

Arizona State University Green Apple Project

Healthy Housing for Seniors



Healthy Housing for Seniors

- ❑ Indoor Environmental Quality
- ❑ Housing & Community Design for Active Aging
- ❑ Assistive Technologies in the Home



Components of Healthy Housing



Aging & Generational Attributes

Physiological Changes

Joints, Bones, Muscles

Respiratory Systems

Sensory

Cognitive Changes

Attention, Reactions

Memory

Emotional Challenges

Depression

Hormonal

Cultural Stereotypes

“The Greenest Generation”



INDOOR ENVIRONMENTAL QUALITY

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Overview

1. Indoor Thermal Conditions

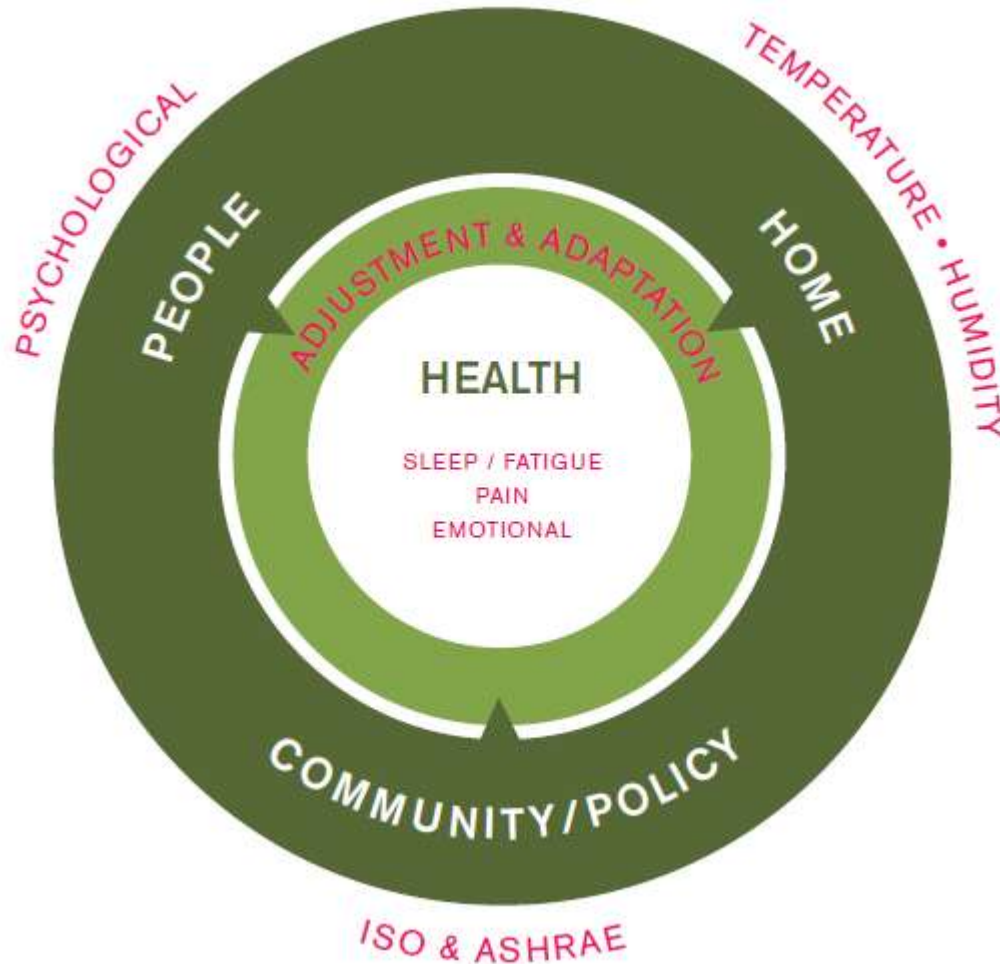
- a) Air Temperature
- b) Relative Humidity

2. Indoor Air Quality

- a) Particle Matter
- b) Aldehydes



Components of Thermal Conditions



STANDARDS

1. **ASHRAE 55-2010**
 - a) Sets parameters to provide adequate and productive thermal conditions
 - b) ASHRAE 62

2. **ISO/TS 14415**, addresses conditions of the working ill and disable
 - a) Describes the wide range of responses of people with special needs.



Temperature & Comfort

“Thermal comfort, or the lack of it, is well understood to be one of the most significant restrictors to the health and general wellbeing of the older people”
(Novieto & Zhang, 2010)

- a) Activity levels are affected
- b) Behavior
- c) Sleeping patterns
- d) Emotional responses



Temperature & Health

1. Novieto and Zhang

- a) More prone to thermal related comfort
- b) Relationships between aging and thermal conditions, aging and gradual changes, thermoregulation

2. Van Hoof and Hensen

- a) Older adults require higher ambient temperatures, about 2°C

3. Parsons

- a) Standards do not consider older adults' requirements
- b) Fitness state decreases, mortality increases on adults 40 and older.



Relationship - Housing & Health

1. Housing/home conditions directly affect health and the ability for independent living for elderly populations
2. Casual links between housing and health include: respiratory conditions, heart disease, cerebrovascular disease, injuries, mental health and some cancers
3. Mortality increases with high temperatures
4. Higher healthcare cost

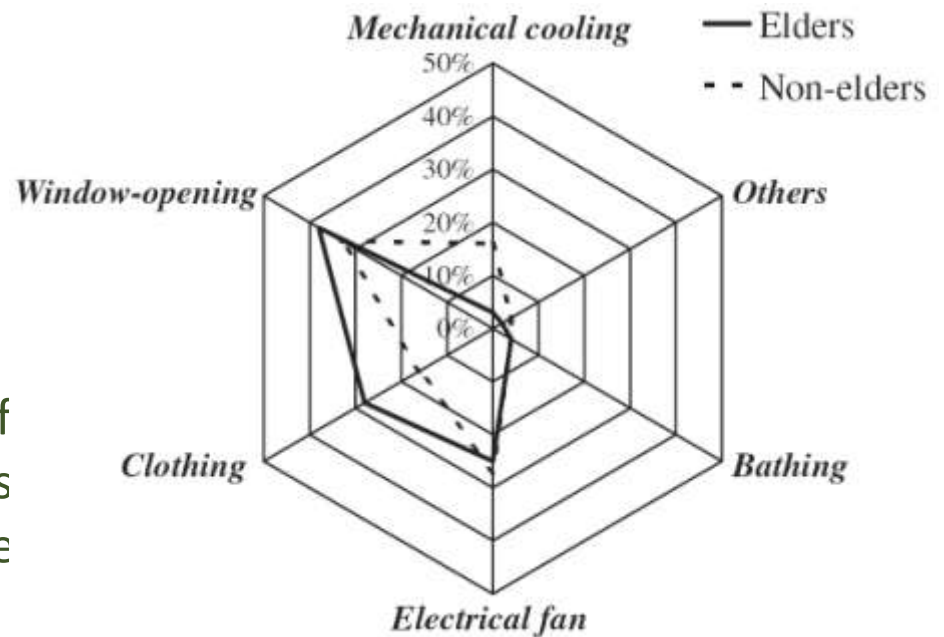


*Image credit:
bocahomecareservices.com*



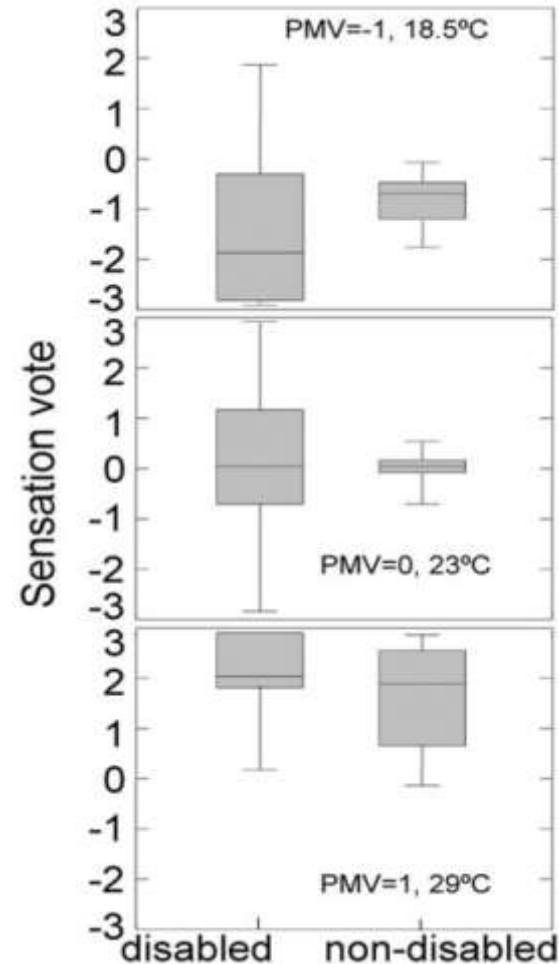
Temperature & Adaptive Behavior

1. Age groups often choose different adaptive strategies for comfort
2. Window opening (summer) and clothing adjustment (winter)
3. Comfort temperature range of 80% of the elderly sample was found to be narrower than the younger population. (23.2-27.1° C (73.7-80.78° F), vs 23.0–28.6° C (73.4-83.5° F))



Thermal Differences due to Age

1. PMV index over estimates the comfort vote for elderly populations by 0.5 scale units
2. All things being equal (uniform clo and activity levels) elderly prefer higher ambient temperatures
3. Under constant temperature experiments older adults preferred warmer temperatures than younger adults
4. Moderate temperature drifts are not seen as unacceptable thermal conditions.



IAQ Overview

1. Thresholds

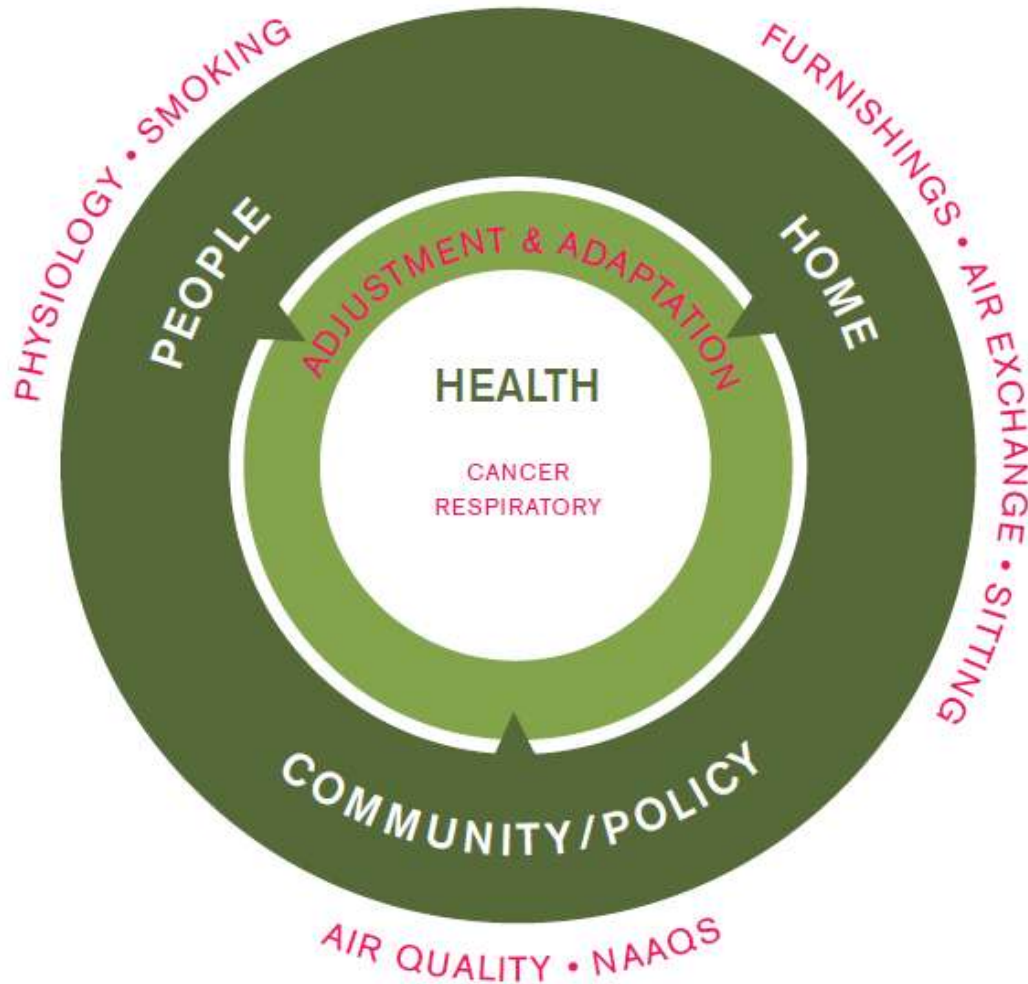
- a) Formaldehyde
- b) Particle Matter

2. IAQ and Health

- a) PM and health Impacts
- b) Indoor formaldehyde



Indoor Air Quality Components



PM exposure guidelines

1. While WHO and other guidelines govern numerous pollutants, do not specifically quantify PM Exposure Guidelines.
2. Standards for ambient (outdoor) air quality cover a range of sizes and time periods.
3. Ambient Air Quality Standards range from:
 - a) $35 \mu\text{g}/\text{m}^3$ for PM_{2.5} over 24-hrs (US NAAQS)
 - b) $50 \mu\text{g}/\text{m}^3$ for PM₁₀ annual average (US NAAQS)
 - c) $50 \mu\text{g}/\text{m}^3$ for PM₁₀ over 24-hr (EU)

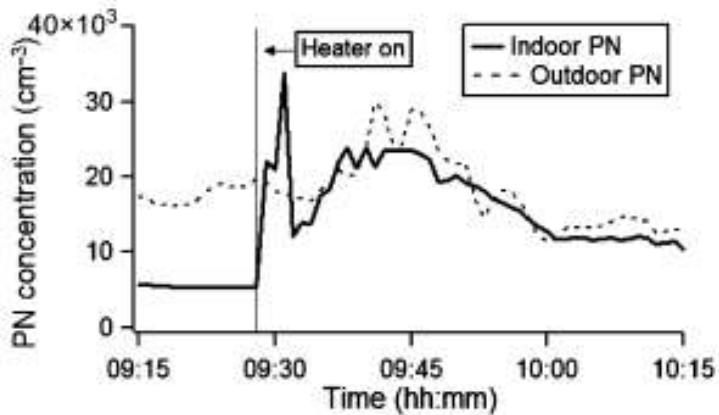
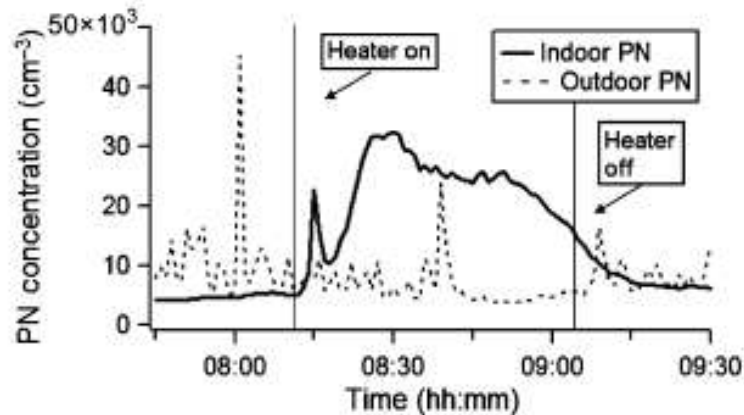
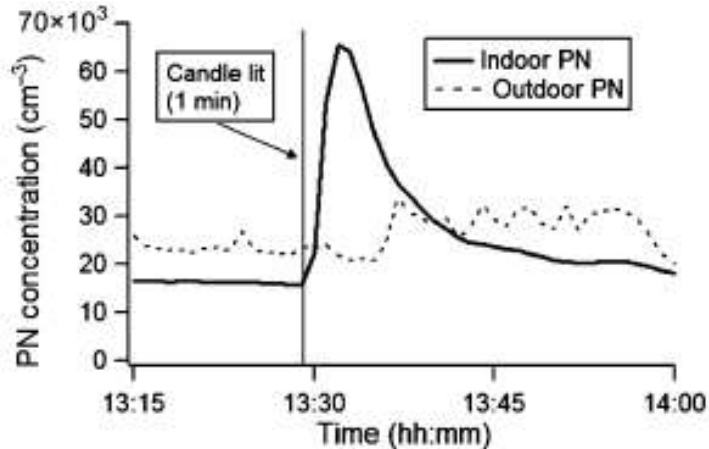
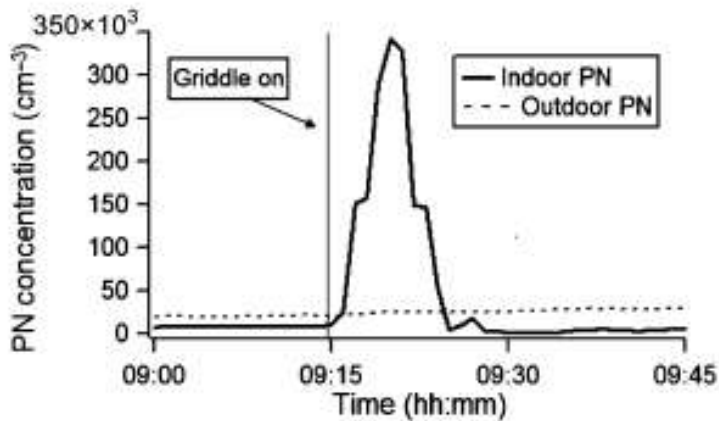


PM & Health Impacts

1. Numerous studies have quantified the increase risk of health impacts from a $10 \mu\text{g m}^{-3}$ increase in PM levels.
2. For PM₁₀, an increase in ambient PM₁₀ of $10 \mu\text{g m}^{-3}$ will lead to:
 - a) An increase daily mortality of 0.5-0.6% (Samet et al. 2000)
 - b) Increased hospitalization for asthma of 1.0-1.5% (Zanobetti et al. 2000)
 - c) Increased hospitalization for chronic obstructive pulmonary disease or cardiovascular disease of 0.5-1.1% (Atkinson et al. 2001)



PM sources



Formaldehyde Thresholds

Table 5. International Guideline Values and Recommendations for Formaldehyde in Indoor Air

country	year issued	value		comments
Australia	1982 ²²⁶	0.1 ppm	120 $\mu\text{g m}^{-3}$	short-duration
	2006 ²²⁷	0.08 ppm	100 $\mu\text{g m}^{-3}$	
Canada	1987 ²²⁰	0.1 ppm	120 $\mu\text{g m}^{-3}$	action level
	1987	0.05 ppm	60 $\mu\text{g m}^{-3}$	target level
	2005 ²²	0.1 ppm	123 $\mu\text{g m}^{-3}$	1 h
	2005	0.04 ppm	50 $\mu\text{g m}^{-3}$	8 h
China	2003 ²²⁵	0.08 ppm	100 $\mu\text{g m}^{-3}$	1 h average
Denmark	1990 ²⁰⁷		0.15 mg m^{-3}	
Finland	2001 ²⁰⁹		30 $\mu\text{g m}^{-3}$	S1
			50 $\mu\text{g m}^{-3}$	S2
			100 $\mu\text{g m}^{-3}$	S3
France	2008 ²¹³		50 $\mu\text{g m}^{-3}$	2 h (proposed)
			10 $\mu\text{g m}^{-3}$	long-term exposure (proposed)
Germany	1977 ²¹⁶	0.1 ppm		
Singapore	1996 ²²⁴	0.1 ppm	120 $\mu\text{g m}^{-3}$	8 h
Hong Kong	1999	0.025 ppm	30 $\mu\text{g m}^{-3}$	level 1 (8 h)
		0.081 ppm	100 $\mu\text{g m}^{-3}$	level 2 (8 h)
		0.3 ppm	370 $\mu\text{g m}^{-3}$	level 3 (8 h)
	2003 ²²¹	0.025 ppm	30 $\mu\text{g m}^{-3}$	excellent
		0.081 ppm	100 $\mu\text{g m}^{-3}$	good
Japan	1997 ²²³	0.08 ppm	100 $\mu\text{g m}^{-3}$	0.5 h
Korea	2004 ²²²	0.1 ppm	120 $\mu\text{g m}^{-3}$	8 h
Norway	1990 ²¹⁰	0.05 ppm	60 $\mu\text{g m}^{-3}$	24 h average
	1999 ²¹¹	0.05 ppm	100 $\mu\text{g m}^{-3}$	30 min average
Sweden	2000	0.08 ppm	100 $\mu\text{g m}^{-3}$	adopted from WHO
Poland	1996 ²¹⁵	0.04 ppm	50 $\mu\text{g m}^{-3}$	category A: 24 h
		0.08 ppm	100 $\mu\text{g m}^{-3}$	category B: 8–10 h
U.K.	2004 ²⁰⁸		100 $\mu\text{g m}^{-3}$	0.5 h
USA (California)	1991 ²¹⁷	0.1 ppm	120 $\mu\text{g m}^{-3}$	action level
		0.05 ppm	60 $\mu\text{g m}^{-3}$	target level (ALARA) ^a
	1999 ²⁰³	0.076 ppm	94 $\mu\text{g m}^{-3}$	1 h (acute REL) ^b
	2004 ²¹⁹	0.027 ppm	33 $\mu\text{g m}^{-3}$	8 h (interim REL)
	2005 ²¹⁸	0.002 ppm	3 $\mu\text{g m}^{-3}$	annual average (chronic REL)
WHO	1987 ²²⁸	0.08 ppm	100 $\mu\text{g m}^{-3}$	0.5 h average

^a ALARA = as low as reasonably achievable. ^b REL = reference exposure limit.



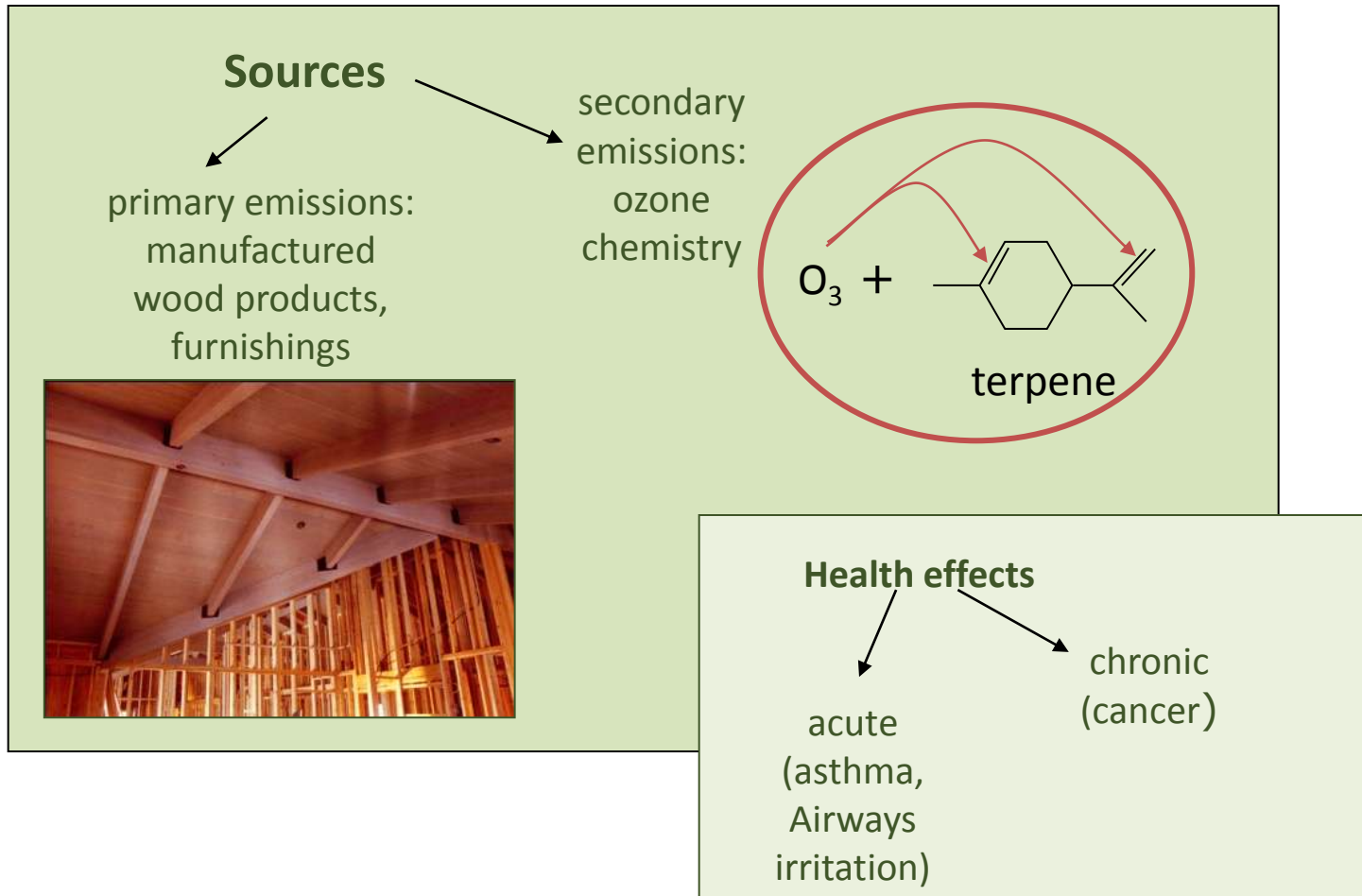
Formaldehyde Indoors

Table 7. Comparison of Formaldehyde Levels in Indoor Air as Determined in Different International Studies

continent/country	location	C _{indoor}	continent/country	location	C _{indoor}
Europe			USA (1989)	470 mobile homes	70 ppb
Germany (1991)	327 residences	55 $\mu\text{g m}^{-3}$ 106 $\mu\text{g m}^{-3}$	USA (2008)	360 travel trailers 90 park models 69 mobile homes	<30 to >300 ppb 81 ppb 44 ppb 57 ppb
Germany (2008)	586 residences	23.5 $\mu\text{g m}^{-3}$ 47.7 $\mu\text{g m}^{-3}$ 6.0 $\mu\text{g m}^{-3}$	Canada (2003)	151 homes (summary of 5 studies)	29.8 $\mu\text{g m}^{-3}$
Germany (2003)	14 office buildings, 1386 measurements	38 $\mu\text{g m}^{-3}$ 98 $\mu\text{g m}^{-3}$	Canada (2005)	59 residences	29.6 $\mu\text{g m}^{-3}$
Germany (2001)	180 Berlin residences	12–649 $\mu\text{g m}^{-3}$ 62 ppb	Canada (2008)	96 Quebec homes	9.6–90 $\mu\text{g m}^{-3}$
Germany (1995)	252 residences	8.8–11.5 $\mu\text{g m}^{-3}$	Latin America		
Germany (1993)	190 residences	25 $\mu\text{g m}^{-3}$	Brazil (2006)	academic institute	<1–82 $\mu\text{g m}^{-3}$ 7–8 $\mu\text{g m}^{-3}$ 5–9 $\mu\text{g m}^{-3}$
Austria (2002)	160 homes	46 $\mu\text{g m}^{-3}$ 468 $\mu\text{g m}^{-3}$ 40 $\mu\text{g m}^{-3}$	Mexico (2003)	different locations	4–122 $\mu\text{g m}^{-3}$
Switzerland (1992)	private residences	0–80 $\mu\text{g m}^{-3}$ 63–384 $\mu\text{g m}^{-3}$ 14–276 $\mu\text{g m}^{-3}$ 37 $\mu\text{g m}^{-3}$	Asia		
Denmark (1987)	14 Danish town halls	19, 21, 26 $\mu\text{g m}^{-3}$ 11 $\mu\text{g m}^{-3}$	Korea (2008)	52 classrooms summer 48 classrooms autumn 46 classrooms winter	70 ppb 40 ppb 60 ppb
Denmark (1991)	2 new twin apartments	8.3 $\mu\text{g m}^{-3}$ 23 $\mu\text{g m}^{-3}$ 29 $\mu\text{g m}^{-3}$ 3 $\mu\text{g m}^{-3}$	Korea (2008)	6 apartments	209–457 $\mu\text{g m}^{-3}$
Denmark (1992)	36 apartments	<3–72 $\mu\text{g m}^{-3}$ 20 $\mu\text{g m}^{-3}$	Korea (2009)	50 school buildings 45 school buildings	150 ppb 100 ppb
Finland (2006)	8 buildings	5.3–73.8 $\mu\text{g m}^{-3}$ 26.7 $\mu\text{g m}^{-3}$	Japan/Korea (2006)	292 new homes 60 new homes	134 $\mu\text{g m}^{-3}$ 86 $\mu\text{g m}^{-3}$
Finland (2009)	23 office buildings	34.4 $\mu\text{g m}^{-3}$ 78 $\mu\text{g m}^{-3}$	Japan (2006)	25 Shimizu residences 21 Shimizu residences 37 Nagoya residences	71.5 $\mu\text{g m}^{-3}$ 25.9 $\mu\text{g m}^{-3}$ 17.6 $\mu\text{g m}^{-3}$
Sweden (2004)	27 Uppsala dwellings	17.7–19.4 $\mu\text{g m}^{-3}$ 12.9–9.3 $\mu\text{g m}^{-3}$ 3.3–32.3 $\mu\text{g m}^{-3}$	Hong Kong (2002)	6 residential homes	11–24 $\mu\text{g m}^{-3}$
Sweden (2005)	64 bedrooms	11.1 ppb 16.1 ppb	Hong Kong (2006)	422 offices	32 $\mu\text{g m}^{-3}$
Sweden (2001)	181 classrooms	21–47 ppb 14–58 ppb	Hong Kong (2009)	100 homes	85.7 $\mu\text{g m}^{-3}$
France (2006)	Strasbourg libraries	19.6 $\mu\text{g m}^{-3}$ 14.3 $\mu\text{g m}^{-3}$ 20.1 $\mu\text{g m}^{-3}$ 32.5 $\mu\text{g m}^{-3}$ 30.5 $\mu\text{g m}^{-3}$ 34 $\mu\text{g m}^{-3}$	China (2004)	28 hotel ballrooms	29.7 $\mu\text{g m}^{-3}$
France (2006)	Strasbourg locations	0–2086 $\mu\text{g m}^{-3}$ 79.9 $\mu\text{g m}^{-3}$ 2.3–866.2 $\mu\text{g m}^{-3}$ 67.1 $\mu\text{g m}^{-3}$	China (2007)	public vehicles	13–94 $\mu\text{g m}^{-3}$
France (2008)	Strasbourg homes		Bangladesh (2007)	91 kitchens, impact on children	26.2 $\mu\text{g m}^{-3}$ 36.9 $\mu\text{g m}^{-3}$
France (2003)	61 Paris dwellings		Africa		
France (2009)	157–187 babies' homes		Egypt (2000)	294 Cairo residences	96.6 $\mu\text{g m}^{-3}$
Italy (2009)	20 homes		Australia/New Zealand		
Poland (2005)	5 office buildings		Australia (2002)	185 homes in Perth	1–166 ppb 20.4–23.8 ppb 3–38 $\mu\text{g m}^{-3}$
Turkey (2003)	399 kitchens in Ankara		Australia (2006)	4 schools	29 ppb
Turkey (2006)	25 Ankara dwellings		Australia (2000)	192 caravans	100 ppb
US/Canada			Other		
USA (1995)	14 residences		aircraft (simulated)	occupied cabin	8–10 ppb
USA (2000)	26 residences		submarine (2006)	submerged operation	<10 $\mu\text{g m}^{-3}$
USA (2000)	4 manufactured houses				
USA (2006)	7 site-built houses				
USA (2006)	different locations				
USA (2007)	234 homes				



Formaldehyde & Health Impacts



DESIGN FOR ACTIVE AGING

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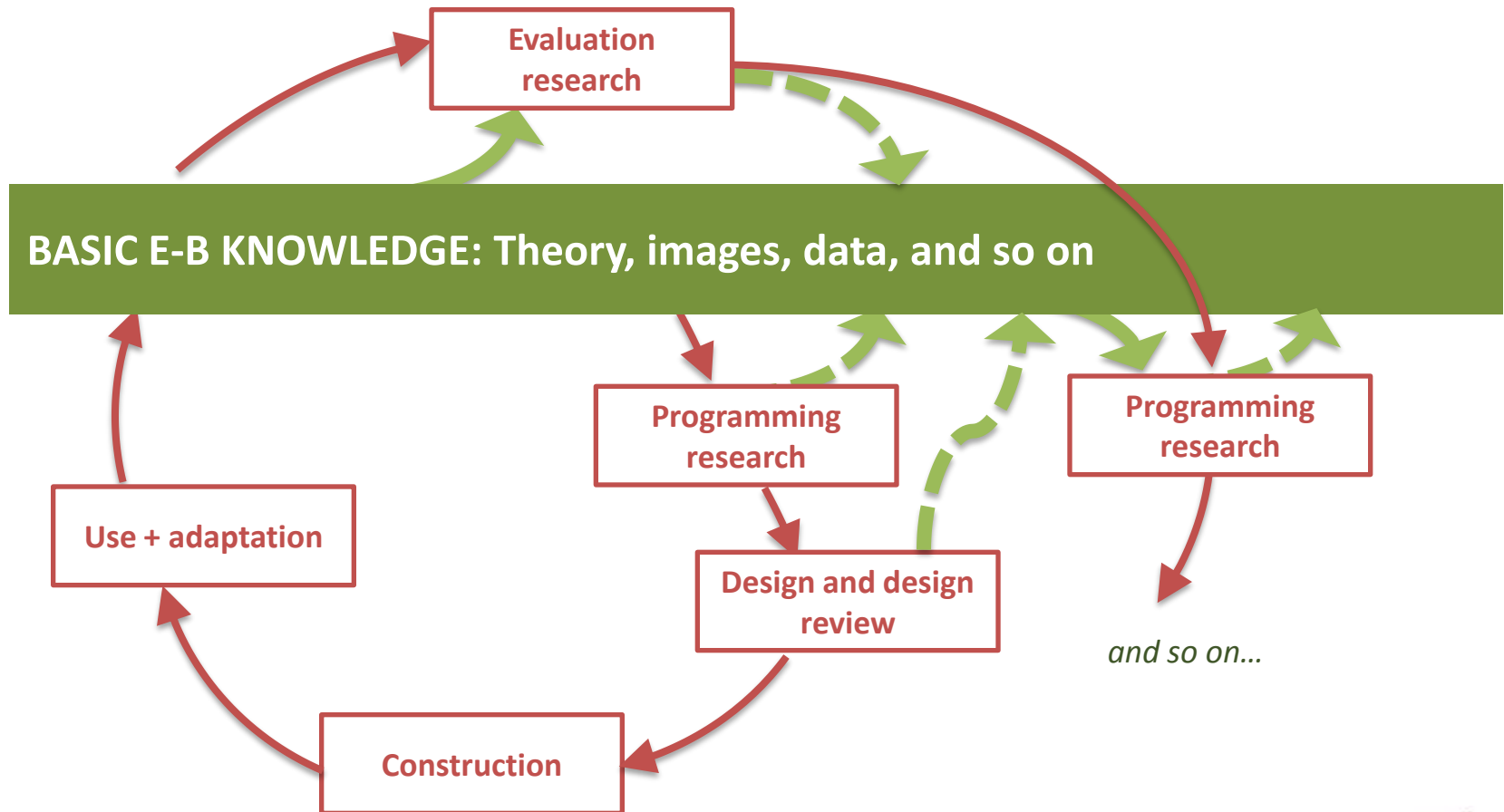
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Scientific Research v Design Research



Occasions for research/design cooperation in the design-process cycle.

From: Zeisel, J. (2006). *Inquiry by Design: Environment/Behavior/Neuroscience in Architecture, Interiors, Landscape, and Planning* (p. 36). New York: W. W. Norton & Co.



Active Aging

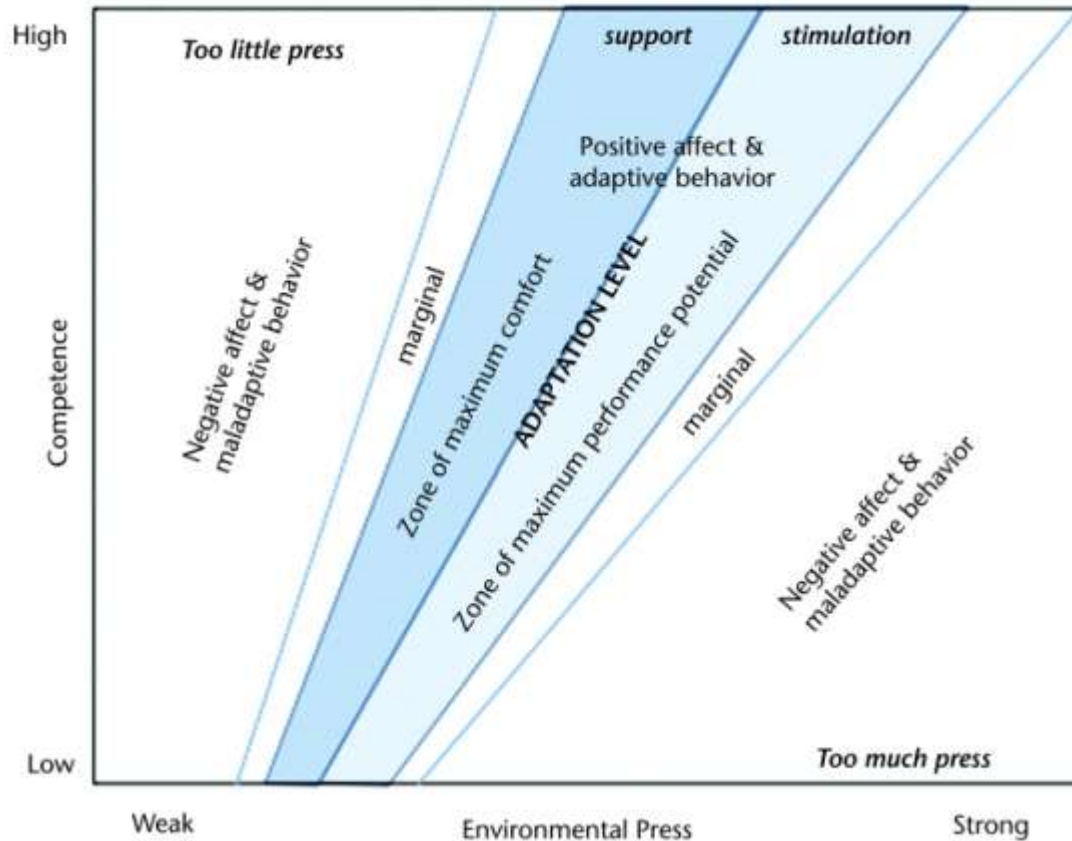
The desire, ability and opportunity for older adults to integrate physical activity into both structured and unstructured daily routines



Includes physical engagement in economic or socially productive activities



Environmental Press-Competence



From: Lawton, M.P. & Nahemow, L. (1973). Ecology and the aging process. In C. Eisdorfer & M.P. Lawton (Eds.), *Psychology of adult development and aging* (pp. 657-668). Washington, DC: American Psychological Association.



Secure Independence



Secure Independence

Safety from Falls & the Unfamiliar

Secure only doors to high-risk areas

Secure outdoor areas

Smooth, well-maintained flooring
and paths

Resilient materials

Lighting and glare

Previewing



Previewing

Home Use & Activity

Small and familiar tasks

Cultural and generational ties



Secure Independence



Small & familiar tasks



Engagement in Place



Engagement in Place

Heighten interest & curiosity

Environmental contrast

Minimize distraction, stress

Auditory privacy

Visual attention

Social gathering places

Places near the heart

Socially stimulating alcoves

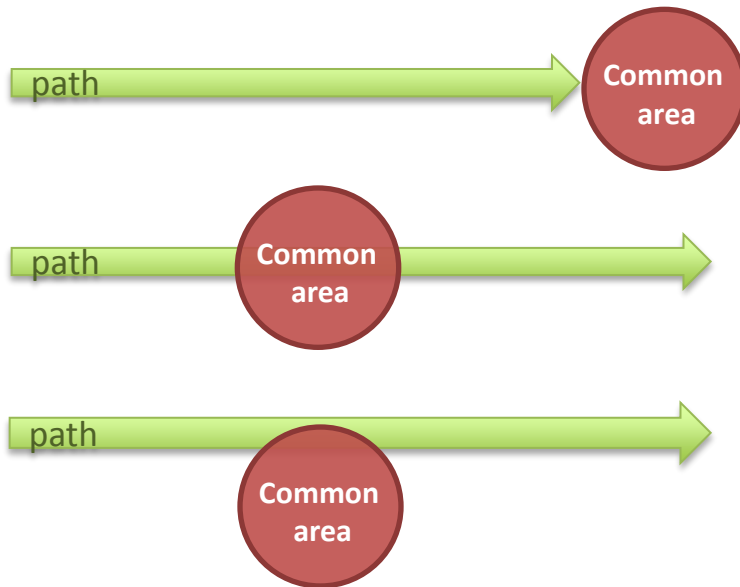
Neighborhood Amenities

Resting areas and furnishings

Transit accessibility



Engagement in Place



Places near the heart

Adapted from: "Common Areas at the Heart."
Alexander, C. , et al. (1977). *A Pattern Language: Towns, Buildings, Construction*. New York: Oxford University Press.



Accessibility for the Whole Person



Accessibility for the Whole Person



Mobility

For wheelchairs & scooters

For walkers and canes

Sensory

Lighting & glare

Auditory

Kinetic & touch

Cognitive

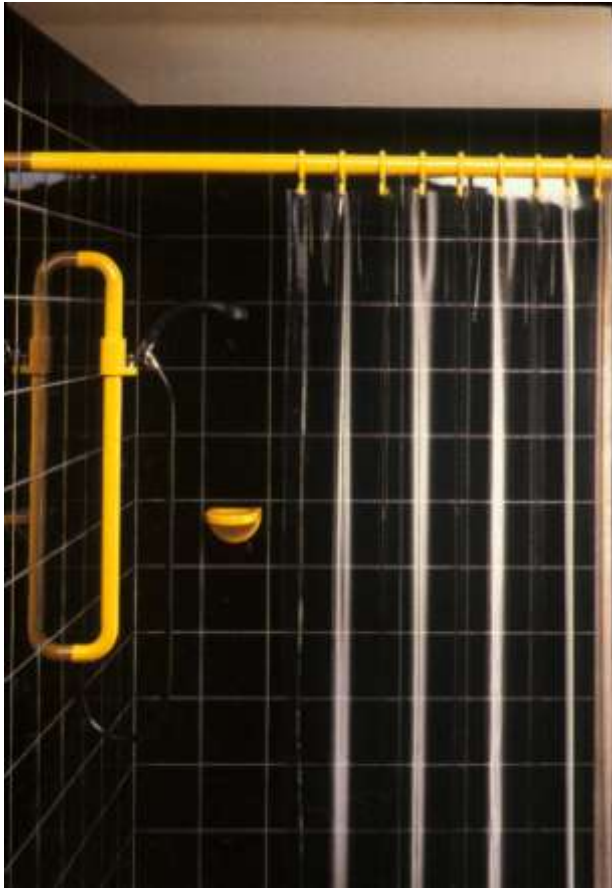
Multiple cues for orientation

Clear floor plan

Control of stimulation



Accessibility for the Whole Person



Color contrast for cueing



Flooring material change as a visual cue



Accessibility for the Whole Person



Enhance touch



Minimize squatting



ELDER HOME HEALTH TECHNOLOGY ASSISTANCE

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Elder Home Health Technology Assistance



Elders in Their Homes

- 65-and-over population (U.S. Department of Health and Human Services' Administration on Aging, 2009)
 - 55 million in 2020
 - 72 million in 2030 (2x 2007)
 - >19 percent of the population
- Chronic diseases with co-morbidity
 - medication
 - complicated
 - compliance issues
 - lifestyle guidance
 - memory assistance
 - physical care
- Chronic physical or mental impairment– (Building Health Systems, RWJ, 2002)
 - 99 million
 - \$470 billion annually



Institute of Medicine

- Nonprofit, non-governmental organization founded in 1970, under the congressional charter of the United States National Academy of Sciences.
- Provides unbiased, evidence-based, and authoritative information and advice concerning health and science policy to policy-makers, professionals, leaders in every sector of society, and the public at large
- In 2001 issued aims and design rules for the new century
 - 6 aims
 - Safe, effective, efficient, patient-centered, timely and provides equitable health care
 - 10 rules
 - Patient as source of control, shared knowledge with free flow of information, evidence-based decision making, continuous healing relationships, customization based on patients needs, transparency, anticipation of needs, decrease in waste & cooperation among clinicians.



Assistive Devices

- Environment Interventions
 - Ramps, lowered cabinets, secure flooring
- Assistive Technology
 - Canes, walkers, bath benches
 - Ehealth, Telemedicine, Telehealth
- Monitoring
 - Self
 - Feedback goes to user
 - Wellness or disease management
 - Heart rate monitors, blood pressure, glucose
 - Wearable sensors
 - Motivation for self-care
 - Challenge to make meet needs of consumer
 - Persuasive technology
 - Remote
 - Feedback goes to family or professional
 - Disease exacerbation, independent living, recuperation
 - Fall sensors, movement monitors , risk evaluation
 - Embedded in environment
 - Detect change in status
 - Just-in-time rescue
 - Reassurance



The Smart Home

- The term "smart home" refers to a residence equipped with technology that facilitates monitoring of residents and/ or promotes independence and increases residents' quality of life. (Demiris & Hensel, 2008)
- Promoting Independence
 - http://www.tiresias.org/research/guidelines/smart_home.htm
 - Provide an environment that is constantly monitored to ensure the householder is safe (activity monitoring)
 - Automate specific tasks that a householder is unable to perform (turning lights on or off)
 - Provide a safe and secure environment (alerting the householder of potentially dangerous activities)
 - Alert helpers or caregivers should the householder be in difficulties (through linking to a local community alarm scheme)
 - Enable and empower the user
 - Facilitate in the rehabilitation of householders (by giving prompts that be auditory and/or visual)



What Do Patients Need to Engage in Proactive Self-care? (Horowitz, 2008)

- Enable early diagnosis
 - Ability to collect data that detects a change, assess the meaning of the data, alert patient and make recommendation for making decisions for action
- Enable personal intervention
 - Empowered without calling a healthcare provider
- Improve the quality of communication
 - Better coordinate/communicate among caregiver, service provider, medical provider and peers



Most Common Assistive Devices

- Purpose
 - gathering and transmitting information, reporting and informing (telemonitoring)
- Types
 - Medication Regulation
 - Wandering precautions
 - Managing wandering in the home (monitoring location)
 - Managing exit from the home (alarms)



Smart Home Research

- Systematic Review of research projects on Smart Homes (Demiris & Hensel, 2008)
 - Physiologic monitoring (47%)
 - Functional monitoring and emergency detection (71%)
 - Safety monitoring and assistance (67%)
 - Security monitoring and assistance (19%)
 - Social interaction monitoring and assistance (19%)
 - Cognitive and sensory assistance (43%)
- Need more research on effectiveness of smart homes



Smart Home Complexity



Photo from -<http://www.homecontrolplus.net/solutions.html>



Labs for Monitoring



Photo from- <http://www.topnews.in/your-smart-house-future-will-take-care-you-old-age-2142820>



Photo from- <http://www.ikrunk.com/most-modern-multi-functional-mirror-designs.html>



Smart Home Mixes Old with Green and High-tech



Photo from-
http://www.nj.com/homegarden/design/index.ssf/2008/09/smart_home_mixes_old_with_gree.htmlphotro



Ambient Kitchen

- Lab-based replication of a real kitchen (Newcastle, UK)
- Preparing food and drink was to their sense of autonomy.
- Prompting people in the early stages of dementia through multi-step tasks (Wherton & Monk, 2008)
- The environment integrates data projectors, cameras, RFID tags and readers, object mounted accelerometers, and under-floor pressure sensing using a combination of wired and wireless networks



Photo from: Oliver et al., 2009



Challenges to Home Design

- Ubiquitous, ambient, non-invasive, & ergonomic
- Aesthetics, trends, style, fashion & compatibility with interior design
 - Cost vs. extension of a few months
 - Balancing health needs with home design
- Avoid image of sickness or disability
- Attractive things work better (Norman, D. *Emotional Design*)
- Aesthetics and usability correlate (Tractinsky et al 2000).
- Floor plan
 - Interaction between devices
 - openness so sensors are not blocked
 - Access to buttons on devices (ex. mirror)
- Connectivity
- Privacy



Conclusion

- Great impetus to keep aging population in their homes
- Smart Home technology is evolving rapidly
- Elders want technology to empower them to make decisions and stay independent
- Research has not focused on effective use
- Many challenges to integration into home
- Opportunities for exploring influence of smart home technology on home design

