Shaping Tomorrow's Built Environment Today

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TO: Dennis Loveday, Chair TC 2.1, d.l.loveday@lboro.ac.uk
Hui Zhang, Research Subcommittee Chair TC 2.1, zhanghui@berkeley.edu

CC: Pawel Wargocki, Research Liaison 2.0, paw@byg.dtu.dk

FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org

DATE: November 20, 2015

SUBJECT: Research Topic Acceptance Request (1777-RTAR), "The Effects of Outdoor Air Supply Rate on Sleep Quality and Next-day Performance"

During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to reject it. The following list summarizes the consensus review comments and questions on this RTAR:

1. The expected project cost is high. Consider breaking the project into two projects – first project is pilot study to develop the research methodology and the second project collects and analyzes the data on a broader scale.

2. Endorsement for this research should be sought from perhaps 62.2, 62.1, 90.2, and EHC as technical co-sponsors. Support and co-funding for the research should also be sought from appropriate organizations such as USGBC, Green Building Initiative, and other parties interested in the topic.

3. Address the comments and concerns that RAC members have raised in the RTAR evaluation sheet under the sections Research Need and Relevance and Benefits to ASHRAE.

By rejecting this RTAR, RAC is strongly suggesting to the TC that this particular topic be dropped from the TC research plan based on the information that has been provided.

An RTAR evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on specific review criteria. This should give you an idea of how your RTAR is being interpreted and understood by others.

If the TC wishes to pursue this topic further, please incorporate the above information into the RTAR with the help of your Research Liaison, Pawel Wargocki, RL2@ashrae.net, prior to submitting it to the Manager of Research and Technical Services for further consideration by RAC. In addition, a separate document providing a point by point response to each of these comments and questions must be submitted with the RTAR. The response to each item should explain how the RTAR has been revised to address the comment, or a justification for why the Technical Committee feels a revision is unnecessary or inappropriate. The RTAR and response to these comments and questions must be approved by the Research Liaison prior to submitting it to RAC.

The next realistic submission deadline for RTARs and WSs is **May 15, 2016** for consideration at the Society's 2016 annual meeting. The submission deadline after that is **August 15, 2016** for the RAC fall meeting.

Project ID	**1777**	
Project Title	**The Effects of Outdoor Air Supply Rate on Sleep Quality and Next-day Performance**	
Sponsoring TC	TC 2.1, (Physiology and Human Environment)	
Cost / Duration	$300k 36M	
Submission History	**1st Submission**	
Classification: Research or Technology Transfer	Technology Transfer	
RAC 2015 Fall Meeting Review		
Essential Criteria	**Voted NO**	**Comments & Suggestions**
Background: The RTAR should describe current state of the art with some level of literature review that documents the importance/magnitude of a problem. References should be provided. If not, then note it in your comments.		**9**- It is indeed meaningful but difficult to get meaningful results. **16** - The summary says this work is needed to develop a new standard for air quality in spaces where people sleep, such as dwellings and hotel hotels. Though not critical, it should be noted that ASHRAE already has standards for these space types, 62.1 for hotels and 62.1 and 62.2 for dwelllings (depending on the nature of the dwelling determins whether its .1 or .2). So the summary should refer to updates of existing standards, not new standards. The background, while interesting, doesn't seem to provide a review of the state of the art, only a review of two relevant publications. I don't know the literature all that well, but there are other relevant studies on outdoor air and at least waking performance. **17** - The background is fairly clear. It does seem to ignore that there are already standards for ventilation in ASHRAE, and that this work would really go to informing those standards regarding potential changes specific to bedroom ventilation rates.
Research Need: Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected.	**13, 6**	**13** - My primary concern with the proposed research is that there is not a clear need established. I question whether it is an appropriate subject for additional standardization/codification. **15** - I voted "yes" because there isn't an "I don't know" button and I don't want to kill the idea completely with a "No" vote. We already have Standard 62.2. Will this enhance it, change it, possible cause it to be re-written? Do we want to start down a path towards separate ventilation standards for every type of room in a building? **6** - This is clearly an interesting topic. However, a lot of factors or uncertainties may arise, making this research potentially uncontrollable. Why so little relevant research on this topic? Why should ASHRAE perform this? Moreover, the RTAR seems to equivalent between ventilation rate, indoor air quality, and CO2 concentrations. These are totally different concepts. CO2 cannot represent indoor air quality, may even not be able to quantify the ventilation condition if indoor CO2 sources are unclear. The sleep measurement requires more scientific method. The next-day performance test is too simple and has to exclude other possible influencing factors. **10** - My concern is principally that the "hard" questions don't seem to be in areas of core ASHRAE competence. The hard Q include interpretation of the sleep information and of the effects (next day). Could we even manage this, or does it belong in a University clinical (sleep) laboratory environment? **16** - I don't' know the basis of the statement that bedrooms are often very poorly ventilated. Only one study is cited; is that the basis for that broad statement? A similarly broad statement is included in the Research Objective as well. I don't see a clear statement of the research need in this section. It does not appear there is any intent to actually measure ventilation rates. Given the title of the effort, this seems sstrange and merits explanation. While it is very difficult to measure outdoor air ventilation rates in individual rooms, that parameter needs to be discussed. I'm guessing they are going to use CO2 concentrations as a surrogate, which is problematic and needs to be discussed if that's the expectation. **17** - While other studies are limited, there are other studies out there as referenced by the RTAR authors. It is not clear to me at all what the intent of the new research is in the context of what has already been done. What added value does this research provide? Why can't we just use what is already done to propose changes to our existing standards? There may be good reasons to do more, but that has not been clearly stated.
Relevance and Benefits to ASHRAE: Evaluate whether relevance and benefits are clearly explained in terms of: a. Leading to innovations in the field of HVAC & Refrigeration b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards. Is this research topic appropriate for ASHRAE funding? If not, Reject.	**13, 6**	**13** - It is not clear that this is a problem that requires a solution. The research would no doubt be interesting as an exercise, but it is not clear that there is a need. **9** - It will be a pioneer work of ASHRAE. **6** - Too much risk for ASHRAE to perform this large project. If the TC really wants to do it, please consider to split it into smaller phased projects to mediate the risk. **7** - Needs co-funding from appropriate organizations. **10 -** ASHRAE is putting substantial effort into becoming a 'player' in residenital. As I think about portfolios, what other residential activities would be more important (whether or not we have requests)? **17** - If this work is needed then it is approporiate for ASHRAE funding. It could certainly impact ASHRAE standards and basic building operation. There are some metrics that are not clear will be included and, if a WS was crafted, should be included. These include air change rates of the bedrooms and some sort of qualitative assessment via a survey or similar approach. It also appears that the wrong box was checked on the form, with Survey being checked and not "Field Tests". I actually think both should be checked.
IF ABOVE THREE CRITERION ARE NOT ALL SATISFIED - MARK "REJECT" BELOW & CONTINUE REVIEW BELOW		
Other Criteria	**Voted NO**	**Comments & Suggestions**
Project Objectives: Based on the background and need, evaluate whether the project objectives are: 1. Aligned with the need 2. Specific 3. Clear without ambiguity 4. Achievable If not, then appropriate feedback should be provided.	**15, 6**	**15** - How they intend to measure and quantify "next-day performance" seemed a bit vague to me. **6** - See above comments. **10** - The RTAR feels too repetitious, so we don't have enough words in each section to both repeat and clearly establish what that section asks for, in this case, the objectives. I can't tell. **16** - This is important work. With some non-major revision of the RTAR I would be supportive of this moving forward. **17** - I think the goals are laudable. I question being able to get such well-matched sleeping areas as are described. I also am not sure that enough is being evaluated. My biggest problem is the fact that it is not clear what the need is for additional research. **3** - Too many subjective factors - waste of money.
Expected Approach and Budget: Is there an adequate description of the approach in order for RAC to be able to evaluate the appropriateness of the budget? If not, then the RTAR should be returned for revision. Anticipated funding level and duration:	**7, 15, 9, 6**	**7** - This project is too expensive. **15** - I think this could be important information to develop, but $300,000 seems like a lot to spend to get it, and no potential co-funders are listed. **9** - The research approach is good, but the budget is too small for the project size. **2** - Slightly too expensive, but it can be addressed in WS. **6** - Budget too high. Objective too ambitious. **10** - Seems from the references that this might be an area of European focus. References include RAC member Pawel Wargocki. What can he tell us about this research area?
References: Are the references provided?		
Decision Options	**Initial Decision?**	**Final Approval Conditions**
ACCEPT AS-IS		**7** - The expected project cost is too high. This project should be funded only if co-funding from an appropriate organization is available. **15** - Would like to see the TC address my comments above in the Research Need or Background section. **9** - The project will be a pioneer and preliminary work. The next step of the project should be stated. It will make clear the project. **2** - Co-sponsors are needed, perhaps 62.2 as well as 62.1. **10** - Agree on the need for strong endorsements from SPCC 90.2, and also from EHCC. If there really is little relevant research, should start with a pilot. **16** - I'm only reviewing, not voting. That is for others.
ACCEPT W/COMMENTS		
REJECT		

ACCEPT Vote - Topic is ready for development into a work statement (WS).
ACCEPT W/COMMENTS Vote - Minor Revision Required - RL can approve RTAR for development into WS without going back to RAC once TC satisfies RAC's approval condition(s)
REJECT Vote - Topic is not acceptable for the ASHRAE Research Program

Research Topic Acceptance Request Cover Sheet

Date: 6/30/2015

(Please Check to Insure the Following Information is in the Work Statement)

A. Title	☑
B. Applicability to ASHRAE Research Strategic Plan	☑
C. Application of the Results	☑
D. State-of-the-Art (background)	☑
E. Advancement to State-of-the-Art	☑
F. Justification and Value to ASHRAE	☑
G. Objective	☑
H. Estimated Duration	☑
I. References	☑

Title:
The effects of outdoor air supply rate on sleep quality and next-day performance

RTAR# 1777
(To be assigned by MORTS)

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:

Fundamentals: Human requirements

Responsible TC/TG: 2.1

Date of Vote: June 30 2015

For		14
Against	*	0
Abstaining	*	0
Absent or not returning Ballot	*	0
Total Voting Members		14

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date):

RTAR Lead Author: David Wyon

Expected Work Statement Lead Author: David Wyon

Potential Co-funders (organization, contact person information):

Research Classification:

- ☑ Basic/Applied Research
- ☐ Advanced Concepts
- ☐ Technology Transfer

	Yes	No
Has an electronic copy been furnished to the MORTS?	✔	
Has the Research Liaison reviewed the RTAR?	✔	

* Reasons for negative vote(s) and abstentions

DRAFT RTAR Template

Title: The effects of outdoor air supply rate on sleep quality and next-day performance

Summary

Describe in summary form the proposed research topic, including what is proposed, why this research is important, how it will be conducted, and why ASHRAE should fund it (50 words maximum)

The proposed study will quantify the effects of bedroom air quality on regular sleep and on the ability to perform work next day, so that this information can be the basis for a new ASHRAE Standard for air quality in places where people sleep, such as dwellings and hotels.

Background

Provide the state of the art with key references (at the end of this document) substantiating it (300 words maximum)

Both sleep and good indoor air quality are generally considered to be essential for human health and well-being, but as many factors affect sleep the field was considered by RAC in 2007 to be too complex for ASHRAE to fund. Only two small experiments on how bedroom air quality affects sleep have been carried out to date (Strøm-Tejsen et a. 2014a, b). In the first, an open window was shown to reduce sleep latency (time taken to fall asleep) because the intervention changed draft and noise as well as air quality. In the second experiment, sleep quality and next-day performance were measured in identical single-occupancy dormitory rooms. The 16 subjects, half of them women, slept at home in their own rooms. They were exposed to two ventilation conditions, each for one week, resulting in average CO2 levels of around 835 and 2395 ppm, respectively. A fan controlled by a CO2 sensor was used to supply outside air to establish the condition with low CO2 level and in the control condition was disabled without the subject being aware of it. Subjects adjusted an electric heater to ensure thermal comfort. The subjects' sleep quality and next-day performance were assessed from subjective responses, from two online performance tests and in terms of movement data recorded on wristwatch-type actigraphs. The results show positive effects of a higher ventilation rate on the perceived freshness of the air, on the subjects' mental state and their feeling of being rested. There was a statistically significant and positive effect on sleep efficiency (time in bed spent asleep) as measured by the actigraphs, and on next-day performance. The field intervention experiment approach has thus yielded statistically significant effects even in relatively small experiments.

Research Need

Use the state of the art described above as a basis to specify the need for the proposed effort (250 words maximum)

People spend one third of their life sleeping, 12-14 hours/day during infancy and 7-8 hours/day during adulthood and this has been found to be essential to human health and well-being. Bedroom temperatures are under individual control and vary widely between individuals as a function of sleepwear, bedcover and mattress insulation, with a trade-off between what is thermally comfortable for sleep and for other activities in the bedroom while not asleep. However, bedrooms with the doors and windows closed for acoustic privacy and energy conservation are often very poorly ventilated indeed, and according to a recent survey (Sleep America 2004), 43% of school-age children under 10 have a TV set in their bedroom, and 11% have a computer. Both contribute air pollution to indoor air (Bakó-Biró et al. 2002; Nakagawa et al. 2003). Bekö et al. (2010) reported that 57% of the bedrooms of Danish children did not fulfil the minimum ventilation requirements stipulated in EN 15251 (2007) for dwellings in general. Energy conservation efforts can make this worse. If bedroom air quality affects sleep, as appeared to be the case in the only experiments reported to date, there might be negative effects on next-day performance. Studies by Tynjälä et al. (1999) and Meijer et al. (2000) among children in Finland and Holland respectively showed a strong correlation between sleep quality and the ability to concentrate the next day. This is likely to be true for adults and could be affecting productivity.

Project Objectives

Based on the identified research need(s), specify the objectives of the solicited effort that will address all or part of these needs (150 words maximum)

The proposed project will perform realistic field intervention experiments to quantify the effects on sleep and next-day performance of increasing the outdoor air supply rate in bedrooms. A number of outdoor air supply rates corresponding to the wide range of CO2 levels (800 - 2500 ppm) that is currently found in bedrooms will be compared in terms of how they affect sleep and how this affects the ability to perform work next day. These effects will be studied in subjects of school age, in young adults and in older adults. Subjects will be compared only with themselves, under systematically different bedroom ventilation conditions, with the windows closed throughout. Parallel series of experiments will be performed in bedrooms in temperate regions and in air-conditioned bedrooms in hot-humid regions. Ventilation rates are often low in both categories due to energy conservation measures.

Expected Approach

Describe in a manner that may be used for assessment of project viability, cost, and duration, the approach that is expected to achieve the proposed objectives (200 words maximum).

Check all that apply: Lab testing ☐, Computations ☐, Surveys ☑, Field tests ☐, Analyses and modeling ☐, Validation efforts ☐, Other (specify) ( )

Field intervention experiments should be performed in regions with clean outdoor air, in identical bedrooms that are similarly furnished. Subjects without illness, allergy or sleep disorders should sleep for one week under each condition, in balanced order. They should be able to select their preferred bedroom air temperature freely, Field intervention experiments should be performed in regions with clean outdoor air, in identical bedrooms that are similarly furnished. Subjects without illness, allergy or sleep disorders should sleep for one week under each condition, in balanced order. They should be able to select their preferred bedroom air temperature freely, because of the large number of uncontrollable factors involved in t. Bedroom IEQ should be recorded continuously in terms of T, RH, air velocity, CO2, illuminance and noise levels. Sleep quality should be assessed with wrist-worn actigraphs that record movement continuously and can reliably distinguish between sleep and waking. This approach has been validated against conventional polysomnographic data (Kushida et al. 2001) and is routinely used to study the side effects of medication on sleep (Sadeh et al. 1995) during everyday life. Questionnaires such as the Groningen Sleep Quality Scale should be used to obtain standardized subjective assessments of sleep quality (Mulder-Hajonides et al. 1980). Next-day performance should be quantified on a number of realistically presented and appropriate everyday tasks typical of schoolwork or office work (e.g. text processing or numeric processing) and on tests of specific cognitive processes such as attentional distribution and working memory capacity.

Relevance and Benefits to ASHRAE

Describe why this effort is of specific interest to ASHRAE, its impact, and how it will benefit ASHRAE and the society. How does it align with ASHRAE Strategic Plans and Initiatives? How does it advance the state of the art in this area in general? Are there other stakeholders that should be approached to obtain relevant information or co-funding? (350 words maximum)

For over one third of the time that building occupants are indoors they are asleep. Domestic and hotel HVAC systems are often switched off for the large part of the day when no occupants are present, but are usually in operation at night. In cold countries, heating requirements are much greater at night than during the day, so windows are kept closed and bedroom ventilation is often very low. In tropical countries a rapidly increasing proportion of households are installing partial air conditioning that almost always takes the form of air conditioning in the bedroom only. This means that the rate at which energy is used to control the indoor climate is rapidly becoming greater at night than during the day in dwellings, hotels and other places where people sleep, yet none of the levels of T or IAQ recommended by ASHRAE are based on how they affect sleep quality. If ASHRAE is to continue to issue guidance for achieving energy conservation in such buildings, they should be based on valid research, not assumptions.

Major hotel operators might be interested to contribute towards this work, with a view to being able to provide better sleeping conditions for their guests.

In view of the undoubted importance of good sleep, public health authorities will be interested in the findings so that they are able to consider the benefit side of the cost-benefit equation underlying the regulations they issue on energy conservation in the ventilation of buildings where people sleep.

Anticipated Funding Level and Duration

Funding Amount Range: $ 300k

Duration in Months: 36

References

List the key references cited in this RTAR

Bakó-Biró Z, Wargocki P, Weschler C, Fanger PO (2002) Personal computers pollute indoor air: effects on perceived air quality, SBS symptoms and productivity in offices. Indoor Air 2002, Monterey, 2, 249-254

EN 15251:2007(E). Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. CEN, Brussels.

Kushida CA, Chang A, Gadkary C, Guilleminault C, Carrillo O, and Dement WC. 2(001) Comparison of actigraphic, polysomnographic and subjective assessment of sleep parameters in sleep-disordered patients. Sleep Medicine, 2(5), 389-396.

Meijer AM, Habekothé HT, and van den Wittenboer GL. (2000) Time in bed, quality of sleep and school functioning of children. Journal of Sleep Research, 9(2), 145-153.

Mulder Hajonides van der Meulen WREH, Wijnberg JR, Hollander JJ, De Diana IPF, and van den Hoofdakker RH. (1980) Measurement of subjective sleep quality. European Sleep Research Society Abstracts, 5, 98.

Nakagawa T, Wargocki P, Sanabe S, Weschler CJ, Baginska S, Bakó-Biró Z, Fanger PO (2003) Chemical emission rates from personal computer. Healthy Buildings 2003, Singapore, 1, 468-473

Sadeh A, Hauri PJ, Kripke DF, Lavie P (1995) The role of actigraphy in the evaluation of sleep disorders. Sleep, 18, 288-302

Sleep America (2004) Survey of children's sleeping habits and arrangements. National Sleep Foundation, USA

Strøm-Tejsen P, Wargocki P, Wyon DP and Kondracka A. (2014a) The effect of air quality on sleep. In: Proceedings of the 13th International Conference on Indoor Air Quality and Climate - Indoor Air 2014, Hong Kong, Paper HP0506

Strøm-Tejsen, P, Wargocki, P, Wyon, DP & Zukowska-Tejsen, D (2014b) The effect of CO2 controlled bedroom ventilation on sleep and next-day performance. In Proceedings of ROOMVENT 2014, Sao Paulo, Brazil

Tynjälä J, Kannas L, Levälahti E, and Välimaa R. (1999) Perceived sleep quality and its precursors in adolescents. Health Promotion International, 14(2), 155-166.