



Windows and Daylighting

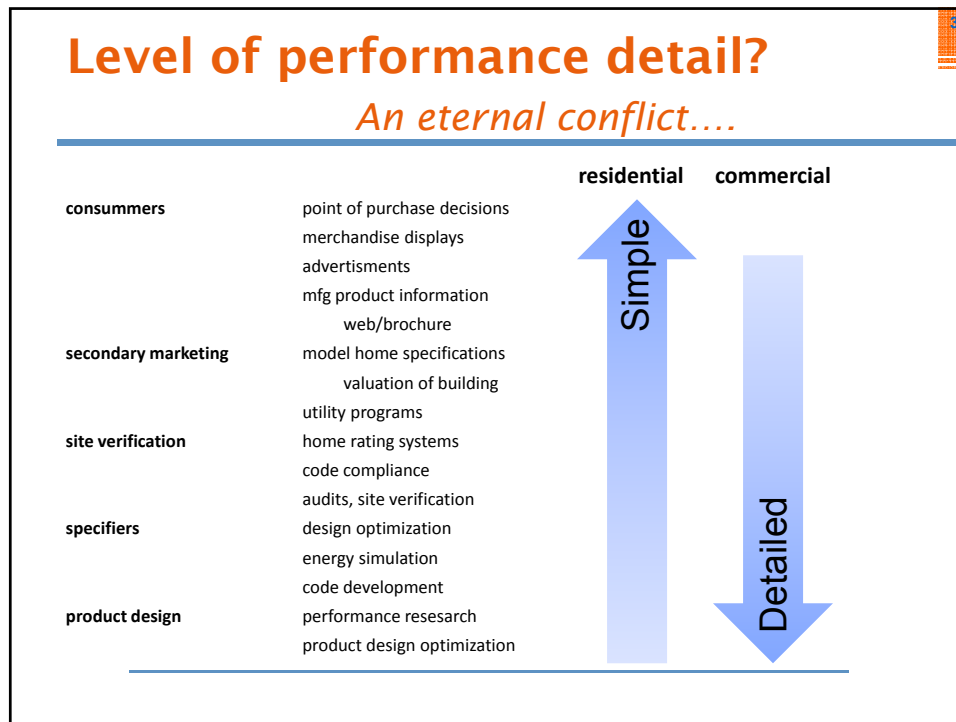
NFRC Meeting, San Francisco, Nov 10, 2010

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Should NFRC rate windows for daylighting?

Cons	Pros
<ul style="list-style-type: none">• It is too complex• There are too many secondary issues like view and privacy• It is a distraction from our core concern with energy• There are others who should do it	<ul style="list-style-type: none">• But it is important• Visual comfort is to daylight – as thermal comfort is to U-value• It is the next major policy push• NFRC has become the preferred source for window performance data



- ## Why so much attention on daylighting??
- Necessary to reach Net Zero buildings
 - 1000's of parametric studies by NREL
 - Concern for "Healthy Buildings"
 - Reduces complaints, "sick building syndrome"
 - Increases tolerance
 - For thermal swings, accoustic, other annoyances
 - Allows for other energy management strategies
 - Improves joy and productivity

Eight Daylight & Productivity Studies:

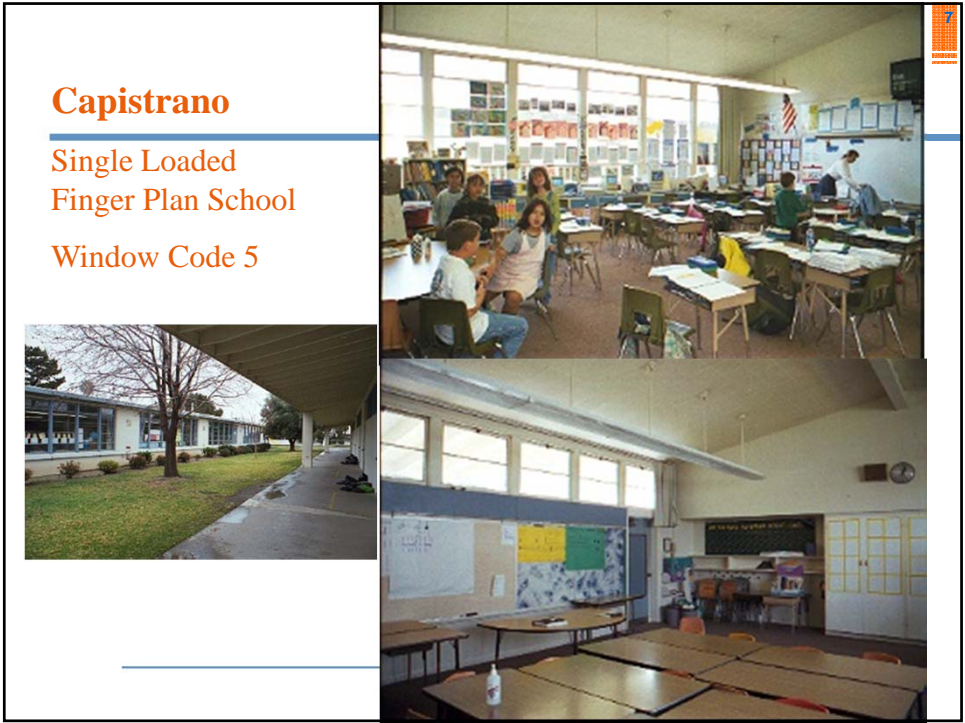
- **Retail**
 - **Two** major chain stores
 - 108 and 74 stores each, sales
 - = greater sales, more transactions
- **Schools**
 - **Four** school districts
 - 8-9000 students each, math and reading test scores
 - Most daylight v no daylight = 20% faster learning
- **Offices**
 - **“Call Center”**
 - 100 subjects, 2 months,
 - = 7% faster work speed w bigger windows, better views
 - **“Desk Top”**
 - 200 subjects,
 - = 10% better cognitive performance (digit span backwards)
 - better health reports and employee satisfaction with workplace

Capistrano Window Code 1

Capistrano Open Classroom Window Code 2



Capistrano -- Open Classroom Window Code 0



Summary Findings:

	Capistrano learning rate	Seattle higher scores	Ft Collins higher scores
Windows	15% - 23%	13% - 15%	14% - 18%
Skylights	19% - 20% A 0% - (21%) B	6% - 8%	0% - 3%
or Daylight	20% - 26%	9% - 13%	7%
and Operable Windows	7% - 8%		

Does View Matter?

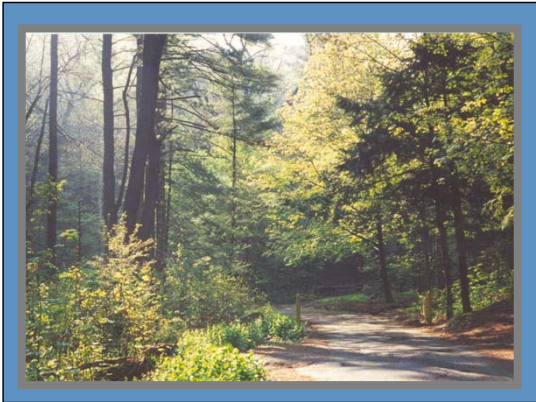
Ask any real estate agent....

residential or commercial....!



View was the big winner in our studies!

- Call Center
 - +7% to +12%
 - Worker speed
- Desktop study
 - +10% to +25%
 - 3 mental acuity tests
 - Less fatigue
- Schools study
 - +7% to +30%
 - Faster math and reading learning



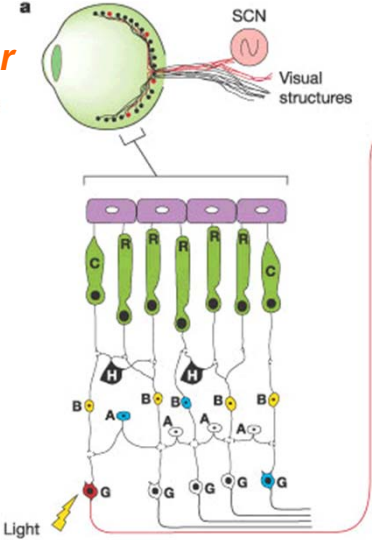
What is the magic of view?

- Is it mental stimulation?
 - A richer visual environment...
 - Is it stress reduction?
 - “Attention Restoration Theory”
 - Is it **vertical, circadian illumination** at the eye ?
 - Allowing us to feed our “appetite” for light?
 - A better measurement than horizontal, photopic lux at the task?
-



The newly discovered *non-optic ganglion receptor*

- There are non-visual light receptors in the retina
 - especially sensitive to blue light
 - similar to the blue sky
- That signal a separate neural and hormonal pathway
 - orchestrating circadian response
 - melatonin, dopamine, serotonin
- Thus, light at the eye effects:
 - **alertness**
 - **mood**
 - **memory**
 - **health**



From: Reppert, S.M. & Weaver, D.R.
Nature 418, 935 - 941 (2002)

Neurotransmitters

- Turned on by DARK
 - Melatonin - sleep, mood, puberty,
 - Norepinephrine - mood, intelligence, insulin resistance
 - Acetylcholine - learning, memory
- Turned on by LIGHT
 - Serotonin - impulse control, carbohydrate cravings
 - Dopamine - motivation, muscle coordination
 - GABA (Gamma-Aminobutyric Acid) - calm, focus, inhibition
- *“Light is a Drug”*

Hormones and Peptides

- Turned on by DARK

- **VIP** Vasoactive Intestinal Peptide Blood pressure
- **GH** Growth Hormone Growth, in children
adults: decrease body fat, increase lean muscles

- Turned on by LIGHT

- **CRF** Corticotropin Releasing Hormone Stress
- **GRP** Gastrin Releasing Peptide Hunger
- **NPY** Neuropeptide Y Hunger
- **FSH** Follicle Stimulating Hormone Reproduction

Daylight

- Is a positive benefit for occupants
 - Healthy, and beautiful, buildings
- Can provide excellent quality illumination
 - Given good design strategies...
- Can save significant energy
 - Given energy optimization...

Provides a Win-Win for occupants and environmental policy advocates

Current Daylight Policy

- Daylighting required in ASHRAE and Title 24
 - Skylighting for big box spaces
 - Min areas recently reduced from 8,000 sf >> 1000 sf
- Daylighting required in LEED and IgCC 2010
 - Min levels of 'Daylight Autonomy' for occupied spaces
- ASHRAE Strategic Research Plan 2010
 - Focus on integrated building design, simulation tools

- www.ashrae.org/research

Recent events

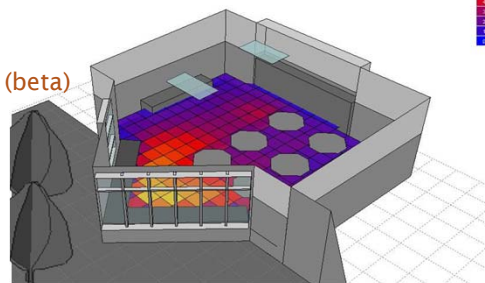
- ASHRAE lighting 2010
 - Photocontrols required for 'daylit' spaces >250 sf
- ASHRAE amendment 'bb'
 - Reduced allowable glass area & SHGC by 25%
 - Challenged by GANA and others
 - Rejected, sent back for re-analysis (1 of 111 approved)
 - Need for more accurate understanding of balance
 - between daylight benefits and thermal impacts

California Reach code, or T-24 2014...

- Require minimum daylit area for commercial buildings ?
 - Improved prescriptive method
 - Simpler, more accurate
 - Based on detailed performance analysis
 - Using 'Dynamic Radiance Approach'
 - Using field studies of obstructions
 - Accounting for occupant actions w blinds

Climate based analysis of daylight performance:


- Simulation Programs
 - DOE 2
 - Energy Plus
 - ComFen & Window 6 (beta)
 - DaySim (Radiance)
 - Daylight 123
 - 3D Studio Max
 - RT-contrib (Radiance)
 - S.P.O.T. (Radiance and DOE2)
 - SkyCalc (Skylights only, DOE2)



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Annual Daylight Performance Metrics

- Being developed by the IESNA Daylighting Metrics subcommittee
 - Requires annual simulations tools
 - Requires detailed performance information
 - Angular dependent values for SHGC and VLT
 - BSDF files for complex fenestration and attachments
 - Operational schedule for operational attachments



Illuminating
ENGINEERING SOCIETY

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Who needs daylight performance metrics?

- Building Owners / Designers
 - Design optimization
 - Post Occupancy Evaluation
 - Sales and leasing
- Manufacturers
 - Optimize products
 - Market benefits
- Incentive Program Managers
 - LEED , CHPS , Energy Star
 - Utility ET / EE programs
 - Tax credits
- Codes & Standards Developers
 - ASHRAE/IES 90.1 & 189
 - IECC / IgCC
 - Title 24, etc



Does blinds operation matter?

- What assumptions should we make?
 - worst case? optimal illumination? whatever?
- What about view preservation?
- **93%** of our field study sites had operable fenestration controls
 - a.k.a. blinds, shades, louvers, curtains, etc.
 - i.e. **they are ubiquitous**
 - let's improve their performance!

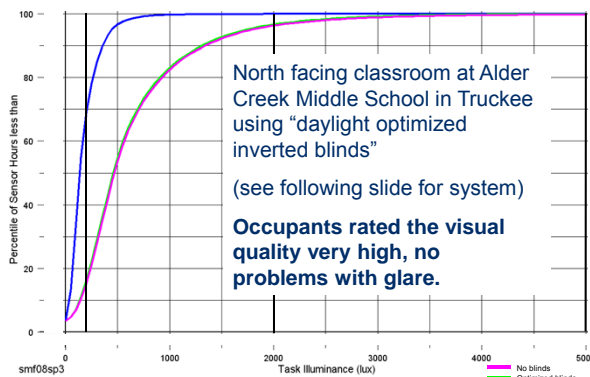


Type 3: Classroom

smf08sp3

Blinds 20%

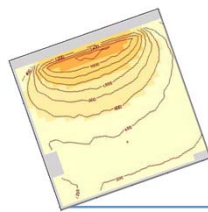
40°, 428/754



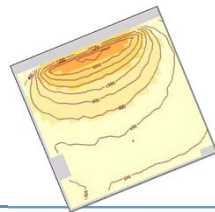
Facing north



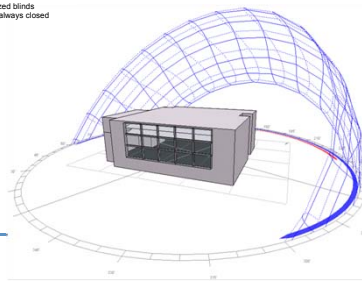
Facing northwest

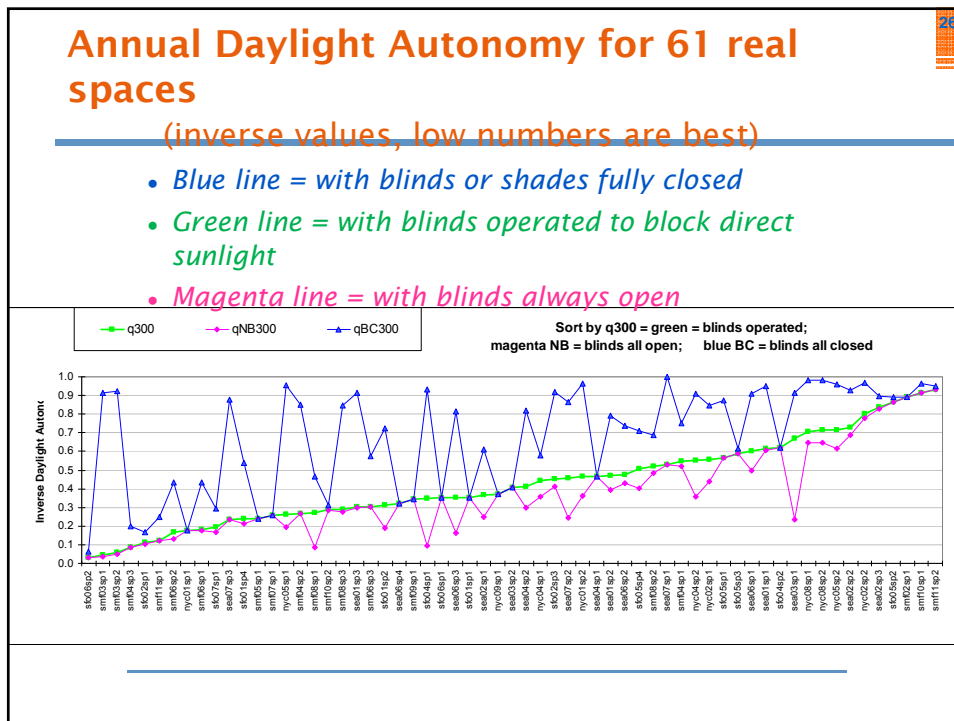
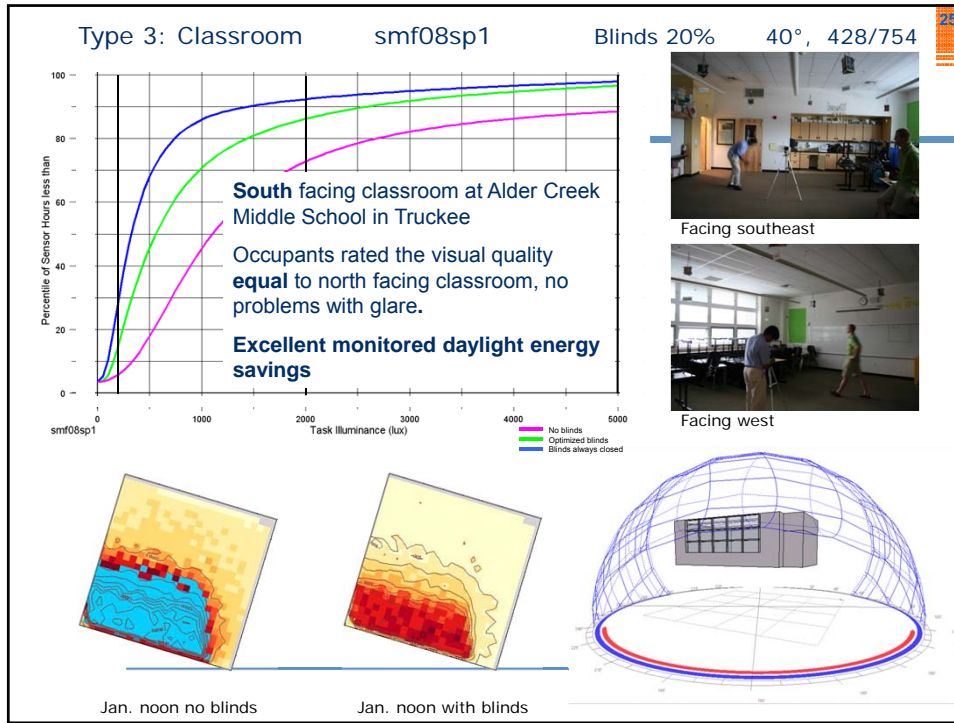


Jan. noon no blinds



Jan. noon with blinds







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Annual Daylight Performance Metrics

- **Daylight Sufficiency**
 - Daylight Autonomy: how much of the floor area achieves a minimum of 30 fc for at least x% of the occupied hours?
- **Sunlight Exposure**
 - What is the maximum number of hours of sunlight that could reach any spot in the space, assuming no blinds operation?
- *Uniformity*
 - *How uniform is the daylight distribution in the space, considered over the whole year?*
- *Blinds operation*
 - *How do the blinds need to be operated in order to meet this visual comfort needs of the occupants?*
- **Glare....**
 - How visually comfortable is the daylight illumination in the space?





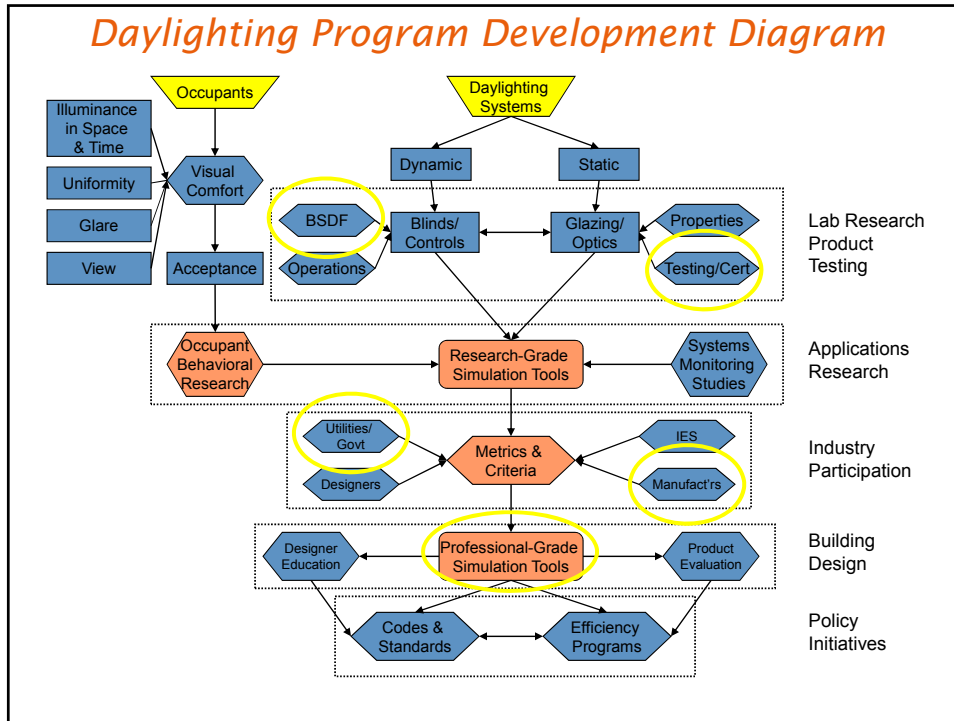
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Daylighting Forum – 100 experts

May 14, 2010 Springs Preserve, Las Vegas

<ul style="list-style-type: none"> • researchers <ul style="list-style-type: none"> • university • national labs • private • software developers <ul style="list-style-type: none"> • energy analysis • lighting analysis • daylight analysis • manufacturers <ul style="list-style-type: none"> • blinds & attachments • skylights • windows • lighting controls 	<ul style="list-style-type: none"> • efficiency program managers <ul style="list-style-type: none"> • utilities & NGOs • state and federal • code and standards <ul style="list-style-type: none"> • ASHRAE & IES & IECC • LEED, CHPS, IgCC • NFRC • CEC • designers and engineers <ul style="list-style-type: none"> • lighting designers • architects • energy consultants
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A Daylighting Analysis Framework: *What do we want to know?*

- **Human Comfort**
 - **Visual performance**
 - Can I see what I need to do?
 - **Visual comfort**
 - Am I comfortable looking around the room?
 - **Thermal comfort**
 - Am I too hot? Or too cold?
- **Energy Impacts**
 - Lighting energy use
 - Cooling energy use
 - Heating energy use



How can we compare performance?

- Which design is more successful?
 - for visual comfort? Where? When? How often?
 - for energy performance? Given what operation assumptions?



Ideally – separate the window functions in space

- **Daylight windows, ideally provide**
 - seasonal adjustment for solar redirection
- **View windows, ideally provide:**
 - occupant daily or hourly control for glare
 - glare sources move!
- **How to model accurately?**
 - different BSDF for each system
 - different operation schedules for each system



Wish List for Software Developers

- **Lighting Analysis Tools** (space level)
 - use annual, climate-based simulations
 - enable hourly blinds operation
 - incorporate complex optical performance data
- **Energy Analysis Tools** (building level)
 - support easy import/export to lighting tools
 - coordinate fenestration controls
 - coordinate lighting controls

Wish List for Manufacturers:

- **Blinds are ubiquitous**
 - make “daylight optimized” blinds
- **Provide more fenestration performance**
 - light, view, air, thermal comfort, and low maintenance, and fashion, and ...and...
- **Provide light distribution data**
 - industry wide standard format reports
 - ease of import into simulation software

Wish List for NFRC:

- Develop testing and reporting standards for daylighting products
 - public libraries of product performance data
 - enable evaluation of system level performance
 - multi-angle, 3D light distribution
 - default values for generic products
 - to be used in professional grade analysis tools
- Rating systems can come much later...
 - and are least important

Subtle changes in daylight patterns can have a big effect on occupant acceptance....

- | | |
|--|---|
| <ul style="list-style-type: none"> • Sunlight in field of view <ul style="list-style-type: none"> • But not on work surface • Judged 'preferred' | <ul style="list-style-type: none"> • ¼ turn of blinds <ul style="list-style-type: none"> • Stripes on work surface • Judged 'just disturbing' |
|--|---|



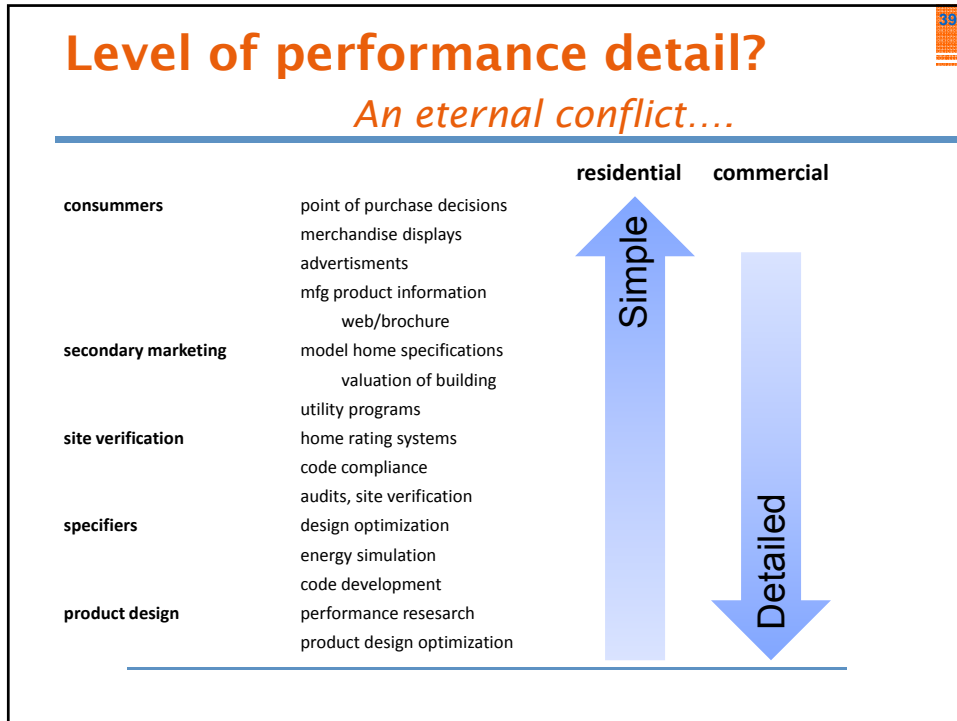
Photos, © Mehlika Inanici & Kevin Van Den Wymelenberg

Wish list for IES:

- Advocate for visual comfort research
 - set research agenda for daylight perception
 - understand physiology
 - understand glare
 - understand view
 - understand circadian needs
 - create predictive models
- Coordinate visual comfort recommendations and metrics with other bodies
 - AIA, ASHRAE, NFRC, etc.

- We swim in a sea of daylight every day...
- Shouldn't we design our buildings to let it in?





Dance with
the daylight...!

Thank you for your
interest!

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