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

James Erickson[1], Ernesto Fonseca[1], Matt Fraser[2]

[1] Stardust Center for Affordable Homes + the Family

[2] School of Sustainability

Arizona State University

James. erickson@asu.edu

Ernesto.fonseca@asu.edu

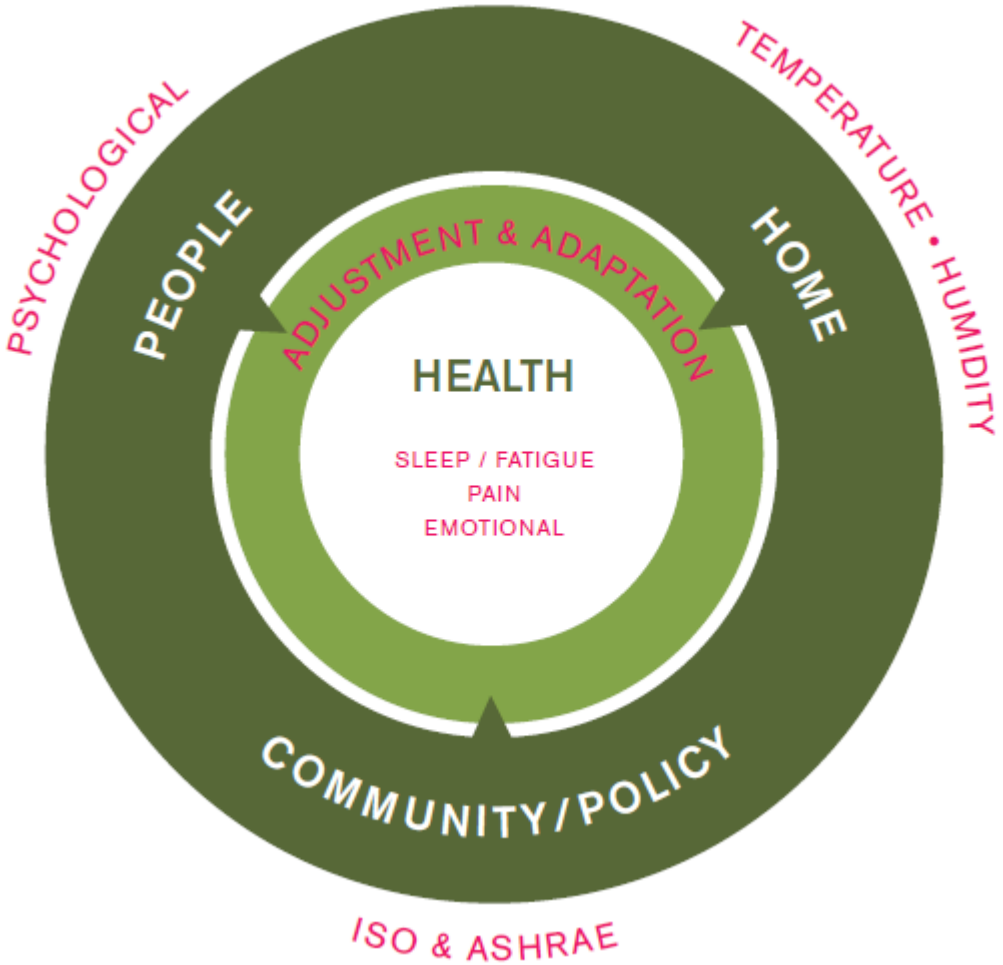
Matthew.fraser@asu.edu

Overview

1. **Indoor Thermal Conditions**
   a) Air Temperature
   b) Relative Humidity

2. **Indoor Air Quality**
   a) Particle Matter
   b) Aldehydes
   c) Acetones
   d) Acetyls

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^{O}C
3. **Parsons**
   a) Standards do not consider older adults' requirements
   b) Fitness state decreases, mortality increases on adults 40 and older.

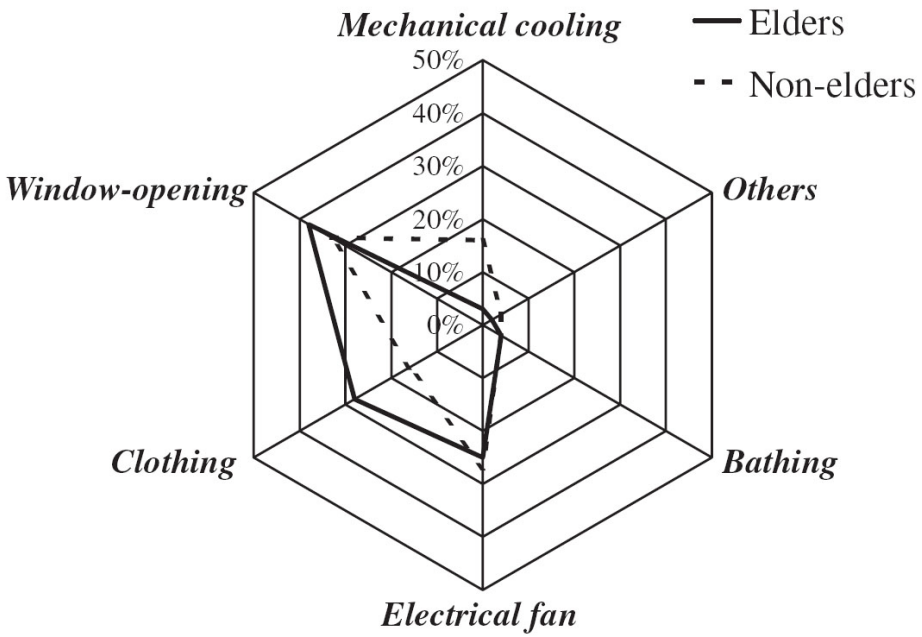
Relationship - Housing & Health

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

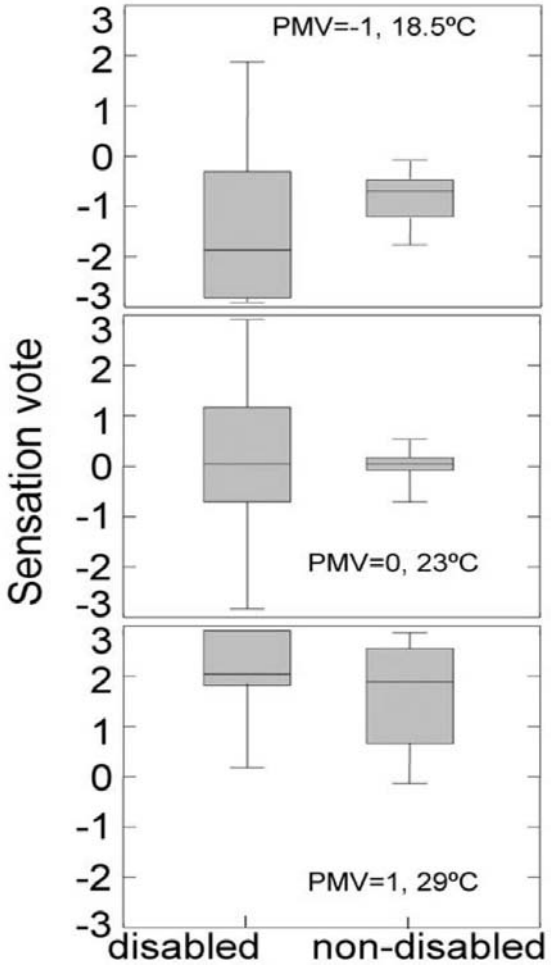
Temperature & Adaptive Behavior

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.

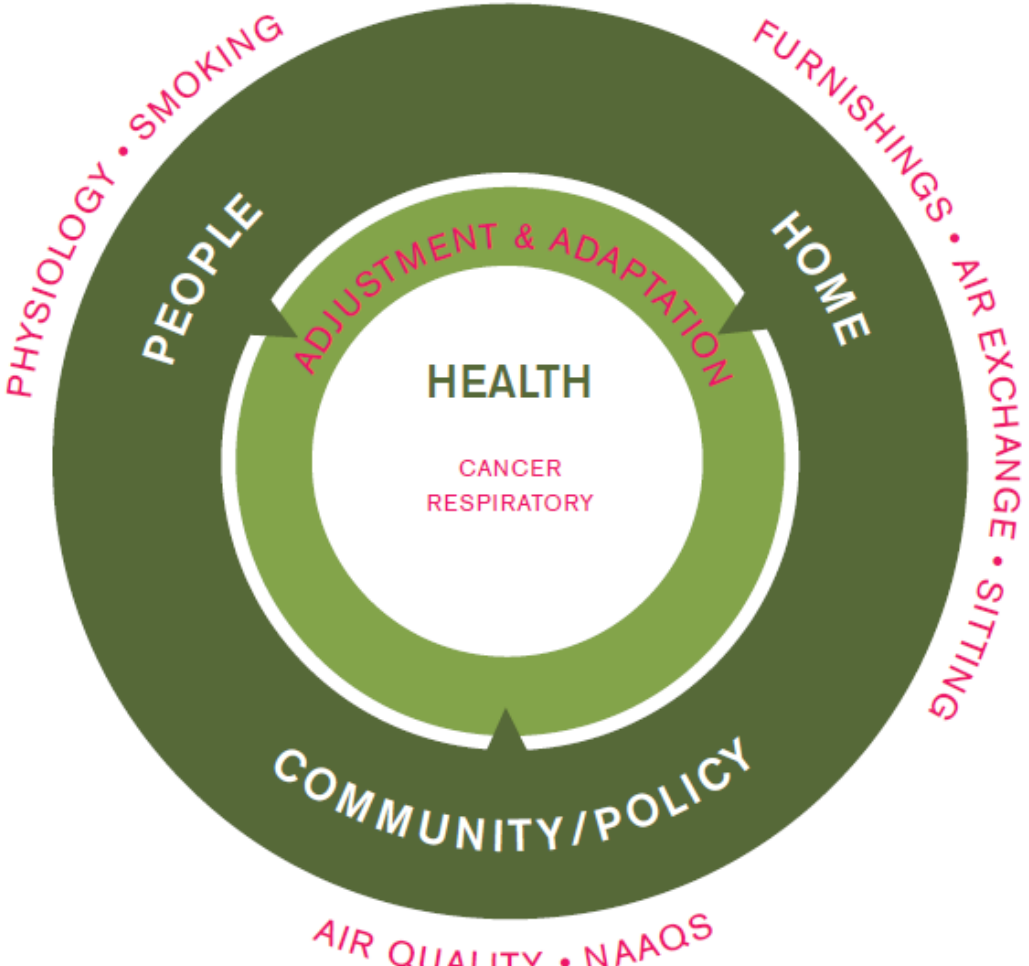


IAQ Overview

1. **Thresholds**
   a) Formaldehyde
   b) Particle Matter

2. **IAQ and Health**
   a) PM and health Impacts
   b) Indoor formaldehyde

Indoor Air Quality Components

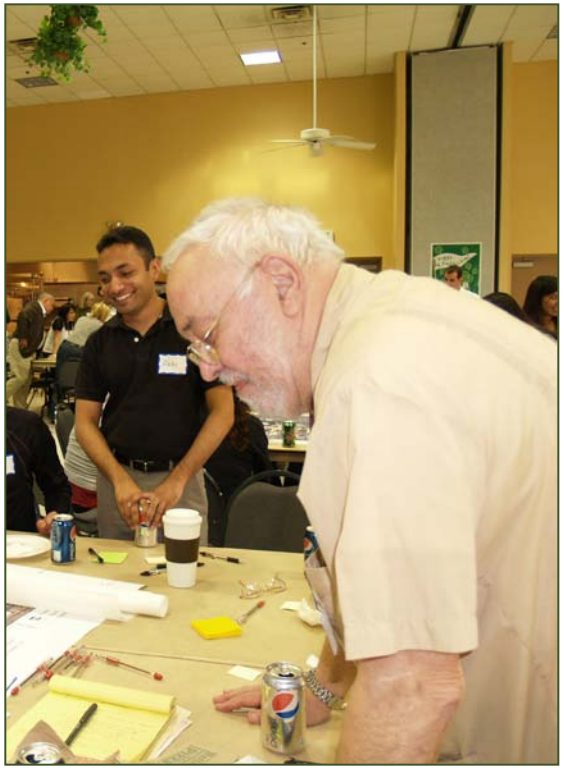


PM exposure guidelines

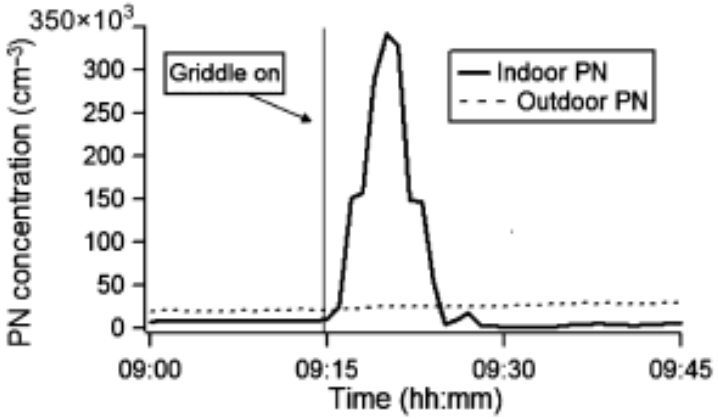
1. While WHO and other guidelines govern numerous pollutants, do not specifically quantify PM Exposure Guidelines.
2. Standards for ambient (outdoor) air quality cover a range of sizes and time periods.
3. Ambient Air Quality Standards range from:
    a) 35 mg/m^3 for PM2.5 over 24-hrs (US NAAQS)
    b) 50 mg/m^3 for PM10 annual average (US NAAQS)
    c) 50 mg/m^3 for PM10 over 24-hr (EU)

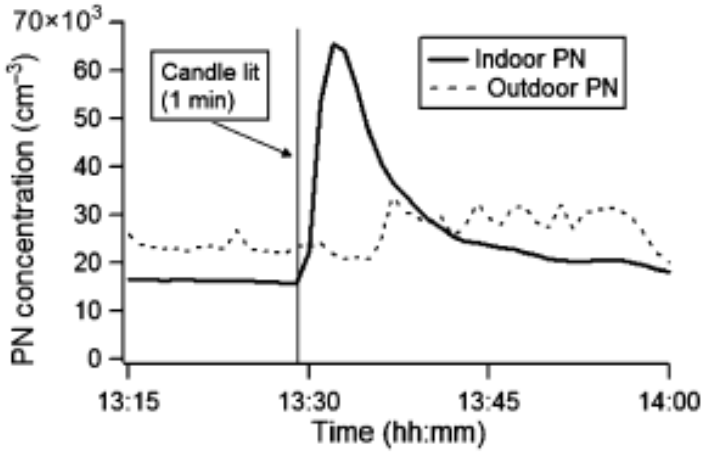
PM & Health Impacts

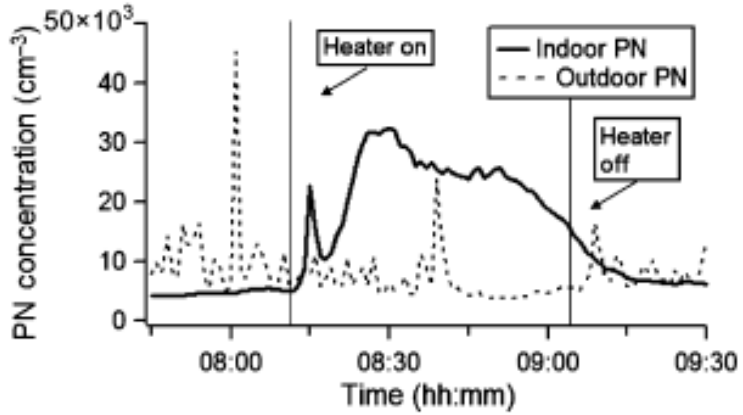
1. Numerous studies have quantified the increase risk of health impacts from a 10 mg m^{-3} increase in PM levels.
2. For PM10, an increase in ambient PM10 of 10 mg m^{-3} will lead to:
   a) An increase daily mortality of 0.5-0.6% (Samet et al. 2000)
   b) Increased hospitalization for asthma of 1.0-1.5%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

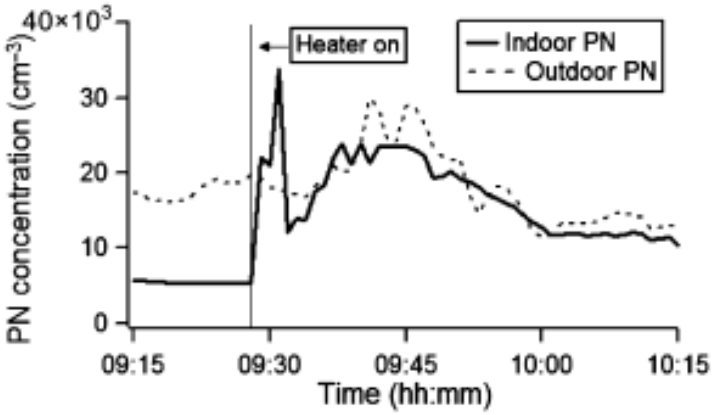


PM sources


350×10³
PN concentration (cm⁻³)
300
250
200
150
100
50
0
Griddle on
Indoor PN
Outdoor PN
09:00
09:15
09:30
09:45
Time (hh:mm)


70×10³
PN concentration (cm⁻³)
60
50
40
30
20
10
0
Candle lit
(1 min)
Indoor PN
Outdoor PN
13:15
13:30
13:45
14:00
Time (hh:mm)


50×10³
PN concentration (cm⁻³)
40
30
20
10
0
Heater on
Indoor PN
Outdoor PN
Heater
off
08:00
08:30
09:00
09:30
Time (hh:mm)


40×10³
PN concentration (cm⁻³)
30
20
10
0
Heater on
Indoor PN
Outdoor PN
09:15
09:30
09:45
10:00
10:15
Time (hh:mm)

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 $\mu g\ m^{-3}$	short-duration
	2006[227]	0.08 ppm	100 $\mu g\ m^{-3}$	
Canada	1987[220]	0.1 ppm	120 $\mu g\ m^{-3}$	action level
	1987	0.05 ppm	60 $\mu g\ m^{-3}$	target level
	2005[22]	0.1 ppm	123 $\mu g\ m^{-3}$	1 h
	2005	0.04 ppm	50 $\mu g\ m^{-3}$	8 h
China	2003[225]	0.08 ppm	100 $\mu g\ m^{-3}$	1 h average
Denmark	1990[207]		0.15 mg m^{-3}	
Finland	2001[209]		30 $\mu g\ m^{-3}$	S1
			50 $\mu g\ m^{-3}$	S2
			100 $\mu g\ m^{-3}$	S3
France	2008[213]		*50 $\mu g\ m^{-3}$*	*2 h (proposed)*
			10 $\mu g\ m^{-3}$	*long-term exposure (proposed)*
Germany	1977[216]	0.1 ppm		
Singapore	1996[224]	0.1 ppm	120 $\mu g\ m^{-3}$	8 h
Hong Kong	1999	0.025 ppm	30 $\mu g\ m^{-3}$	level 1 (8 h)
		0.081 ppm	100 $\mu g\ m^{-3}$	level 2 (8 h)
		0.3 ppm	370 $\mu g\ m^{-3}$	level 3 (8 h)
	2003[221]	0.025 ppm	30 $\mu g\ m^{-3}$	excellent
		0.081 ppm	100 $\mu g\ m^{-3}$	good
Japan	1997[223]	0.08 ppm	100 $\mu g\ m^{-3}$	0.5 h
Korea	2004[222]	0.1 ppm	120 $\mu g\ m^{-3}$	8 h
Norway	1990[210]	0.05 ppm	60 $\mu g\ m^{-3}$	24 h average
	1999[211]	0.05 ppm	100 $\mu g\ m^{-3}$	30 min average
Sweden	2000	0.08 ppm	100 $\mu g\ m^{-3}$	adopted from WHO
Poland	1996[215]	0.04 ppm	50 $\mu g\ m^{-3}$	category A: 24 h
		0.08 ppm	100 $\mu g\ m^{-3}$	category B: 8−10 h
U.K.	2004[208]		100 $\mu g\ m^{-3}$	0.5 h
USA (California)	1991[217]	0.1 ppm	120 $\mu g\ m^{-3}$	action level
		0.05 ppm	60 $\mu g\ m^{-3}$	target level (ALARA)[a]
	1999[203]	0.076 ppm	94 $\mu g\ m^{-3}$	1 h (acute REL)[b]
	2004[219]	0.027 ppm	33 $\mu g\ m^{-3}$	8 h (interim REL)
	2005[218]	0.002 ppm	3 $\mu g\ m^{-3}$	annual average (chronic REL)
WHO	1987[228]	0.08 ppm	100 $\mu g\ m^{-3}$	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}
Europe		
Germany (1991)	327 residences	55 $\mu g\ m^{-3}$
		106 $\mu g\ m^{-3}$
Germany (2008)	586 residences	23.5 $\mu g\ m^{-3}$
		47.7 $\mu g\ m^{-3}$
Germany (2003)	14 office buildings, 1386 measurements	6.0 $\mu g\ m^{-3}$
Germany (2001)	180 Berlin residences	38 $\mu g\ m^{-3}$
		98 $\mu g\ m^{-3}$
Germany (1995)	252 residences	12−649 $\mu g\ m^{-3}$
Germany (1993)	190 residences	62 ppb
Austria (2002)	160 homes	8.8−115 $\mu g\ m^{-3}$
		25 $\mu g\ m^{-3}$
Switzerland (1992)	private residences	46 $\mu g\ m^{-3}$
		468 $\mu g\ m^{-3}$
Denmark (1987)	14 Danish town halls	40 $\mu g\ m^{-3}$
		0−80 $\mu g\ m^{-3}$
Denmark (1991)	2 new twin apartments	63−384 $\mu g\ m^{-3}$
		14−276 $\mu g\ m^{-3}$
Denmark (1992)	36 apartments	37 $\mu g\ m^{-3}$
Finland (2006)	8 buildings	19, 21, 26 $\mu g\ m^{-3}$
Finland (2009)	23 office buildings	11 $\mu g\ m^{-3}$
Sweden (2004)	27 Uppsala dwellings	8.3 $\mu g\ m^{-3}$
Sweden (2005)	64 bedrooms	23 $\mu g\ m^{-3}$
		29 $\mu g\ m^{-3}$
Sweden (2001)	181 classrooms	3 $\mu g\ m^{-3}$
		<3−72 $\mu g\ m^{-3}$
France (2006)	Strasbourg libraries	20 $\mu g\ m^{-3}$
		95 $\mu g\ m^{-3}$
France (2006)	Strasbourg locations	5.3−73.8 $\mu g\ m^{-3}$
France (2008)	Strasbourg homes	26.7 $\mu g\ m^{-3}$
France (2003)	61 Paris dwellings	34.4 $\mu g\ m^{-3}$
		≈ 78 $\mu g\ m^{-3}$
France (2009)	157−187 babies' homes	17.7−19.4 $\mu g\ m^{-3}$
Italy (2009)	20 homes	12.9−9.3 $\mu g\ m^{-3}$
Poland (2005)	5 office buildings	2.3−32.3 $\mu g\ m^{-3}$
Turkey (2003)	399 kitchens in Ankara	0−2086 $\mu g\ m^{-3}$
		79.9 $\mu g\ m^{-3}$
Turkey (2006)	25 Ankara dwellings	2.3−866.2 $\mu g\ m^{-3}$
		67.1 $\mu g\ m^{-3}$
US/Canada		
USA (1995)	14 residences	11.1 ppb
	26 residences	16.1 ppb
USA (2000)	4 manufactured houses	21−47 ppb
	7 site-built houses	14−58 ppb
USA (2006)	different locations	19.6 $\mu g\ m^{-3}$
		14.3 $\mu g\ m^{-3}$
USA (2007)	234 homes	20.1 $\mu g\ m^{-3}$
		32.5 $\mu g\ m^{-3}$
		20.5 $\mu g\ m^{-3}$
		34 $\mu g\ m^{-3}$

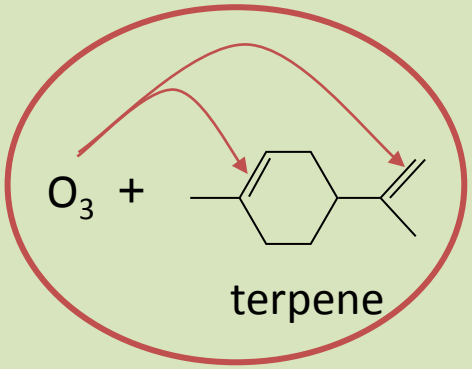
continent/country	location	C_{indoor}
USA (1989)	470 mobile homes	70 ppb
		<30 to >300 ppb
USA (2008)	360 travel trailers	81 ppb
	90 park models	44 ppb
	69 mobile homes	57 ppb
Canada (2003)	151 homes (summary of 5 studies)	29.8 $\mu g\ m^{-3}$
Canada (2005)	59 residences	29.6 $\mu g\ m^{-3}$
Canada (2008)	96 Quebec homes	9.6−90 $\mu g\ m^{-3}$
Latin America		
Brazil (2006)	academic institute	<1−82 $\mu g\ m^{-3}$
		7−8 $\mu g\ m^{-3}$
		5−9 $\mu g\ m^{-3}$
Mexico (2003)	different locations	4−122 $\mu g\ m^{-3}$
Asia		
Korea (2008)	52 classrooms summer	70 ppb
	48 classrooms autumn	40 ppb
	46 classrooms winter	60 ppb
Korea (2008)	6 apartments	209−457 $\mu g\ m^{-3}$
Korea (2009)	50 school buildings	150 ppb
	45 school buildings	100 ppb
Japan/Korea (2006)	292 new homes	134 $\mu g\ m^{-3}$
	60 new homes	86 $\mu g\ m^{-3}$
Japan (2006)	25 Shimizu residences	71.5 $\mu g\ m^{-3}$
	21 Shimizu residences	25.9 $\mu g\ m^{-3}$
Japan (2004)	37 Nagoya residences	17.6 $\mu g\ m^{-3}$
Hong Kong (2002)	6 residential homes	11−24 $\mu g\ m^{-3}$
Hong Kong (2006)	422 offices	32 $\mu g\ m^{-3}$
Hong Kong (2009)	100 homes	85.7 $\mu g\ m^{-3}$
China (2004)	28 hotel ballrooms	29.7 $\mu g\ m^{-3}$
China (2007)	public vehicles	13−94 $\mu g\ m^{-3}$
Bangladesh (2007)	91 kitchens, impact on children	26.2 $\mu g\ m^{-3}$
		36.9 $\mu g\ m^{-3}$
Africa		
Egypt (2000)	294 Cairo residences	96.6 $\mu g\ m^{-3}$
Australia/New Zealand		
Australia (2002)	185 homes in Perth	1−166 ppb
		20.4−23.8 ppb
Australia (2006)	4 schools	3−38 $\mu g\ m^{-3}$
Australia (2000)	192 caravans	29 ppb
		100 ppb
Other		
aircraft (simulated)	occupied cabin	8−10 ppb
submarine (2006)	submerged operation	<10 $\mu g\ m^{-3}$

Formaldehyde & Health Impacts

Sources

primary emissions: manufactured wood products, furnishings

secondary emissions: ozone chemistry



Health effects

acute (asthma, Airways irritation)

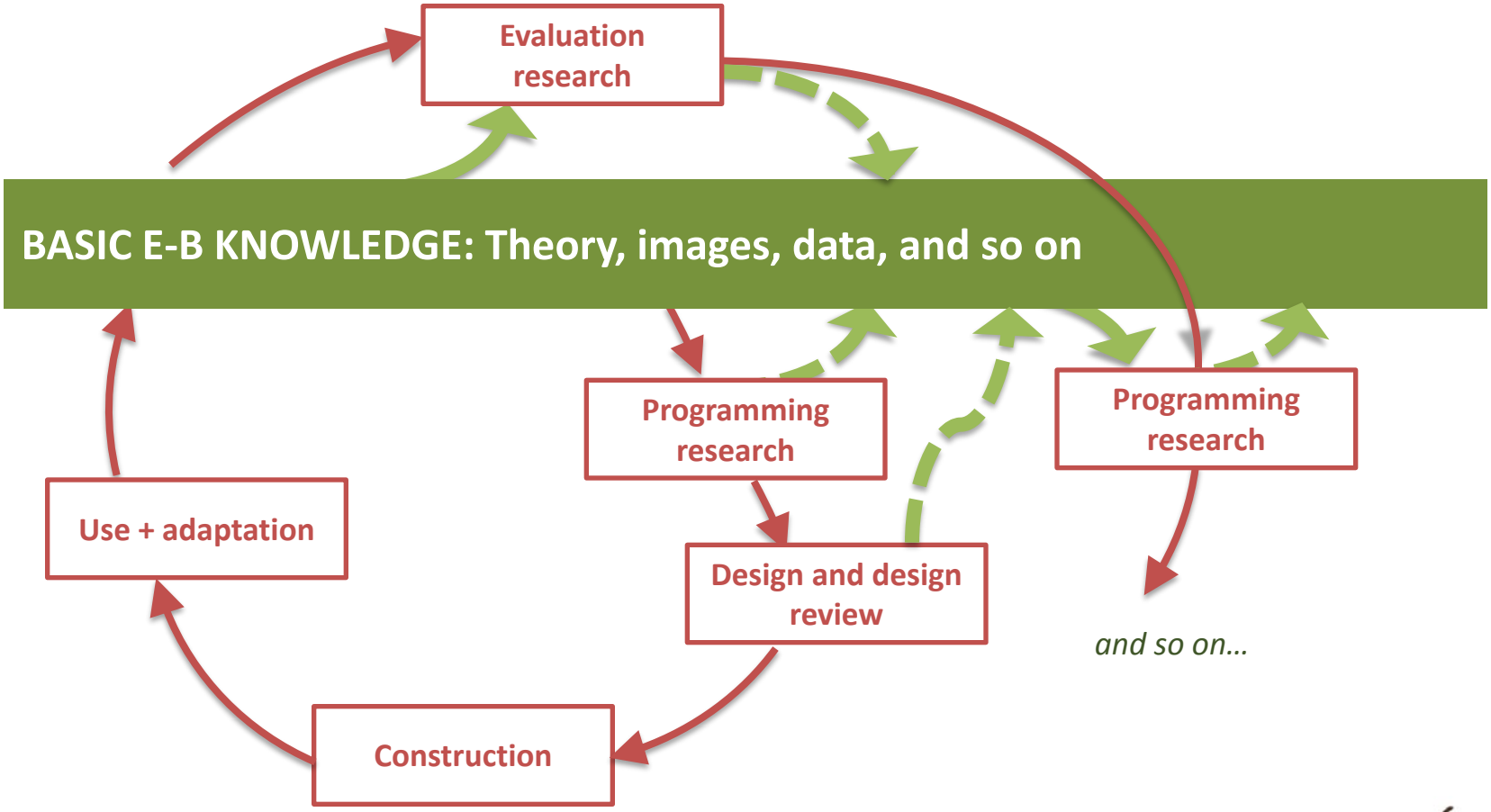
chronic (cancer)

DESIGN FOR ACTIVE AGING

Sherry Ahrentzen, Elif Tural
Stardust Center for Affordable Homes + the Family
Arizona State University

Sherry.ahrentzen@asu.edu
Elif.tural@asu.edu

Scientific Research v Design Research



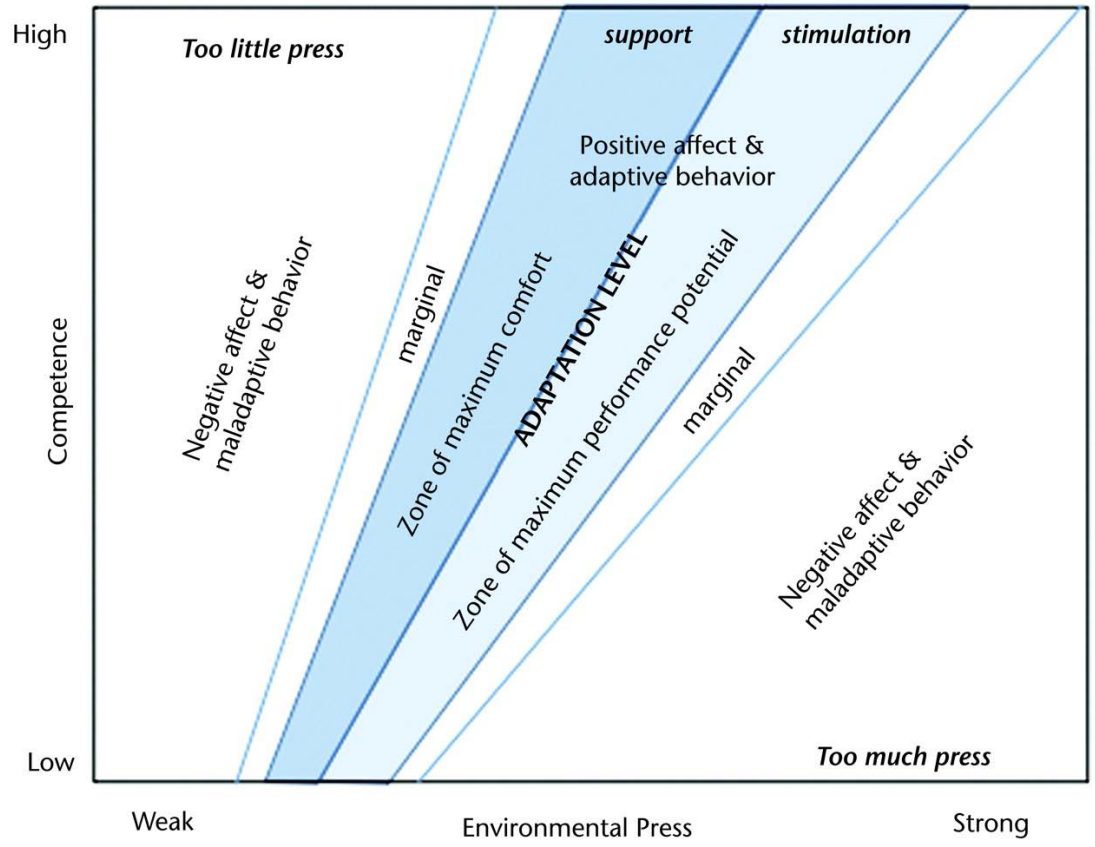
Occasions for research/design cooperation in the design-process cycle.
From: Zeisel, J. (2006). *Inquiry by Design: Environment/Behavior/Neuroscience in Architecture, Interiors, Landscape, and Planning* (p. 36). New York: W. W. Norton & Co.

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

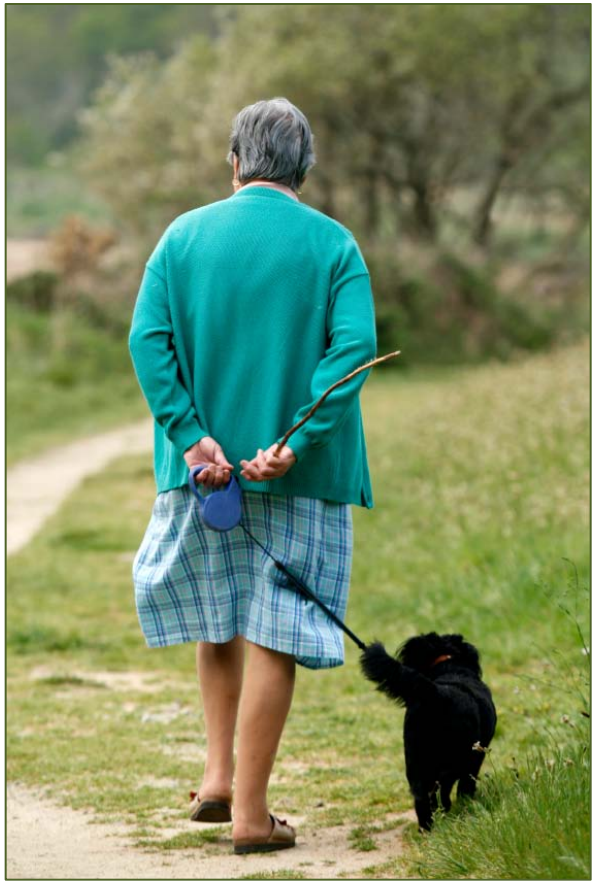
- Secure only doors to high-risk areas
- Secure outdoor areas
- Smooth, well-maintained flooring and paths
- Resilient materials
- Lighting and glare
- **Previewing**

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

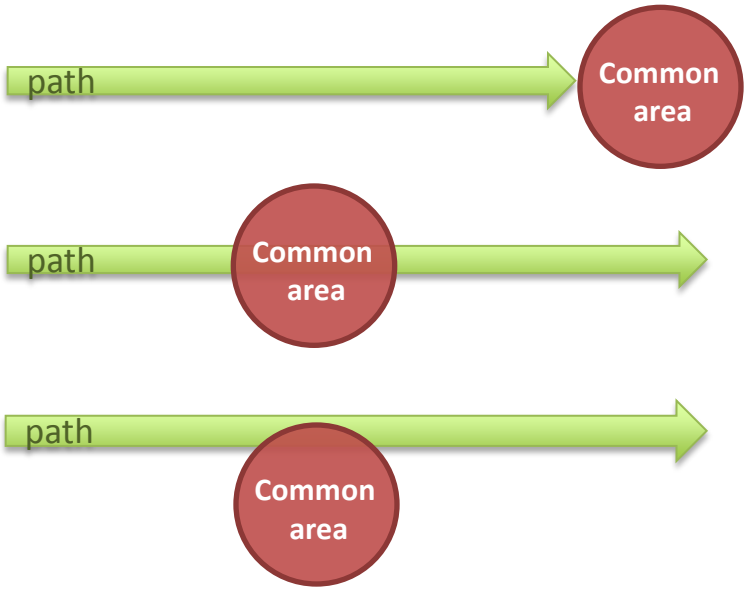
Social gathering places

- **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

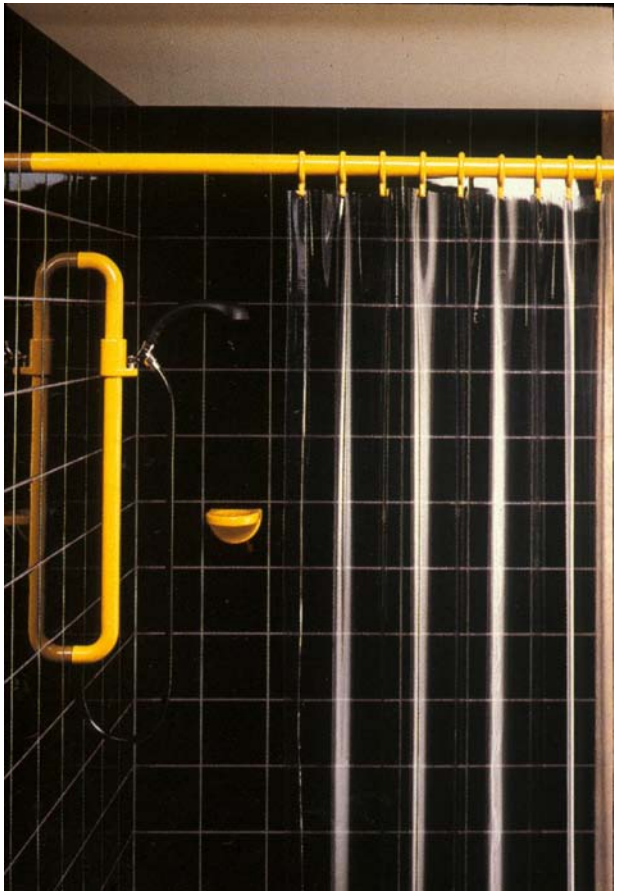
Sensory

- Lighting & glare
- Auditory
- **Kinetic & touch**

Cognitive

- **Multiple cues for orientation**
- Clear floor plan
- Control of stimulation

Accessibility for the Whole Person

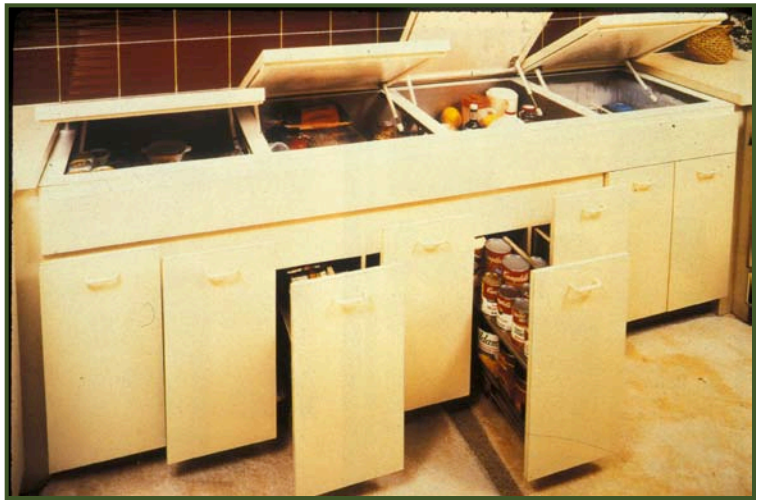


Color contrast for cueing

Flooring material change as a visual cue

Accessibility for the Whole Person

Enhance touch



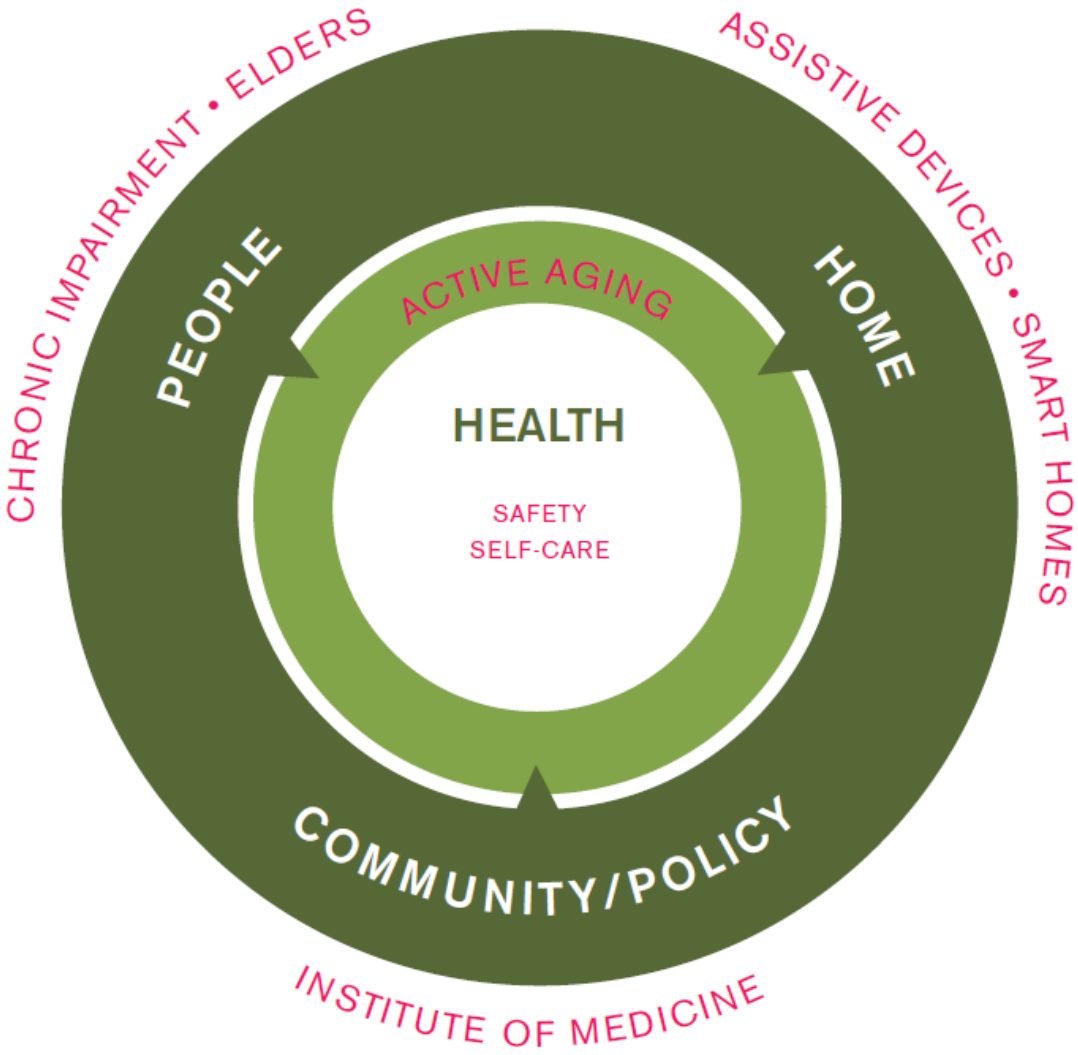
Minimize squatting

ELDER HOME HEALTH TECHNOLOGY ASSISTANCE

Kim Shea
College of Nursing and Healthcare Innovation
Arizona State University

Kimberly.shea@asu.edu

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 b 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