions were coded and ranked for statistical analysis and supplemented by measuring the lighting parameters in the common rooms (see *Indoor Lighting)*. However, measuring during a non working day would allow a broader survey including corridors and toilets.

Qualitative research also has implications concerning the evaluation of colour contrast, which has been assessed by the author through visual comparison and therefore may have been biased (e.g. due to the author's sight). In order to quantify the colour contrast strategies, it is considered that the guidance provided in BS 8300:2009+A1:2010 (BSI, 2010), as well as required surfaces' light reflectance values (LRV) should be included within the dementia-design guidelines.

Analysis of the indoor visual design

Common rooms and corridors follow dementia-friendly design principles in 86% and 71% of the criteria studied (respectively), but only 40% of the checklist criteria are found in the toilets (Figure 2).

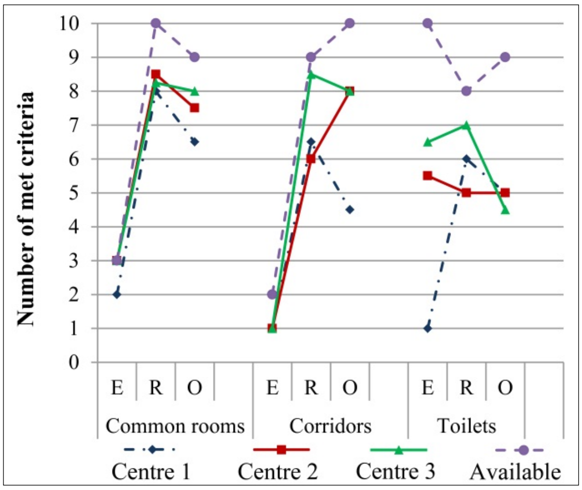

Figure 2 Number of met criteria (E: essentials, R: recommendations; O: other criteria).

Glare management is provided in all centres by light blinds, avoiding excess while allowing daylight in.

The research has highlighted that strategies using colour contrast are barely implemented. The analysis of the results suggests that contrast between users' doors and walls is incidental; and only centre 3 uses a purposely camouflaging strategy. This solution was proposed to the staff to tackle an exit-seeking behaviour detected in room 2.2 (Marquardt, 2011).

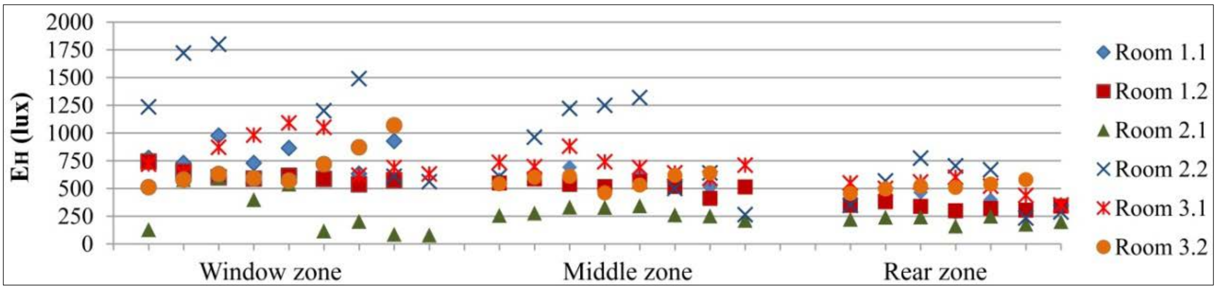

Figure 3 E_H values within the window, middle and rear zones

The lowest compliance with the criteria was found in the toilets, where yellow-red colours to assist the users have not been implemented. Besides, the toilets of centre 1 with their white-colour uniformity, were adversely reported by the staff: "Sometimes, men confuse the waste bin with the toilet. Maybe because everything is white". Although no other situation lacking visual dementia-friendly design criteria was claimed while conducting this study, similar research in Irish day care centres found misinterpretations caused by colour differences within an object (Cahill et al., 2003). It is unclear whether the lack of complaints regarding insufficient visual aids is the result of the staff continuosly monitoring the users, or if the lack of a supportive environment generates the need for such sustained guidance (Lyman, 1989).

Finally, outdoor views when sitting inside are possible in centres 2 and 3, but not in centre 1. Large windows, allowing interaction with the outdoor environment, are recommended not only in order to enhance users' contact with reality (Altomonte, 2008) but also to reduce sundowning behaviours (Willatt, 2011). However, during this research it has been reported that there may be the need to pull down blinds to reduce behavioural disturbances, such as "agitation due to strong winds outside or sundowning during winter afternoons" or "the lack of self-recognition when seeing their reflection in the window (mirror effect)". Thus, a design with large windows may be counterproductive from a behavioural point of view and should be combined with other solutions.

INDOOR LIGHTING

Methodological limitations

Field studies were conducted in mid-July (due to the highest contribution of daylight in the year) and during working hours, so only two rooms per centre were studied and the measuring points, as well as the lighting layout, were conditioned by the occupancy.

Whereas lighting for visual tasks is well understood and applied to building design, the circadian effects of light are still on their way to comprehension for building use (Boyce, 2010; Konis, 2014) and benchmarks and metrics for non-visual effects are still to be defined (Bellia et al., 2011; Konis, 2014).

In this research, E_V at the eye level was measured with a lux meter because there is no commercial device to measure the retinal illuminance and consider the light spectrum (Aarts & Westerlaken, 2005). Lux values are photopic measurements and they do not indicate circadian efficiency (Webb, 2006), but estimation is possible if combined with CCT values. Therefore, the measurements made in this research are a solid base to conduct a preliminary analysis of the non-visual effects of light.

Analysis of E_H values

Values of E_H ranging from 300 lux to 700 lux at the WP level (Figure 3) were achieved mainly due to the use of electrical lighting (rooms 1.1 and 1.2), daylight (room 2.2) or a combination of both (rooms 3.1 and 3.2). A particular case is room 2.1, where values above 300 lux were only achieved in 7 of 27 measurements due to insufficient daylight availability and poor electrical light substitution. In addition, although task performance was generally enhanced up to 3 metres away from the window, the area under daylight conditions should be up to 5 metres under an optimum daylight design (Leslie, 2003).

Cornelissen et al. (1995) conclude that, while high light levels are related to better visual performance, some visually impaired subjects perform worse under medium or high light levels due to severe discomfort. Evans et al. (2009) point that personal preferences may also affect the optimum light levels for task performance. Both studies suggest a personalised design, which is not possible for community centres like the ones studied in this research.

Finally, since the fieldwork was conducted in mid-July, lower values should be expected in winter. Thus, spaces with higher dependency on daylight may present problems to reach the needed thresholds.

Analysis of E_V and CCT values

Levels of E_V, particularly within the window zone, suggest circadian entrainment in rooms 1.1, 2.2, 3.1 and 3.2 if gazing towards the window, with values above the minimum threshold of 400 lux in 78%, 89%, 100% and 89% of the cases respectively. Whereas rooms 1.2 and 2.1only exceeded 400 lux in 19% and 6% of the cases (Figure 4).The contribution of natural light provides high values of CCT, from 6000 K under CIE overcast sky to 7000-20000 K under a cloudy sky (Chain et al., 2001). Thus, measurements above the circadian 5000 K threshold were found in rooms with higher WWR: 93% in room 2.1 and 100% in rooms 2.2, 3.1 and 3.2.

Significant values above 6500 K were only found in room 3.1 due to a high WWR in two different facades. CCT values depend upon indoor temperature (van Hoof et al., 2009), although this is not significant in this research since the average indoor temperature of the centres was constant (24 ºC).

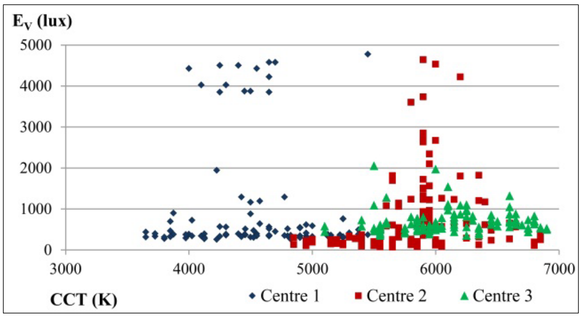

Figure 4 Fieldwork values of E_V and CCT

INDOOR DAYLIGHT

Methodological limitations

Assumptions and generalisations were thoroughly implemented in the scene modelling process, following Reinhart's "daylight simulation checklist" (Reinhart, 2011) aiming to get representative results of the real situation. Although the conventional CIE overcast sky does not consider sunlight or dynamic factors, the latest versions of IESve include the CIE standard overcast conditions to consider location, time of year and hour of the day, generating more realistic results (IES support team, n.d.). Nonetheless, Iversen et al. (2013) evaluated daylight accuracy calculations among several simulation programs and IESve software was found to deliver significantly lower values than other simulation programs. They linked this inaccuracy to inappropriate interpretations of daylight obstructions when using 3 ambient bounces (default settings), and thus recommending the use of 7 ambient bounces (Table 4).

Even so, difficulties modelling the scene were found, mainly because material's properties set into IESve ModelIT (e.g. glass transmittance) are not directly imported into RadianceIES. Consequently, several simulations were conducted until the geometry and the material´s properties were in accordance with the real ones. In the case of centres 1 and 2, the E_H simulations' outcomes match the field measurements under CIE standard overcast sky, with a difference below 10%. However, the simulation of centre 3 under a sunny sky (Table 2) did not match the E_H measured values in the window zone of room 3.1, where BPS values are 47% higher than measured values (Figure 5). One possible reason for this disagreement could be that glass light transmittance, indoor material reflectance and artificial lights were estimated from observation. Nevertheless, equal settings were applied in room 3.2, where the difference of values in window zone is below 3%. Thus, since centre 3 is located in a rural environment, it is hypothesised that the existence of outdoor elements blocked both daylight and sunlight within a bigger radius than the scene that was modelled in IESve (e.g. mountains) and a model including such topographical features would enhance the BPS. This was not the case for centres 1 and 2, because they are located within urban environments and all external features were included in the scene.

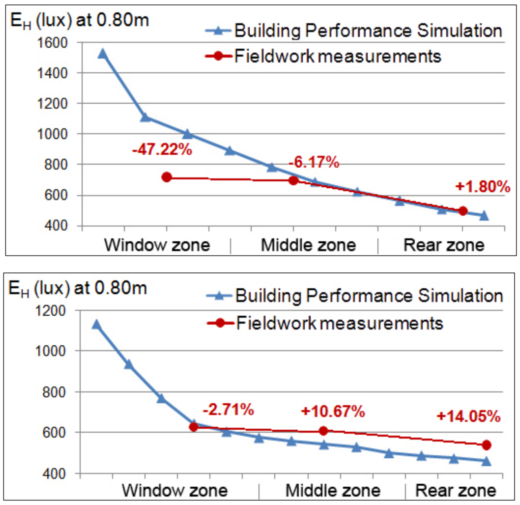

Figure 5 Comparison between BPS and site measurements. Rooms 3.1 (above) and 3.2 (below)

Regarding room 3.2, E_H field values are higher than BPS (11% middle zone; 14% rear zone). This discrepancy is attributed to an underestimation of artificial lighting so that a general agreement between BPS and fieldwork may be concluded.

Although RadianceIES can calculate E_V in a specific point (perspective settings), only E_H was simulated since both DF and dynamic metrics (sDA and UDI) are metrics related to a WP level horizontal grid.

Daylight factor

Current daylight availability was assessed in the area between the window and five metres away (Leslie, 2003) using BPS. As expected, the DF values are higher in the window zones, and the larger the size of the window, the better the DF results. Thus, room 3.1 is the only room where the average DF is above the 5% benchmark (Figure 6), thanks to a WWR of 0.99 in two facades. In centre 1, both winter solstice and equinox showed DF=0.

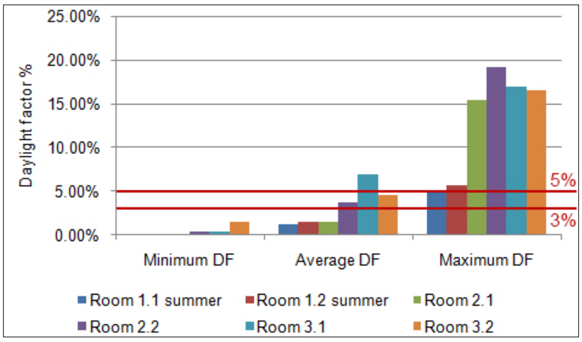

Figure 6 Daylight Factor in common rooms

Windows connect indoor and outdoor environments, having not only visual, thermal and acoustical but also psychological implications that should be considered through holistic design. Whereas a tall window gives complete information about the external environment (from the ground to the sky) and introduces light deeper into the room but can generate overheating due to sunlight, horizontal windows provide better views (Altomonte, 2008).

General recommendations for facade design are to maximise south-north facades, to use skylights (uniform light, CCT ≥ 5000 K), to have windows located in more than one facade, to avoid direct sunlight and to use light indoor surfaces (Leslie, 2003). Among the day care centres studied, the solution broadly used was light reflective indoor materials and control of direct sunlight through indoor blinds, as well as openings in two facades in the case of room 3.1. Nevertheless, no skylights were included and building orientations were merely aligned with the road. Thus, these two design principles were included in the BPS conducted.

Regarding energy savings, artificial light dimmers linked to daylight sensors are the most efficient solution while allowing personal configurations (Altomonte 2008). However, caution should be applied when using these systems for people with ADOD, since misunderstanding of their functioning may cause "confusion and anxiety" (Van Hoof & Kort, 2009). The present research is focused on visual aspects, so no thermal evaluation was made.

BPS: enhancing dementia-friendly daylight design

Following general guidance and the possibility to use daylight dynamic metrics in BPS (sDA and UDI), a study of the room with lower daylight performance (room 1.2) was conducted using IESve RadianceIES to evaluate applicable daylight strategies. Several simulations were made, studying different window layouts, orientation and outdoor elements (Table 6).

Table 6 BPS settings

Code	Orientation	WWR	Sill height	Notes
BC	East	0.29	1.41 m	Base case
S1	East	0.29	1.41 m	External louvres and internal window recess removed
S2	East	0.29	1.00 m	
S3	East	0.49	1.00 m	
S4	South	0.49	1.00 m	
S5	North	0.49	1.00 m	
S6	West	0.49	1.00 m	
S7	East	0.29	1.00 m	Two north oriented skylights

1. Spatial Daylight Autonomy (sDA)

DA is "the percentage of the occupied hours of the year when a minimum illuminance threshold is met by daylight alone" (Reinhart & Walkenhorst, 2001). The aim of the BPS was to obtain more than 500 lux during more than 50% of the year in the maximum room area posible, studied at WP level (Table 5). The first simulation shows the existing results with a sDA of 23% (base case). An improvement of 20% is reached by removing external louvres and internal window recesses (S1) and both strategies were maintained throughout the rest of the simulations. Lowering the window from 1.41 m to 1.00 m (in order to allow outdoor views) had a minimal impact on improving daylight levels (S2), whereas raising the WWR from 0.29 to 0.49 increases daylight levels. These two parameters were tested in the four orientations against the S2 benchmark (sDA = 41%), ranging from an improvement of 28% for the existing east orientation (S3); increment of 11% with north orientation (S4); increase of 51% with south orientation (S5) and improvement of 23% with west orientation (S6). The final test, using both the existing WWR and orientation, considered a windowsill height of 1m (outdoor views) and two north oriented skylights (3.5 m long x 0.7 m height; 1.2 m distance to the north wall and 1.7 m distance between them), giving a sDA of 98%.

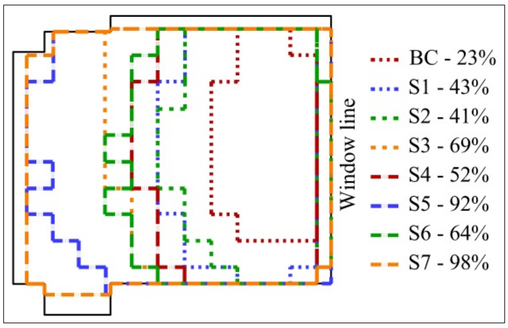

Figure7 sDA in room 1.2

2. Useful Daylight Autonomy (UDI)

Simulations 5 and 7 showed the highest levels of sDA (92% and 98% respectively). However, it is hypothesised that south oriented windows with WWR=0.49 (S5) would imply glare risk whereas north oriented skylights would introduce neutral daylight into the room (S7). Thus, UDI was studied at WP level in order to include the risk of glare in the daylight assessment, analysing the room area that is above the threshold of 2,500 lux during more time of the year. If a thermal evaluation were to be made, UDI would also support the study of possible overheating (Nabil & Mardaljevic, 2006).

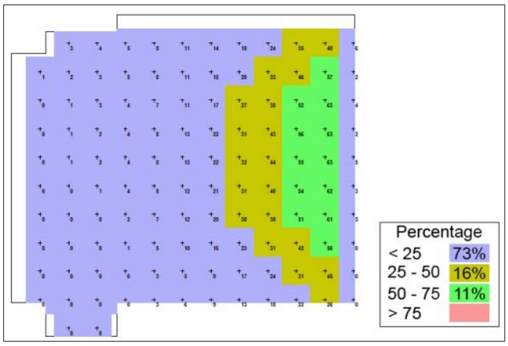

Figure 8 S5 - UDI values > 2,500 lux in room 1.2

In the case of S5, an area of 11% of the room would be above the glare risk threshold from 6 to 9 months every year (50% - 75% of the year), whereas in the case of S7, the whole room area would be under risk glare less than 3 months per year (< 25% of the year).

Although there are examples of dementia-friendly accredited buildings, such as highly commended centres by the Dementia Services Development Centre in the UK, no examples of projects relying on BPS have been found. Since the use of climate-based metrics has been found to be a suitable tool for designing daylight spaces, it is considered that dementia-design guidelines should require the use of BPS during the daylight design process.

Finally, it has been shown that a daylight space, can be obtained by using north oriented skylights with horizontal windows, providing high levels of uniform light (low glare risk) while using a modest WWR (allowing outdoor views but also window camouflaging in case of users' agitation caused by external events or mirror effect).

CONCLUSIONS

Age-related visual decay and diseases, combined with cognitive dementia decline and brain damage, result in the reduction of visuo-perceptual ability and decreased physical performance. Dementia-friendly design considers these processes and aims to create a supportive environment. The research has found that a notable qualitative improvement can be achieved by using colour contrast strategies and yellow-red colour schemes to aid the users and reduce their sustained monitoring. Moreover, a quantitative enhancement can be obtained by establishing LRV thresholds within the dementia-design criteria.

Although E_H values at WP level are generally above the 500-lux threshold, reliance on artificial lighting has been proved and only three rooms showed daylight engagement (2.2, 3.1 and 3.2). High E_V and CCT values to entrain circadian rhythms are only met in rooms with high daylight contribution and therefore centres 2 and 3 are within the supportive range whereas centre 1 falls below the benchmarks. Based on BPS and climate-based metrics, the use of north oriented skylights with horizontal windows is considered a valid dementia-friendly solution. Thus, BPS should be included into the dementia-friendly design requirements, since its implementation can enhance daylight contribution from the early stages of the architectural design. However, further research is required to define benchmarks and metrics for non-visual effects of light in order to add a photobiological approach to the BPS capabilities.

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