# Individual controls: sustainable, smart lighting for people, organizations, and the environment

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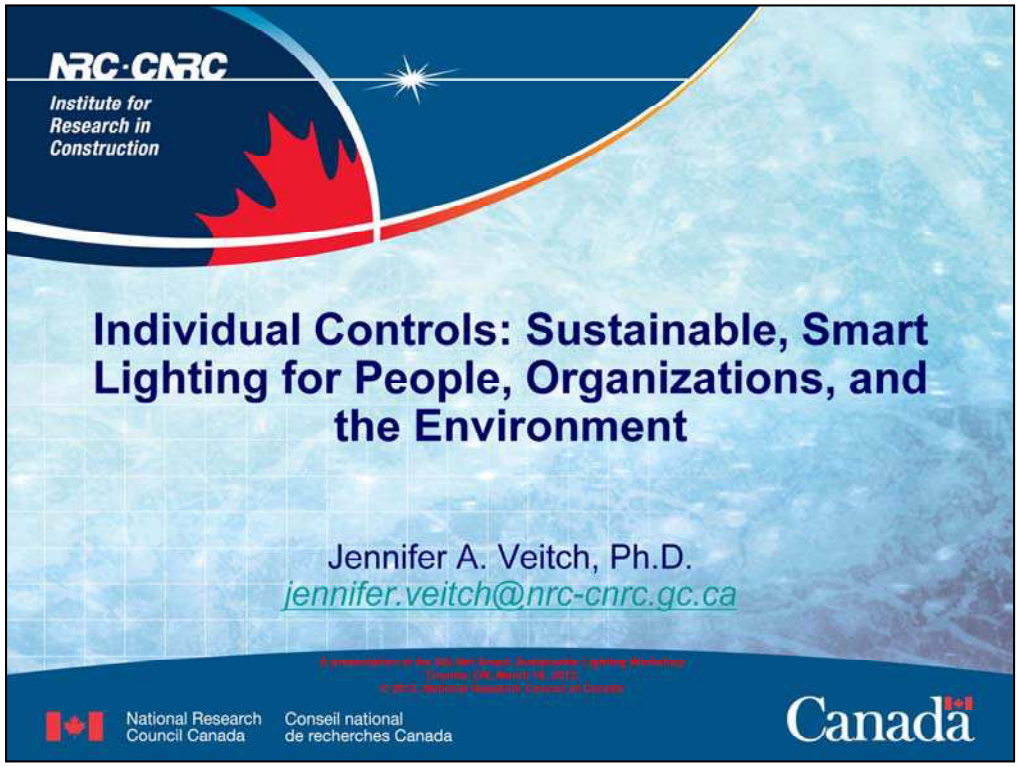


**Individual Controls: Sustainable, Smart Lighting for People, Organizations, and the Environment**

Jennifer A. Veitch

NRC Institute for Research in Construction

Exciting advances in lighting technologies will deliver a better future if we apply them intelligently, remembering what we already know about delivering good lighting quality. Among the more persistent questions has been whether providing better lighting has benefits for organizations. Over fifteen years of laboratory and field research enables our research group to answer “yes!” to this questions. We used laboratory methods to demonstrate that people prefer a mixture of direct and indirect lighting that lights the entire workspace and individual personal control over the local lighting. Working in conditions that one personally prefers leads to the judgement that the space is attractive, better mood, and less visual and physical discomfort. Field investigations have taken this farther, showing that satisfaction with the lit environment is predicts greater job satisfaction, greater organizational commitment, lower intent to turnover, and fewer health problems. Moreover, the (fluorescent) installation we studied used over 60% less energy than the system it replaced. These findings are notable because all of the workplace conditions studied are more than merely adequate. Done right, smart lighting can benefit individuals, their employers, and the environment.

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## Canadian Buildings and Energy

- Buildings account for 35-40% of national energy consumption
- Commercial and institutional buildings contribute ~13% of greenhouse gas emissions and ~13% of total energy use
- Commercial building energy use increased 35% from 1990 to 2004

Source: Natural Resources Canada, Office of Energy Efficiency



National Resources Canada, Office of Energy Efficiency. (2006). Retrieved April 18., 2007 from: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/publications.cfm?attr=0

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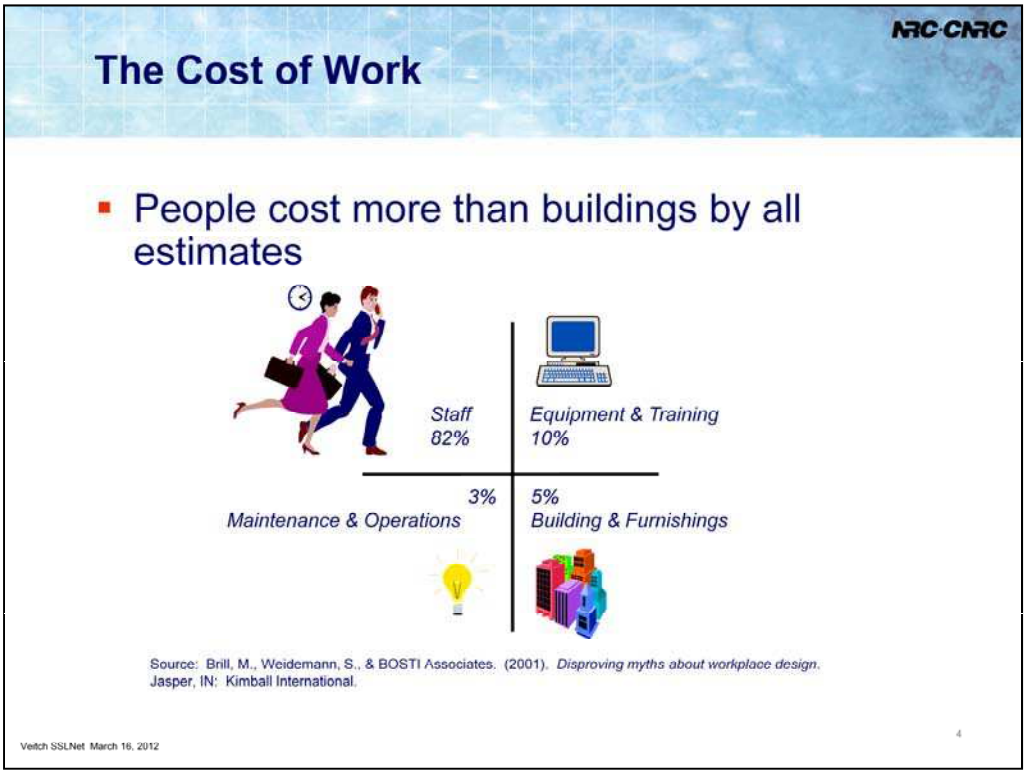
# People in Buildings

- People spend 90% of their time indoors




This type of statistic is often quoted as a reason why we need productivity research. The client wants to spend as little as possible on the two bottom categories because they are direct costs to the business. Sometimes they forget that it's the people - their salaries and benefits - that are the biggest costs. Thus, making an equipment or maintenance decision that makes it more difficult for people to do their jobs could cost a lot more than the original choice. People cost 10x more than providing and maintaining a building for them to work in.

Another reason why organisations are often reluctant to spend money on the bottom two categories is because investments here usually entail an upfront cost – this actually makes the organisation less productive in the short term, while these upfront costs are being absorbed. In the longer term though, these investments can be beneficial to productivity.

Another interesting way to think about this issue is to consider the success of high-tech companies. The 10% of costs for equipment and training didn't used to be presented in these charts: through the early 1990s the equation was 92% people, 8% maintenance and building. We have been sold on the value of such "productivity-enhancing" equipment such as faster and faster PCs, networks, e-mail systems, and elaborate software – despite the hidden costs of disruption while new technologies are implemented, and people get used to using them. Where's the data that it enhances anyone's productivity (apart from Microsoft's)? I've yet to see any convincing evidence - but like anyone else I like to have a fast computer to work on.

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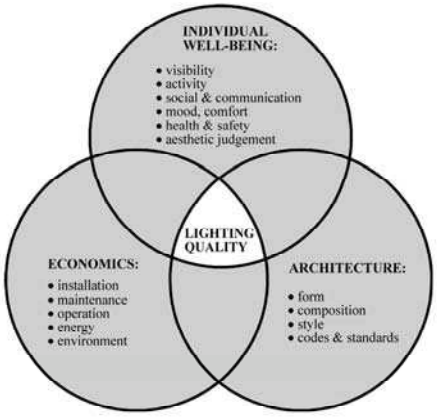
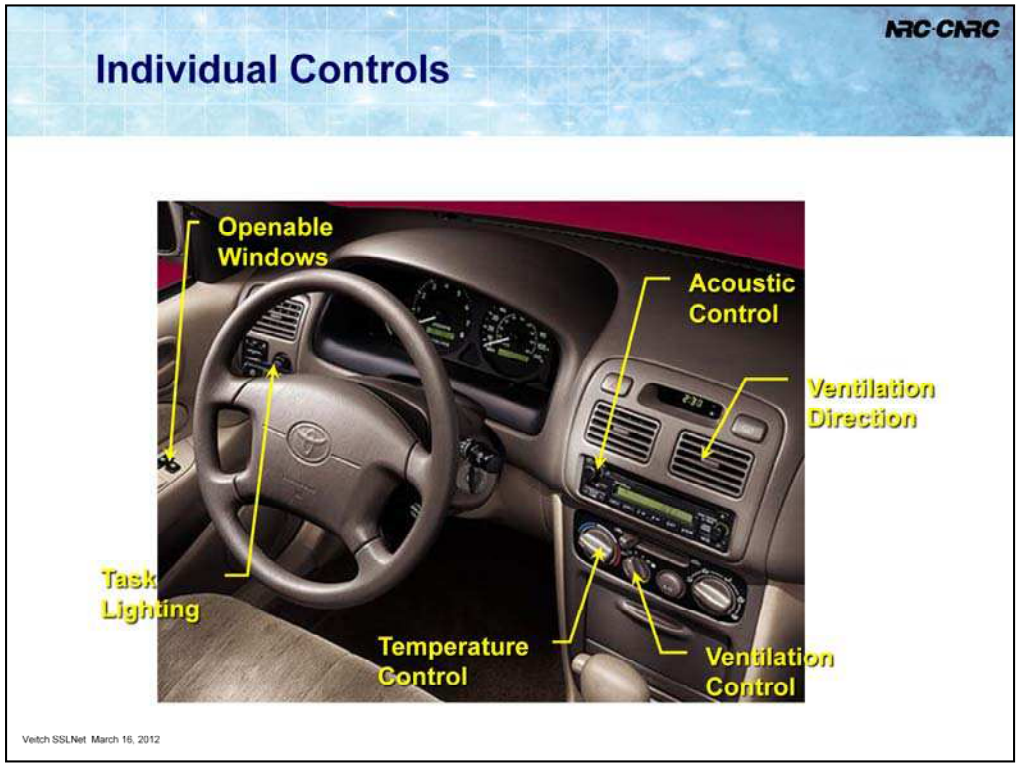
# Research Question

- Can office lighting go beyond providing adequate conditions for seeing?
- Can it be smart and sustainable?

→ Yes.






This analogy is a favourite one of my colleague, Dr. Guy Newsham. He likes to contrast our usual lack of control in offices with the control available to the occupants of even a basic automobile (like this Toyota Corolla). A car, where one might spend an hour a day, gives control over temperature, lighting, air flow, and acoustic environment, as well as letting occupants open a window. Many offices, where people spend up to 10 hours a day, provide none of this control. The justification for not providing control in offices is that it's cheaper, more cost-effective.

Funny, the car industry doesn't have the same mentality. Imagine a more basic Corolla with windows that were fixed shut. It doesn't allow you to vary the temperature, it's 22$^{o}$C all the time, and you can't change the direction of the airflow, it's always overhead. They still supply a radio, but it's on all the time and only plays one channel: the sound of your neighbour talking on the phone. It's $1000 cheaper, how many cars do you think they'd sell? How cost-effective would this new model be for Toyota? Personal control is not an optional extra in the car industry!

## Building the Evidence

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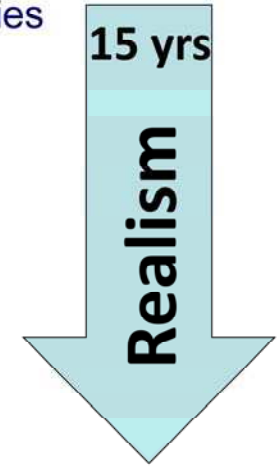
- Highly-controlled laboratory studies
- Quasi-realistic laboratory study
- Field studies



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# Light Right Albany Experiments

Experiment #1

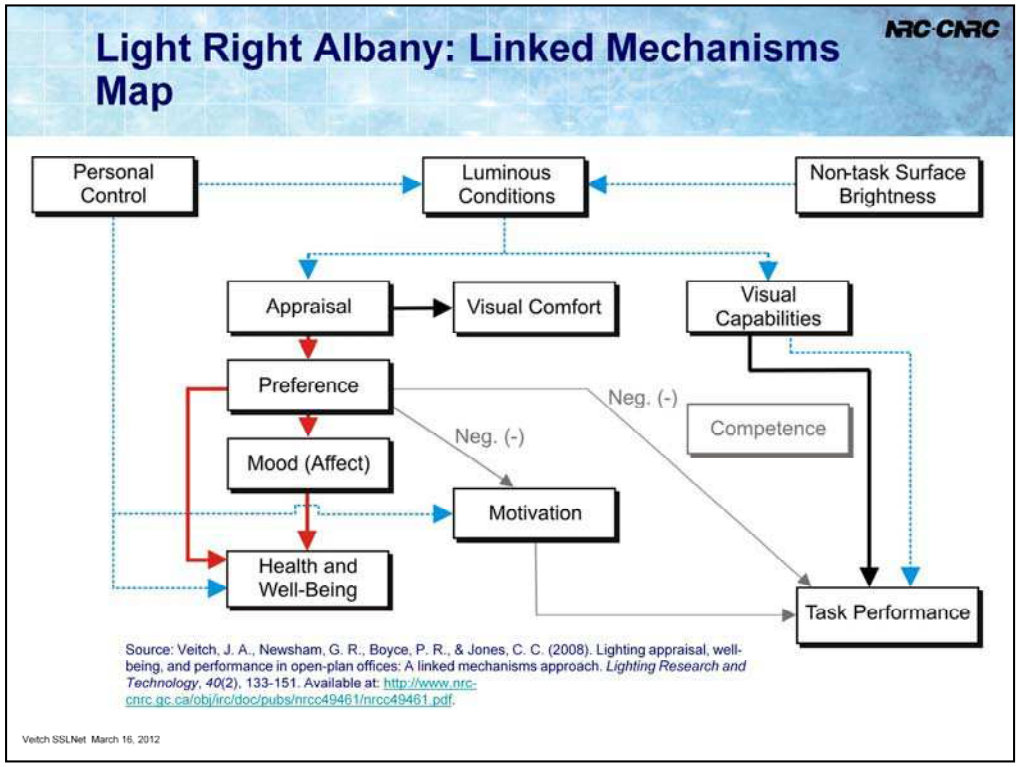




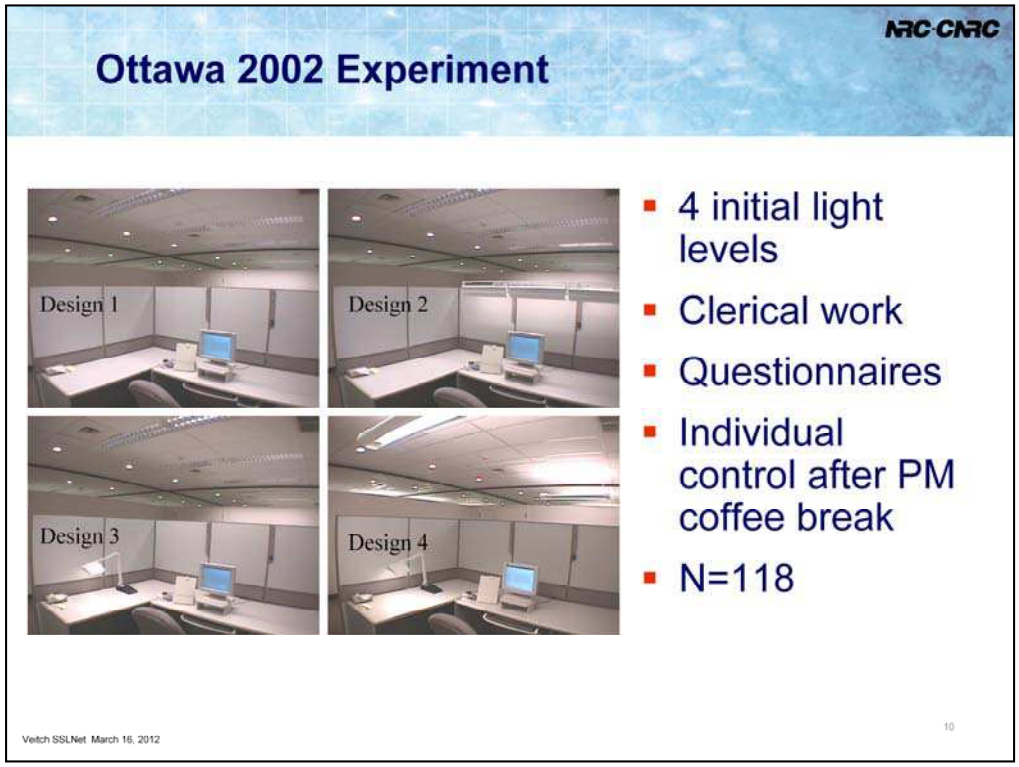
Experiment #2



- Temps, 1-day exposure
- Tasks & questionnaires
- Linked mechanisms map




A paper on these results in LR&T (Veitch, J. A., Newsham, G. R., Boyce, P. R., & Jones, C. C. (2008). Lighting appraisal, well-being, and performance in open-plan offices: A linked mechanisms approach. *Lighting Research and Technology, 40(2),* 133-151) received the Society of Light and Lighting 2008 Leon Gaster Award (best applications paper)




Two typical open-plan office cubicles (see one here).

Partition reflectance= 0.51

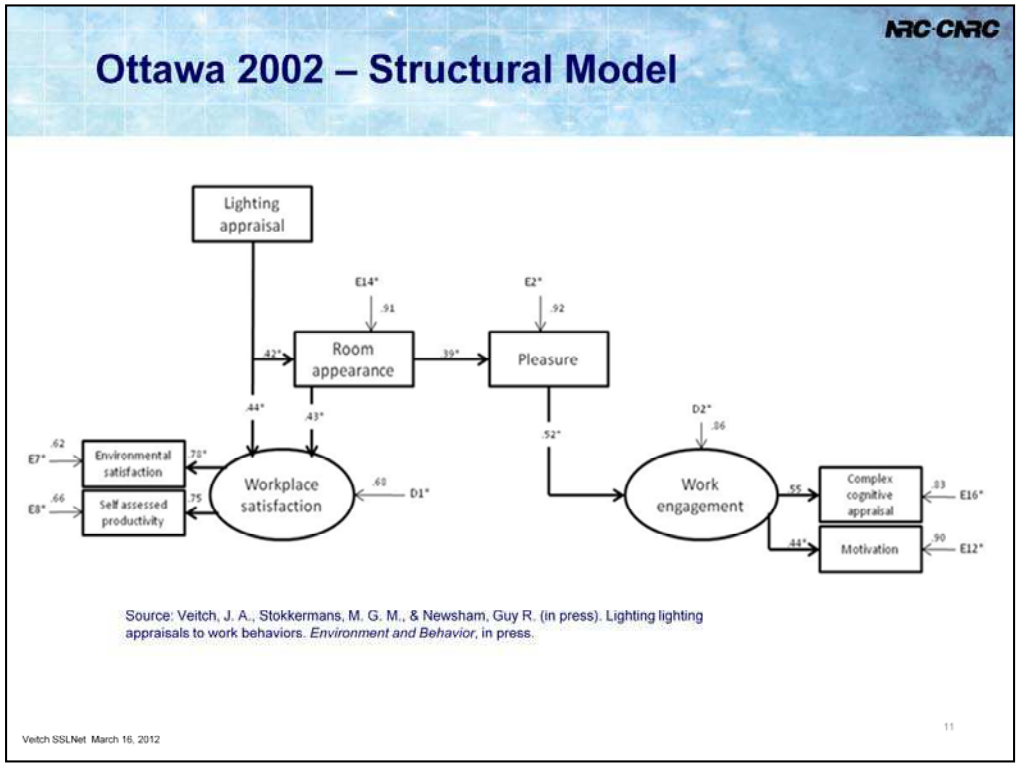
Installed 4 different lighting designs:

1. Standard deep-cell parabolic (4 x 2-lamp luminaires per WS), could deliver over 1000 lx to desktop at maximum output
2. Parabolic + custom wall-washer (3 x 1-lamp) to potentially increase vertical luminance in field of view.
3. Parabolic + angle-arm task light
4. Suspended dir/indirect (1 x 2-lamp per WS) + task light, far fewer lamps, therefore capable of lower light level than parabolics

The original experiment was reported in:

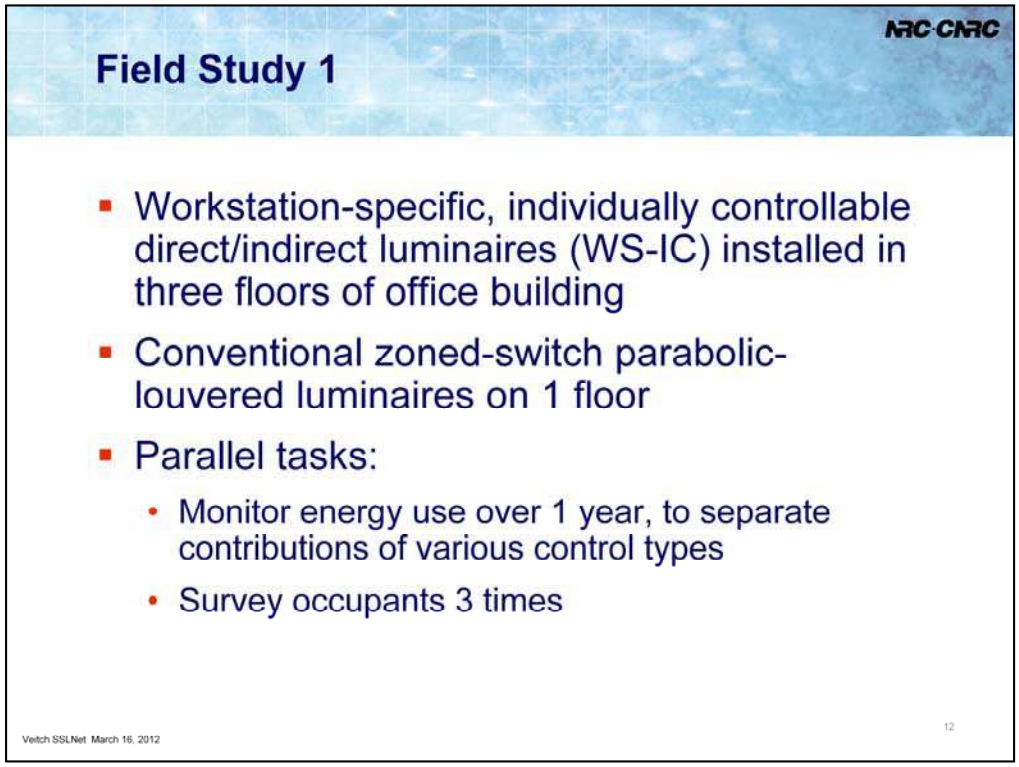
Newsham, G. R., Veitch, J. A., Arsenault, C. D., & Duval, C. L. (2003). *Lighting for VDT workstations 1: Effect of control on energy consumption and occupant mood, satisfaction and discomfort* (IRC Research Report RR-165). Ottawa, ON: NRC Institute for Research in Construction. Retrieved from http://irc.nrc-cnrc.gc.ca/fulltext/rr/rr165/.

Newsham, G. R., Veitch, J. A., Arsenault, C. D., & Duval, C. L. (2004). *Lighting for VDT workstations 2: Effect of control and lighting design on task performance and chosen photometric conditions* (IRC Research Report RR-166). Ottawa, ON: NRC Institute for Research in Construction. Retrieved from http://irc.nrc-cnrc.gc.ca/fulltext/rr/rr166/.



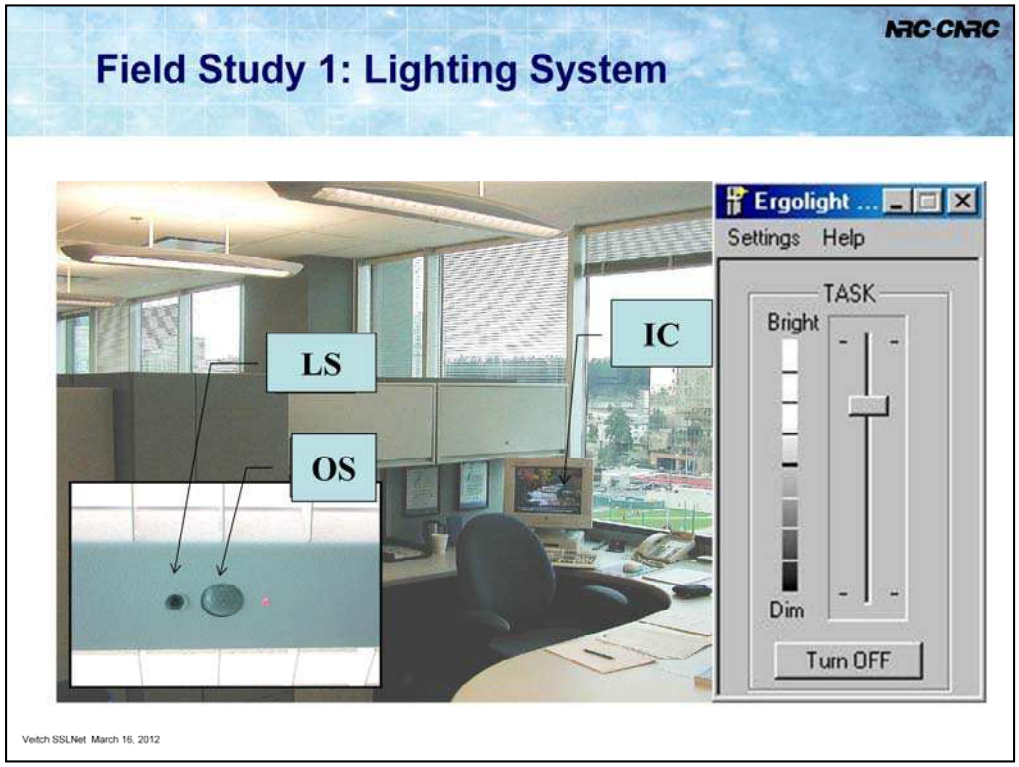

This re-analysis is from

Veitch, J. A. , Stokkermans, M. G. M., & Newsham, G. R. (2011). Linking lighting appraisals to work behaviors. Manuscript in preparation.

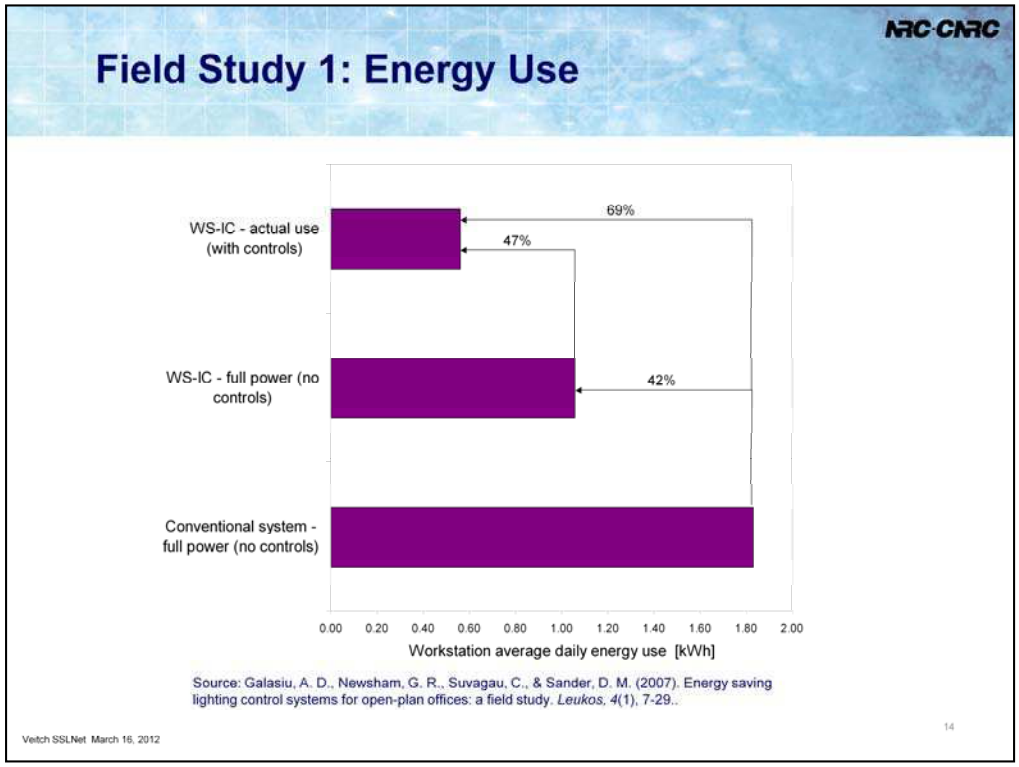



Lighting consumes about 30% of electricity in commercial buildings, making it a prime target for efficiency programs. However, changing to more energy-efficient lighting can be costly and complex. Furthermore, managers express concern that if they make the wrong choice they could adversely affect occupants, which would cost far more than any energy saved.

On the plus side, if one could demonstrate that a new technology benefits occupants, one could faciliate its adoption by demonstrating that the net costs will be lower.




This lighting system is workstation-specific; each cubicle has its own luminaire. One lamp shines up, indirectly illuminating the space by reflecting off the ceiling. In this study that lamp was on throughout occupied hours (7 am - 7 pm). The two direct (down) lamps were controlled by the individual using an on-screen slide (IC, shown right). The light sensor (LS) would dim the downlights in response to the presence of daylight. The occupancy sensor would turn the lights off if the cubicle was empty for 15 minutes; it did this in a slow ramp.




The energy analysis part of the study involved collecting lighting system data for a full year from the WS-IC luminaires. This chart shows total energy use for a conventional system, for WS-IC if all lamps were on at full power for all the occupied hours, and for WS-IC as actually used, taking into account savings associated with the occupancy sensors, the light sensors, and the individual controls.

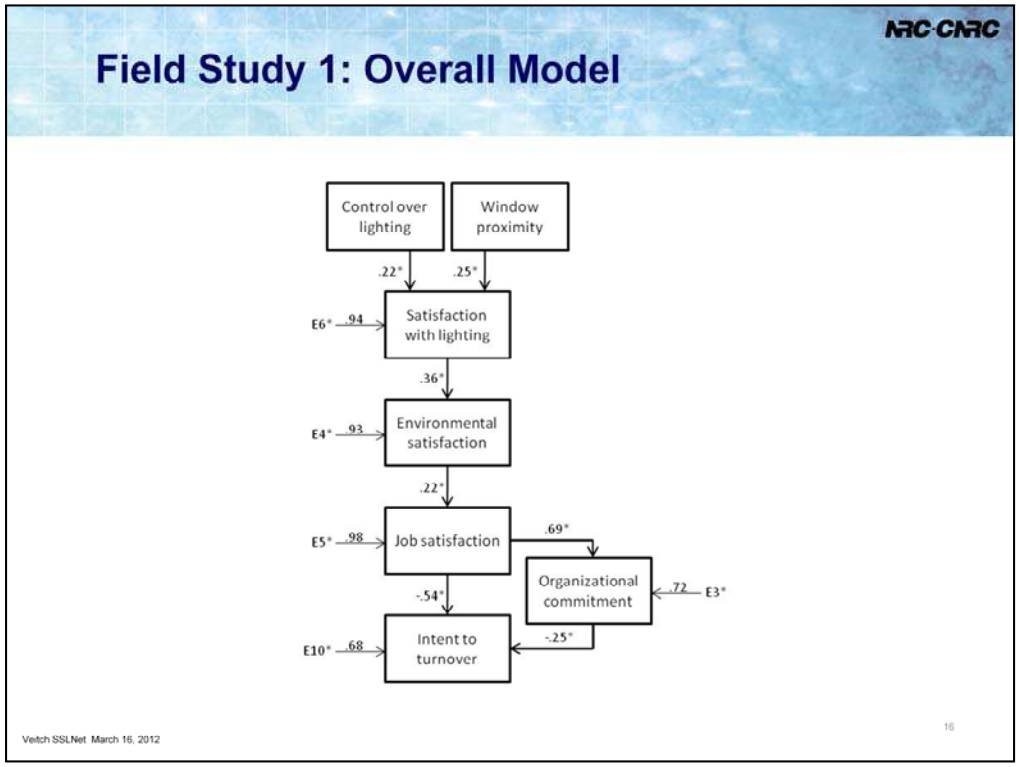
The individual controls alone account for about 10% of the energy savings. Of the three, the OS are the biggest source of savings, because of all the times when people are out of the office (Galasiu et al., 2007). With a shorter time to turn off, and a faster ramp down, the savings could be even greater, although there is an issue with frequent switching and lamp life that limits how often one wants the lamps to cycle on and off.

Reference:

Galasiu, A. D., Newsham, G. R., Suvagau, C., & Sander, D. M. (2007). Energy saving lighting control systems for open-plan offices a field study . *Leukos*, *4*(1), 7-29.

## Field Study 1: Conclusions

- WS-IC are preferred over the recessed parabolic-louvered luminaires - results almost identical to the Light Right experiments
- Individual control over lighting contributes to organizational effectiveness through job satisfaction

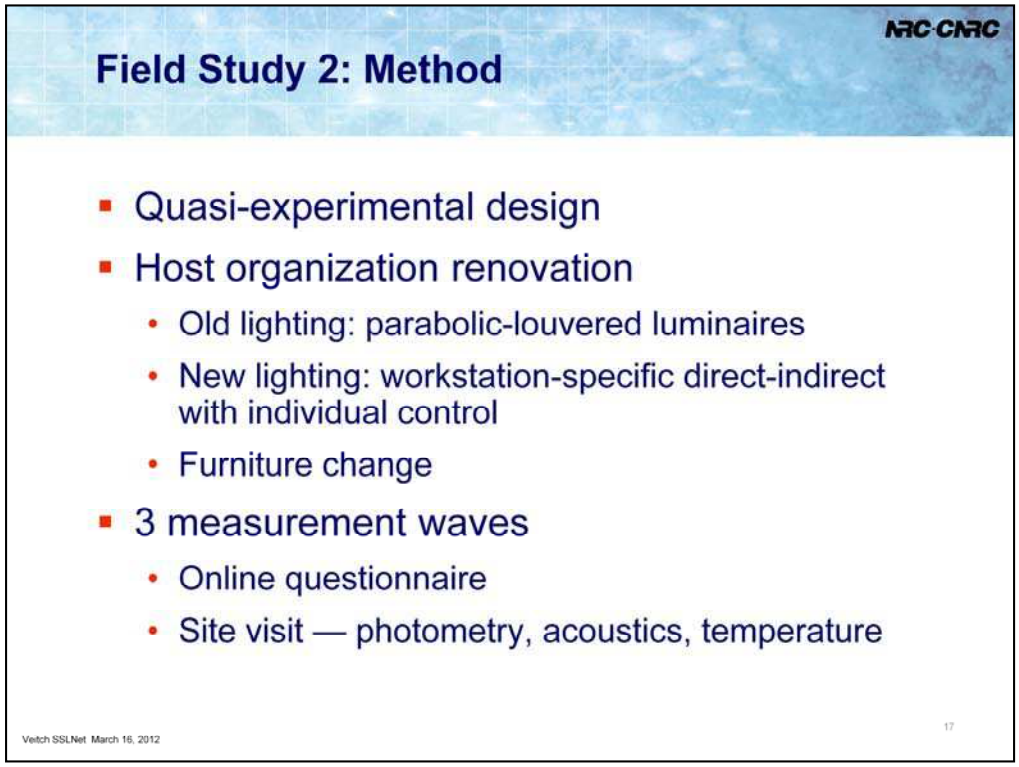



We developed this model based on our own prior research and on the literature:

Boyce, P. R., Veitch, J. A., Newsham, G. R., Jones, C. C., Heerwagen, J., Myer, M., et al. (2006). Lighting quality and office work Two field simulation experiments. *Lighting Research and Technology*, *38*(3), 191-223.

Carlopio, J. R. (1996). Construct validity of a physical work environment satisfaction questionnaire. *Journal of Occupational Health Psychology*, *1*, 330-344.

Veitch, J. A., Charles, K. E., Farley, K. M. J., & Newsham, G. R. (2007). A model of satisfaction with open-plan office conditions COPE field findings. *Journal of Environmental Psychology*, *27*(3), 177-189.




Veitch, J. A., Newsham, G. R., Mancini, S., & Arsenault, C. D. (2010). *Lighting and office renovation effects on employee and organizational well-being (*No. NRC-IRC RR-306). Ottawa, ON: NRC Institute for Research in Construction. Available at: http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr306.pdf.

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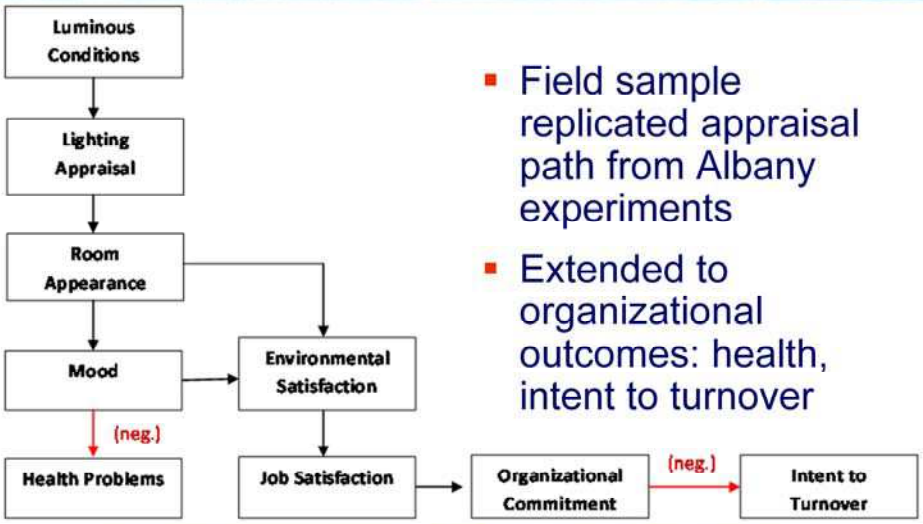
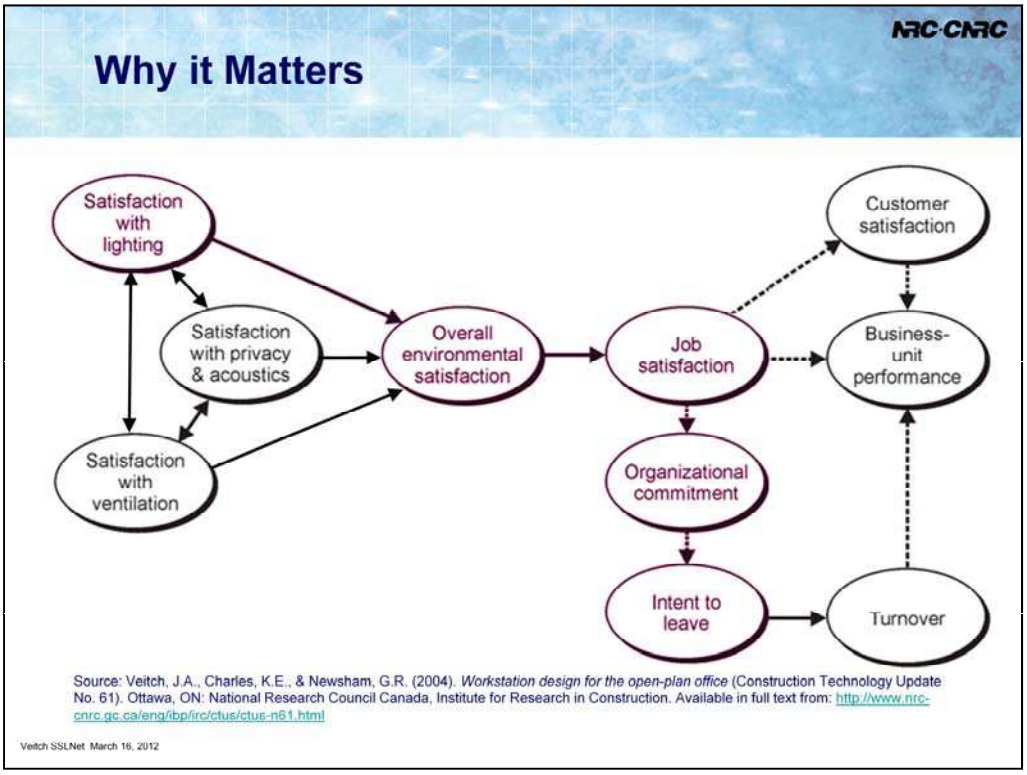
# Linked Mechanisms Map Test




- Field sample replicated appraisal path from Albany experiments
- Extended to organizational outcomes: health, intent to turnover

Veitch, J. A., Newsham, G. R., Mancini, S., & Arsenault, C. D. (2010). *Lighting and office renovation effects on employee and organizational well-being* (NRC-IRC Research Report RR-306). Ottawa, ON: NRC Institute for Research in Construction. Available at: http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr306.pdf.




Organizations with higher job satisfaction have more committed employees who have a lower intent to leave and lower turnover. They also have better business unit performance and higher customer satisfaction.

The results we have found here show that good lighting is part of this process. We can design good lighting that is energy-efficient, but energy efficiency should not be not the only, nor the most important, determinant of lighting installations in offices. Lighting is for people, and people determine the success or failure of the organizations they work for.

## Discussion

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- Over 15 years of investigations show that individual controls deliver smart, sustainable lighting:
  - Positive mood
  - Better health & well-being
  - Energy savings
  - Better organizational efficiency

## Credits


- Colleagues and collaborators: Chantal Arsenault, Peter Boyce, Cara Donnelly, Anca Galasiu, Judi Heerwagen, Claudia Hunter, Carol Jones, Sandra Mancini, Roger Marchand, Michael Myer, Guy Newsham, Dan Sander, Mariska Stokkermans, Cristian Suvagau, Jana Svec
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