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USING TASK AMBIENT SYSTEM TO IMPROVE COMFORT AND PRODUCTIVITY IN OFFICE BUILDINGS

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To all of you,

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PREFACE

Searching the perfect environment: The thermal delight

One of the reasons why regional architecture is different from one site to another is the local climate. If we give a look to few examples of vernacular and regional architecture, we can see how the shape of buildings is connected to the climate, and how this shape contributes to the heating, cooling and lighting of the internal environment.

The most primitive dwelling of many cultures was typically just a small round shelter with a firepit at its center. Also in great examples of ancient architecture the most important architects have responded to the needs for environmental control using the shape buildings themselves. At the beginning a simple fireplace had the important role of heating the whole environment where people lived, from a simple hole in the ground to a more developed fireplaces.

Around the end of the Middle Ages the notion of a chimney to channel off the smoke of the fire began to take hold, and also the development of heating systems started. During the following centuries, technology developments changed the concept of environment within the building and the shape of buildings to respond to the climate. An example was in the Eighteenth Century when Benjamin Franklin enclosed the fire in a metal box to control the rate of combustion and to separate the combustion gases from the surrounding air, and than moved it out into the middle of the room where its heat could radiate in all directions.

In the 1960s the development of the mechanical systems allowed the control of lighting, heating and cooling of buildings. The more the technology was developed to control completely the thermal environment, the more people became curious about what a truly optimal thermal environment might be. [Heschong L., 1979]

Fanger, in the late 70s, defined the comfort zone for the occupants and the most important variables that influence the condition of thermal comfort. He focused on the effort of eliminating the causes of local and global discomfort and the main purpose of the

INTRODUZIONE

I sistemi localizzati per il miglioramento delle condizioni di comfort e della produttività

I sistemi di ventilazione e le condizioni climatiche termiche all'interno degli edifici sono i fattori che maggiormente determinano il livello di salute della persona, il suo livello di comfort e lo stato di benessere. I sistemi di ventilazione influiscono sul corpo umano attraverso un effetto fisiologico conseguente alla purezza e al moto dell'aria, e in modo indiretto per l'umidità' e la temperatura dell'aria ambiente. I sistemi di ventilazione e condizionamento tradizionali (HVAC) hanno come scopo ultimo l'ottenimento di un ambiente uniforme, stabile e neutrale, infatti, lo scopo principale è quello di assicurare una sensazione neutrale per ottenere comfort termico per gli occupanti. Negli ultimi decenni, e' stato dimostrato da molte ricerche come l'ambiente termico e la qualità dell'aria negli edifici abbiano notevole influenza sulla salute, sul comfort e sulla produttività degli occupanti.

Come ormai ben noto la condizione di discomfort termico, in particolare discomfort localizzato, è uno dei maggiori oggetti di lamentele per quanto concerne i luoghi di lavoro. Per questo motivo le persone possono essere considerate ricca sorgente di informazione per quanto riguarda la qualità dell'ambiente interno e gli effetti di questo sul comfort e sulla produttività, come confermato dai risultati di una indagine a larga scala sviluppata dal Center for the Built Environment presso l'Università della California, Berkeley [Zagreus L., 2004].

L'uniformità che si cerca di ottenere con i sistemi tradizionali non tiene in considerazione le preferenze individuali in termini di temperatura, movimento dell'aria e sensazione termica. Inoltre bisogna anche tener conto che l'aria di rinnovo immessa che raggiunge la zona di respirazione della persona può essere di scarsa qualità, poiché è già miscelata con l'aria ambiente, peggiorando la qualità in termini di umidità e inquinamento per le emissioni dei materiali utilizzati nella costruzione.

Recenti prove di laboratorio suggeriscono come un ambiente diversificato possa portare a livelli di comfort termico superiori a quanto non sia possibile ottenere attraverso il miglior controllato, neutro e uniforme possibile ambiente interno. [Zhang, H., 2003]

I sistemi di ventilazione personalizzata (PVS) sono uno sviluppo dei sistemi tradizionali HVAC, con la possibilità di migliorare il comfort delle persone creando e controllando il proprio microambiente secondo le preferenze personali. Possono inoltre diminuire il rischio di effetti della Sick Building Syndrome (SBS) nonché ridurre il rischio di trasmissione di agenti contagiosi tra i singoli occupanti.

I sistemi PVS cercano di evitare quindi gli effetti indesiderati dei sistemi tradizionali immettendo l'aria esterna trattata direttamente nella zona di respirazione di ogni singolo occupante. Per poter ottenere in maniera efficace questi effetti, è necessario che la progettazione dei sistemi localizzati tenga in considerazione l'attività degli occupanti e l'azione del moto dell'aria immessa sui flussi attorno al corpo [Melikov A.K., 2004]. L'uso dei sistemi localizzati potrebbe inoltre permettere un più ampio range di temperature all'interno dell'edificio, per mezzo dell'introduzione di asimmetrie locali, sia per quanto concerne il riscaldamento che il raffrescamento. In questo modo l'energia utilizzata per il condizionamento dell'aria potrebbe essere ottimizzata, mentre la persona stessa si troverebbe in grado di poter modificare l'ambiente direttamente circostante a se stesso secondo le proprie preferenze.

Scopo di questo studio è valutare la possibilità di rendere maggiormente comfortevole l'ambiente per le persone nei luoghi di lavoro, grazie all'uso dei sistemi personalizzati in condizioni di raffrescamento e di riscaldamento; e se congiuntamente a questo è possibile ottenere anche un aumento di produttività della persona. Un secondo fine e' la stima dei consumi di un tale tipo di sistemi di condizionamento localizzato e la comparazione dell'efficienza di questi con sistemi HVAC con l'uso di diversi sistemi computazionali. L'uso di sistemi personalizzati, infatti, non e' legato soltanto ad un miglior comfort per la persona, ma deve anche essere cost-effective.

E' ormai ben noto come la maggior parte delle lamentele negli ambienti di lavoro faccia riferimento a situazioni di mani e piedi freddi in ambienti freddi, e nel caso contrario, in condizioni estive, di troppo caldo al livello della testa. Questi discomfort localizzati alle estremità hanno un forte effetto sulla sensazione di comfort globale percepito dalla persona, e l'eliminazione o comunque la diminuzione di queste cause di discomfort si rendono necessari per il mantenimento del comfort termico globale dell'occupante. Le estremità sono vulnerabili alle cause di discomfort perché non sono isolate, o comunque il livello di isolamento dall'ambiente circostante è molto basso. Tuttavia proprio il basso livello di isolamento termico rende possibile un'azione localizzata di riscaldamento o raffrescamento delle estremità in maniera efficiente, tale da riportare la persona al livello di comfort globale.

Per poter analizzare e studiare i temi descritti in precedenza, abbiamo allestito una camera climatica (CEC) presso l'Università della California, Berkeley, per poter condurre dei test di laboratorio su soggetti umani. Durante le prove di laboratorio abbiamo testato sistemi personalizzati in condizioni interne variando da eccessivamente freddo a eccessivamente caldo. Abbiamo sviluppato una serie di dispositivi task-ambient per variare localmente le condizioni climatiche alle estremità in ambiente caldo e freddo. Lo sviluppo di un dispositivo per le mani, per ottenere una maggior destrezza in ambiente freddo; un dispositivo per migliorare la sensazione di comfort localizzato nelle estremità inferiori. Nel caso invece di ambiente caldo, i dispositivi sviluppati apportano aria fresca di rinnovo direttamente nella zona di respirazione, in modo da migliorare la qualità dell'aria percepita e la sensazione di comfort. Il design di questi prototipi è stato sviluppato attentamente in modo da evitare quelle che sono altre cause di discomfort localizzato, come la secchezza degli occhi, tipica nei casi in cui ci si trova in ambienti con movimento dell'aria elevato.

Tutti i dispositivi sviluppati sono stati collegati da un'unita' di controllo che permette al soggetto in questione di modificare in maniera veloce e semplice temperatura dei dispositivi e movimento dell'aria. Questo ci ha permesso di confrontare l'effetto della possibilita' di controllo dell'ambiente sul comfort termico.

Una serie di sensori wireless permette di registrare il consumo energetico richiesto dai singoli prototipi, valori che sono utilizzati in un secondo tempo per la comparazione di questo tipo di sistemi rispetto ad un sistema più tradizionale HVAC. Per le simulazioni numeriche abbiamo anche tenuto conto che i prototipi sono stati sviluppati per ottenere un maggior comfort della persona e che quindi non si e' cercato di raggiungere la massima efficienza energetica.

I test sono stati svolti in tre fasi, ogni fase di durata di circa un'ora. In ordine casuale durante le tre ore di test, la persona ha lavorato in tre differenti condizioni climatiche. In alcuni casi non erano disponibili sistemi localizzati, in altri casi i sistemi localizzati avevano un valore prefissato, in altri casi il soggetto aveva la possibilità di modificare le condizioni in uscita, in termini di temperatura e di velocità dell'aria e la temperatura dei sistemi PVS utilizzando l'unità di controllo. Questo ci ha permesso di confrontare l'effetto sulla persona della possibilità di modificare e gestire il microclima attorno a sé rispetto una condizione di passiva presenza all'interno di un ambiente condizionato. Ogni mezz'ora, durante i test, e' stato chiesto ai soggetti di rispondere ad un questionario, nel quale venivano poste domande in riferimento ai singoli terminali e alle condizioni di comfort e discomfort. Abbiamo sviluppato il questionario in maniera tale da poter ottenere una risposta il più possibile oggettiva e attendibile riguardo la sensazione termica, il comfort termico, l'accettabilità, la qualità dell'aria percepita, un possibile effetto di discomfort causato dalla secchezza degli occhi, e le preferenze in ordine di movimento dell'aria e di temperatura per le estremità inferiori e superiori.

Durante i test inoltre e' stata valutata la qualità delle prestazioni sottoponendo all'attenzione del soggetto una serie di test che comprendono la risoluzione di semplici problemi di matematica e logica e un test di battitura. Abbiamo focalizzato la nostra attenzione sul metodo migliore per la valutazione delle produttività della persona durante i test, cercando di simulare al meglio un tipico lavoro di ufficio.

Abbiamo compiuto i test su un gruppo di 18 persone, divise in 9 donne e 9 uomini, omogeneo secondo il grado di età, compreso tra i 20 e i 30 anni. Per la scelta dei soggetti abbiamo intervistato un largo gruppo di persone, reclutate all'interno dell'università e tra professionisti. Ogni soggetto ha partecipato al test in cinque differenti condizioni climatiche (18ºC, 20ºC, 24/25ºC, 28ºC, 30ºC), 90 test in totale.

Prima della partecipazione ai test, abbiamo chiesto ai soggetti di partecipare a delle sessioni informative in modo tale da evitare l'effetto della curva di apprendimento nelle loro performance.

Come descritto in precedenza questo studio ci ha visti impegnati su diversi piani, primo fra tutti lo sviluppo dei sistemi localizzati. In secondo luogo abbiamo sviluppato il sistema di controllo dei sistemi, cercando di avere un ulteriore controllo e monitoraggio del dispendio di ogni singolo terminale. Lo sviluppo dei questionari da sottoporre ai soggetti durante i test, compresa la scelta e modifica degli strumenti da utilizzare per la misura della produttività della persona. Non ultima la messa a punto il sistema di condizionamento dell'impianto HVAC della camera climatica per i successivi test.

INTRODUCTION

Task ambient systems to improve comfort and productivity

Ventilation and thermal conditions inside a building are among the primary factors determining human health, comfort and well-being. They cause different effects on the human body through the physiological effect of air purity and motion, and indirect effect through their influence on the temperature and humidity. Uniform, stable and neutral indoor thermal environments are the purposes of heating, ventilating, and air-conditioning (HVAC) systems. The aim is to assure neutral sensation in order to achieve thermal comfort for the occupants. During the last six decades researches have demonstrated how the thermal environment and the air quality in buildings affect occupants' health, comfort and productivity. As Chen, Moser and Suter noted "because up to 90% of a typical person's time is spent indoors and a large fraction of that time is spent in a residential or commercial environment, the quality of the indoor air is an important component influencing our overall level of health and comfort".[Chen, 2002]

It is well known that thermal dissatisfaction, caused mainly by local discomfort is the major complaint in office buildings. Building occupants are a rich source of information about indoor environmental quality, and its effect on comfort and productivity as confirmed by the results of a survey developed by the Center for the Built Environment at the University of California, Berkeley. Office workers' preferences for air movement have been extracted from a database of indoor environmental quality surveys performed in over 200 buildings. Dissatisfaction with the amount of air motion is very common, with too little air movement cited far more commonly than too much air movement [Zagreus L., 2004; Huizenga C., 2006].

The almost homogenous environment does not take into account individual preferences in terms of air temperatures, movement and thermal sensation. Moreover, the air that reaches the occupant's breathing zone may be of poor quality because it has already been mixed with the room air, gaining heat and humidity and being polluted by emissions of building materials and the occupants themselves.

Evidence from laboratory research suggests that diversified environments could produce levels of thermal comfort higher than possible even with the best-controlled neutral and uniform environments. [Cabanac, 1971; Mower, 1976; Attia and Engel, 1981; Zhang, H., 2003]

Personalized Ventilation System (PVS) is a development of the HVAC system that has the potential to improve occupants' comfort with the possibility of generating and controlling their own preferred microenvironment, to decrease Sick Building Syndrome (SBS) symptoms and reduce the risk of transmission of contagious agents between occupants. PVS systems aim to avoid the undesirable effects of the traditional HVAC system by supplying treated outdoor air directly to the breathing zone of each occupant. In order to perform efficiently in room practice, the design of PVS should take into consideration the occupants' activity and the airflow interaction with the thermal plume around the human body [Melikov A.K., 2004].

The use of PVS systems could allow a large range of environmental temperature by introducing local cooling/heating asymmetries. In this way the energy needed for ambient conditioning could be optimized while the individual is empowered to adjust the immediate environment to his or her personal preferences.

Moreover many studies (Wargocki ,2006; Witterseh et al., 2004; Holmberg and Wyon 1967) show that mental performance is better in a cool environment than in a warm environment. Pepler and Warner (1968) found that the conditions for optimal mental performance are different than for optimal thermal comfort. The subjects performed best at 20ºC, which was felt to be uncomfortably cold. Therefore, there is no uniform condition that can satisfy both the thermal and mental performance requirements. In addition, manual dexterity requires warm hands. Hedge (2004) found that when (uniform) room air temperature decreased from 25ºC to 20ºC, typing mistakes rose by 74% and typing output fell by 46%. The thermal stratification that often occurs in room environments (warmer at head level and cooler at hand level) makes the problem even worse than a uniform environment.

The purpose of the study is to evaluate whether it is possible to provide comfort to the occupants by task-ambient conditioning (TAC) systems in cool and warm environments, and whether the productivity of people is enhanced. We also compared the efficiency of task/ambient systems versus a traditional HVAC system by the use of different computational tools.

Cool hands and feet, and warm head discomforts are common complaints in office environments. These localized discomforts of the extremities dictate the overall thermal comfort felt by the occupant, and removing discomfort in these body parts is essential in maintaining the whole body thermal comfort. The extremities are vulnerable to discomfort in part because they are uninsulated or relatively uninsulated. However the low clothing levels make it possible to locally heat or cool the extremities in an energy-efficient manner, thereby restoring comfort.

In order to investigate the above-described issues, we set up the Controlled Environment Chamber (CEC) at the University of California, Berkeley to conduct Human Subject Tests (HST). The room air temperature was set from cool to warm, and several task-ambient devices were applied and tested. We developed four task-ambient devices to warm up hands and feet in cool environments, and to cool down head and hands in warm environments. We developed and prototyped a heated keyboard that will warm up the hands in cool environments while the person is typing, increasing dexterity and local thermal comfort. A foot-warming device was designed to improve thermal comfort in cool environments. In warm environments, a local device was prototyped to cool down the air in the breathing zone of an occupant, in order to provide a better environment increasing the perceived air quality and thermal comfort. The design of these devices was studied carefully in order to increase the comfort avoiding local discomfort such as eye dryness, which is likely to happen when the air movement is relatively high.

All the devices were regulated by a control unit that allows the subject to easily modify the local temperature and air movement. The effect on thermal comfort and sensation of having the control on the local environment was also analyzed.

A set of wireless sensors recorded the energy required by the local devices for a following energy consumption comparison between the task/ambient system and a more traditional HVAC system. Those values were used to adjust a numerical code. Those four devices were designed in order to improve the local environment, but it is obvious that we need to develop more energy efficient prototypes.

The timing of the tests scheduled three phases, each approximately one hour. In random order during the three-hour tests, the occupant ran simulated office work in different environment condition: lack of PVS systems, PVS with a fixed value, and control over the supply temperatures and air velocity of the local devices through the control unit. We chose to change randomly the conditions in order to avoid the possible effect of habit. This allowed us to compare the impact of the PVS when subjects have control over their environment to the conditions when subjects do not have control.

During the tests every half hour the subjects will be surveyed to determine their responses to the task-ambient devices that we have designed. We have developed the survey program in order to obtain the most objective and reliable responses from the subjects. The survey questions will address overall and local thermal sensation, overall and local thermal comfort, acceptance, perceived air quality, eye dryness and preference, air movement preference, hands and feet warming preferences.

Because the warm hands are beneficial for dexterity and a cool head may be beneficial for mental performance, we evaluated the work performances in the tests by asking subjects to conduct problem solving and typing tasks. We focused our attention on the best possible way to evaluate the work productivity of the subjects during the tests, a way which simulates the real office work more closely. After evaluating different tools, we settled for a set of math solving problems and easy logical games. The subjects will also be scored using a typing test as another way to evaluate their productivity.

18 subjects, 9 men and 9 women, will participate in the experiments. Each subject will attend to five tests under different room air temperatures (18ºC, 20ºC, 24-25ºC, 28ºC, 30ºC), 90 tests in total.

We interviewed a large group of people and then recruited the subjects in order to have a homogeneous group. The ages of the 18 subjects are in the 20-30 range and they are both students and professionals. Before running the Human Subject Tests, we asked the subject to attend to two training session, in order to avoid the effect of the learning curve in their performances.

The development of this experiment has involved several important and time-consuming tasks, including: (1) development of TAC devices, (2) development of control and monitoring system, (3) development of survey questionnaire, (4) identification and testing of productivity measurement method, (5) set-up of HVAC system for full-scale test chamber, (6) recruitment of human subjects.

developments of heating and cooling systems was to maintain the environment as uniform as possible.

But is the uniformity of the environment around the occupant really accepted from people? Recent evidence from laboratory research suggested that diversified environments could produce higher levels of thermal comfort than possible for the best-controlled neutral and uniform environments. [Zhang, H., 2003] Our nervous system is much more attuned to noticing changes in the environment than to noticing steady state. The thermal sense is intricately bound up with the experience of our bodies. We continually sense the heat flow of our bodies, information that creates a general background for all other experiences. This renewal mechanism seems to be especially active for the thermal sense when we experience a temperature change within the basic comfort zone. Just think about having a nice walk in a clear cold winter day , feeling the warmth of the sun radiation and the cold air around. Thermal information is never neutral; it always reflects what is directly happening to the body, because the thermal nerve endings are not temperature sensors, but heat flow sensors.

During the last century the technology development of heating and cooling systems aimed to achieve a thermal 'steady state' across time and a thermal equilibrium across space. But we know that none of them are easy to achieve since the radiant and ambient heat are very unstable forms of energy, and in nature the environment is never uniform. For these reasons we should then stop focusing our attention on the thermal discomfort, and start thinking more actively to the possibility of enhancing the *thermal delight*. With "thermal delight" we want to define the appreciation of an environment by the occupant, a positive state of mind, instead of the negative discomfort.

One factor that can help to appreciate the thermal function of an environment is variability. We are more likely to notice the function of something if there are times when it is not in operation, and to notice the significance of something if there are times when it is not there.

The present research addresses to the evaluation of a possible thermal delight within a building by the use of local thermal asymmetry and to the control of the microenvironment. The possible consequent effects on productivity are analyzed as a potential positive side effect.

2. HUMAN SUBJECT TESTS
EXPERIMENTAL FACILITY

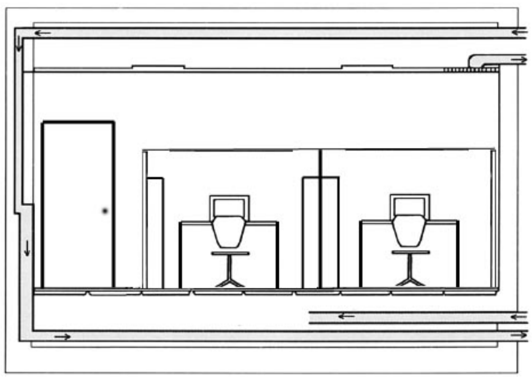
We designed a Task-Ambient Conditioning (TAC) system consisting of four subcomponents, each under the user's control. The four subcomponents address the head-hand-foot combinations. This chapter is intended to explain the experimental facility, highlighting the development and functionality of each local device and the effects of its application on occupant's thermal comfort.

2.1 Experimental facility. The Controlled Environment Chamber

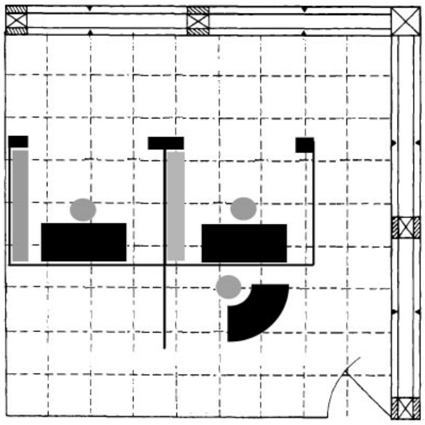
During the time between March and May 2007, we performed 90 Human Subject Tests (HST) under non-uniform conditions in the Controlled Environmental Chamber (CEC) at the University of California (U.C.), Berkeley.

The chamber was set up in order to appear as a conventional office. This layout was intended to make the subject feel as normal as possible, so that the environment would not intrude on their subjective perception.

The CEC has a 5.5 m by 5.5 m floor and a 2.5 m high ceiling (18 ft x 18 ft x 8 ft 4 in). Carpet tiles cover a raised access floor, and the walls are heavily insulated. [Figures 2.3-2.5] The room has windows on two walls to provide a view to the outside. [Figure 2.6] The suspended ceiling contains patterned acoustical tiles. A raised access floor results in a 0.6 m high sub-floor plenum and the suspended ceiling provides a 0.5 m high ceiling plenum.



[Figure 2.1: Cross section of the CEC]



[Figure 2.2: Plan view of CEC with workstations denoted WS1, WS2]

The CEC's air distribution system permits ducted or plenum air to be supplied to and returned from the test chamber at any combination of ceiling and floor locations. To investigate the Task Ambient devices (TAC) applied to the partitions during the well-controlled experiments, a separate supply line was ducted through the sub-floor plenum and connected via flexible duct to the air devices located in the workstation. [Figures 2.5] A separate conventional ducted ceiling-based air distribution system (in combination with space loads) was used during all thermal tests in order to maintain the average room air temperature at the desired level. All air from the chamber, including the volume supplied from the task conditioning devices, return through a single ceiling-level return register. In addition, the CEC's air distribution system includes a separately controlled supply of air through the plenum-wall construction of the two exterior chamber walls. [Fisk, 1991]

[Figure 2.3, 2.4, 2.5: Raised floor in the CEC and flexible ducts that connect the system to the desk-mounted PVS.]

[Figure 2.6: The room has windows on two walls to provide a view to the outside.]

During the tests, the room was divided into three sections separated by 65 inches high partitions. The partitions are high enough to create a visual barrier for the subjects during the tests. Half of the room was used as test station which includes two workstations with computers for the subjects to work on and to respond to the surveys, a set of local devices to modify the thermal conditions to the individual body parts and a control system that allowed the changing in local environment conditions and record all the changes in voltage.

The researcher's station included a chair, a table, and a computer to download the data from the sensors measuring the subject's skin temperature.

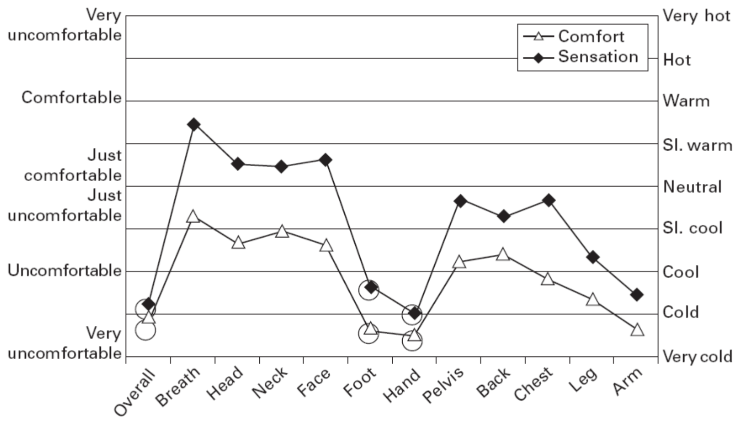
[Figure 2.7-2.8: Room layout]

2.2 Local devices

Sensation and comfort for local body parts vary greatly in subjects exposed to uniform environments. Hands and feet feel colder than other body parts and skin temperature of this local body parts is the lowest.

Arens et al. showed how the overall comfort follows the worst local (hands and feet in cool conditions) comfortable votes very closely, meanwhile the head region comfort exerting little apparent influence. [Arens E., 2006]

Zhang learnt from previous HST that in cool environments, warming hands could effectively remove cool-hand discomfort and enhance whole-body thermal comfort. Moreover, the occupant productivity could be affected by the hand skin temperature since a low temperature could lead to low dexterity level. When the fingers' temperature is below 15°C, the dexterity is decreased. [Wang D., 2005] During the HST we will investigate the effect of cooling and warming hands on typing, as an aspect of productivity. We therefore designed heated keyboards, which can be used in cool environments together with feet-warming device. Following the development of prototypes.



[Figure 2.9: Local and overall thermal sensation and comfort in a uniform/cold environment. From Thermal and Moisture Transport in Fibrous Materials, edited by N. Pan and P. Gibson, 2006]

A conductive hand warmer and a radiant foot warmer heat the extremities during the simulated cool (winter) conditions. For the simulated summer conditions, a head-ventilation device cools the head by air motion, and a hand-cooling device operates through conduction and air motion. The development of these devices took quite a long time, since great care was taken in designing these systems in order to make them simple, energy efficient, and as practically applicable as possible. [Figure 2.10] [Zhang, 2008]

Hand warmer. The hand warmer is a curved surface made of 1/16"aluminum sheet with very high heat conductance. There are electrical heating tapes underneath the aluminum to warm up the palm surface quickly and efficiently while the subject is typing. During the tests we observed that the aluminum surface temperature is typically 35ºC.

We used commercially available heated keyboard and mouse, controlled by on-off switches. We found during the pilot tests that the surface temperature of the heated keyboard was too low for a strong impact on hand warming. The hand warming observed in these tests came mainly from the palm warmer, with its higher temperature and a more conductive surface. While typing the subject touches the hand-warming device with a larger surface of his/her hands. This could be corrected in future keyboard designs.

Hand ventilation device. The aluminum palm warmer is at the front edge of a tray holding the keyboard. Beneath the keyboard but within the tray there are three small computer fans (2 Watt/each). The fans direct air through a small gap between the keyboard and the palm warmer. The gap acts as a linear nozzle creating a sheet of air that moves horizontally over the keyboard so that the hands are convectively cooled by room-temperature air when typing, but the air does not come into the user's face. The air is drawn into the fans from the back of the keyboard tray, so the cooling is entirely by re-circulated room air. The velocity at the hands is low, around 0.5 m/s.

Feet warmer. We fabricated a well-insulated box, with a reflective foil lining inside, and with a curtain in front. There is a 123 Watt heating lamp installed at the top of the box. With the insulation and the curtain, the feet are warmed not only by the radiation from the heating lamp, but also from the warm air trapped inside the box. Air temperature in the box is typically 32ºC. Partial heating rates are created by cycling the lamp on-off for varying lengths of time.

Head ventilation devices. We positioned two nozzles of 2-inch diameter to supply air at 0.6 m (2 ft) away from the center of the subject's chair on both sides of the workstation. The nozzles are in pilaster-like towers in the workstation partitions, and are connected to a fan in the plenum underfloor. A duct installed in the Controlled Environmental Chamber connects this tower and the fan with a cooling air supply. It is designed in such a way that when the cooling supply fan is *on*, it supplies the cool air to the tower nozzles. The cool air is from 100% outdoor air after air-conditioning. When the cooling supply fan is *off*, the fan connected to the tower recirculated air from the underfloor plenum to the breathing region. Since the air under the plenum is connected to the Controlled Environmental Chamber through openings in the raised floor, the air from the nozzles so is re-circulated room air.

The system's peak wattage for cooling is 41W, and for heating at steady state is 90 W. The system was tested in an environmental chamber operated across a range of temperatures representing a wide range of practical winter and summer conditions (18-30ºC, or 65-86 ºF). Electricity use and environmental parameters were measured.

To avoid the risk of dry eye discomfort, we installed the nozzles on both sides of the occupant towards the occupant's cheeks and the breathing zone in front of them. In this way, the air movement does not affect the eye zones directly. It is not even present at the back of the neck, which is more sensitive to draft than the face. The outlet velocity from the head ventilation device at the outlet is about 6 m/s. It reduces to around 1 m/s near the cheek. We believe this nozzle configuration can be practically implemented in real office environments, integrated into furniture and conventional arrangements of office partitions.

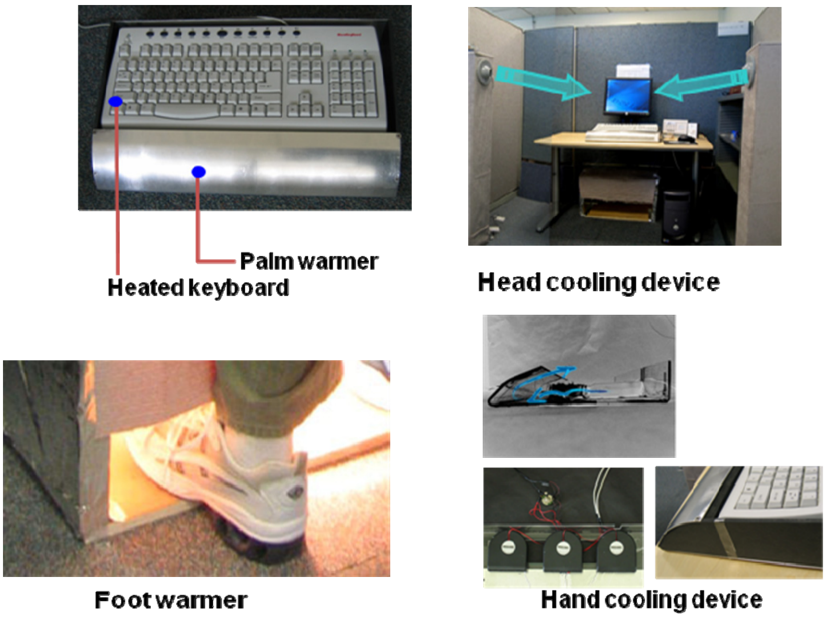
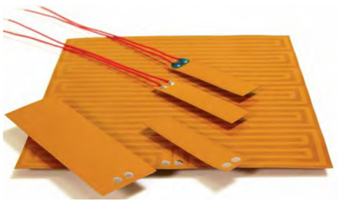


Figure 2.10: TAC devices used during the Human Subject Tests

2.3 Development of local devices

a. Hand-warming devices

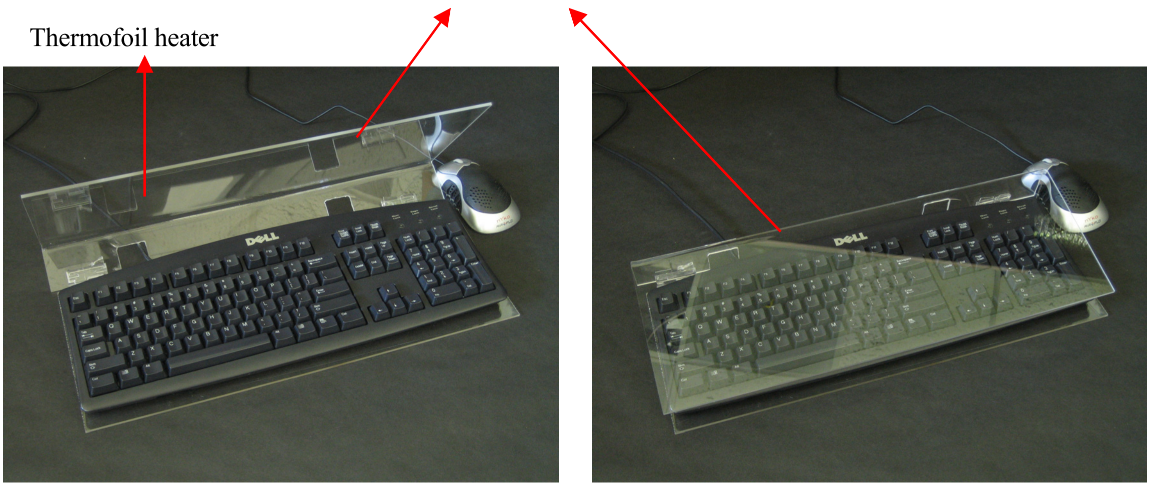
The first prototype developed for the HST was intended to warm up hands by radiation. The heated screen provided pleasant warmth to the hands in cool environments, without blocking the view of the typing area while the occupant was typing. In order to build our prototype we taped a clear thermofoil film on clear screen placed on the top of the keyboard. The surface temperature of the thermofoil film could be adjusted by changing the supply voltage.



[Figure 2.11: Thermal-Clear™. Specifications Temperature range: -55 to 120°C (-67 to 248°F).Insulation: Optical grade polyester is standard. Transparency: 82% minimum light transmission over the visible spectrum. Heating element: Resistive wire, diameter 0.0008" (0.02 mm). Resistance tolerance: ±10% or ±0.5, whichever is greater. Leadwires: PTFE insulated wire is standard. Lead connections are welded and anchored between heater layers for strength.]

The heated screen can be easily open or closed

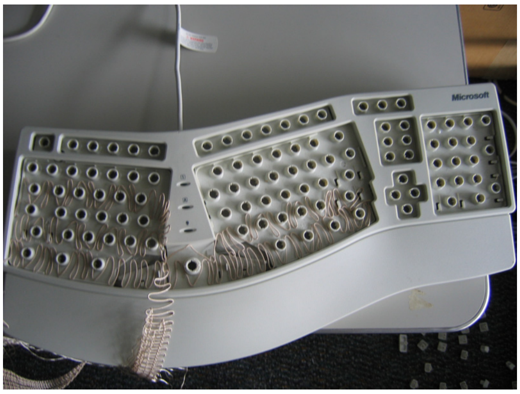
Thermofoil heater



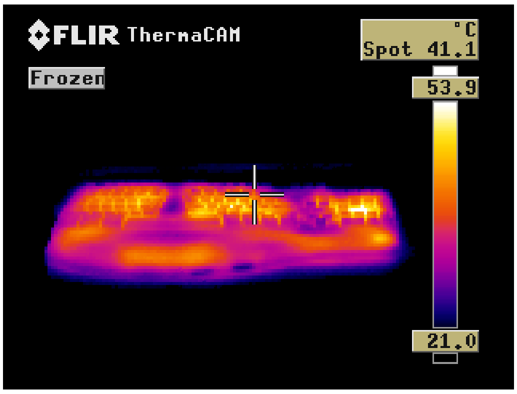
[Figures 2.12, 2.13: Radiant hand-warming device. When pushing the keyboard tray back, the screen folded automatically. In the IR picture the clear the thermal-clear heater is attached only to half the side of the clear screen, in order to see how the thermal-clear heater warms up the keyboard.]

[Figure 2.14-2.15: Radiant hand-warming device. The clear screen with the thermal-clear heater]

During a first set of pilot tests, few people voted as uncomfortable the sensation of warmth provided with the heated screen to the upper part of the hands. For this reason a standard keyboard was internally provided with a resistance wire, inserted below the keys and connected to a potentiometer.



[Figures 2.16, 2.17: The resistance wire is applied between the keys and the topside of the keyboard.]

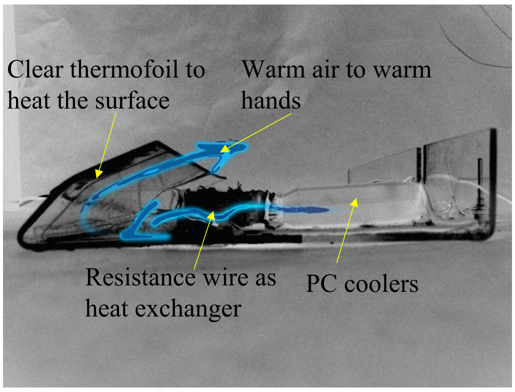


[Figures 2.18, 2.19: IR picture of the heated keyboard]

By supplying voltage to the resistance wire, the keyboard could be heated, warming up hands by conduction while the user was typing. Varying the voltage to the resistance wire it was possible to adjust the temperature of the keyboard. The warm keyboard provided higher comfort level, but in order to reach temperatures high enough to warm up the hands, the power demand was high and the high temperatures could interfere with the functioning of the keyboard itself.

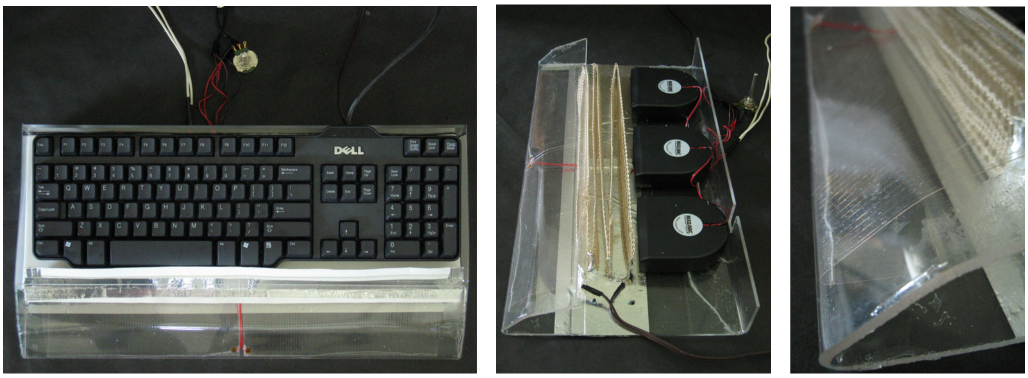
The following step for the hand-warming prototype was the idea of a device that could easily host a standard keyboard, while providing warmth to hands, instead of modifying the keyboard itself.

A clear acrylic panel was cut and bent in a comfortable shape for the hands. This “shoe-box’, as we named it, hosts different systems to transfer heat to the hands. A few layers of the resistance wire served as heat exchanger for the air to be warmed up. Changing the supply voltage to the resistance wire it was possible to increase the temperature of the keyboard.

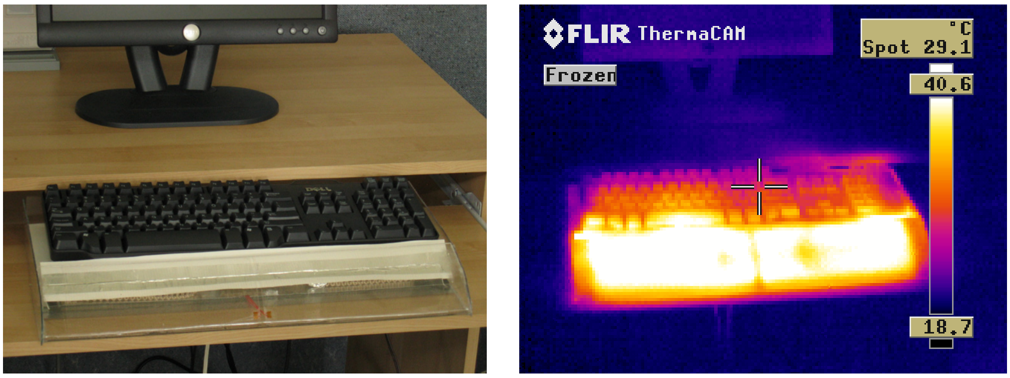


[Figures 2.19: The hand-warming device #3: The shoe]

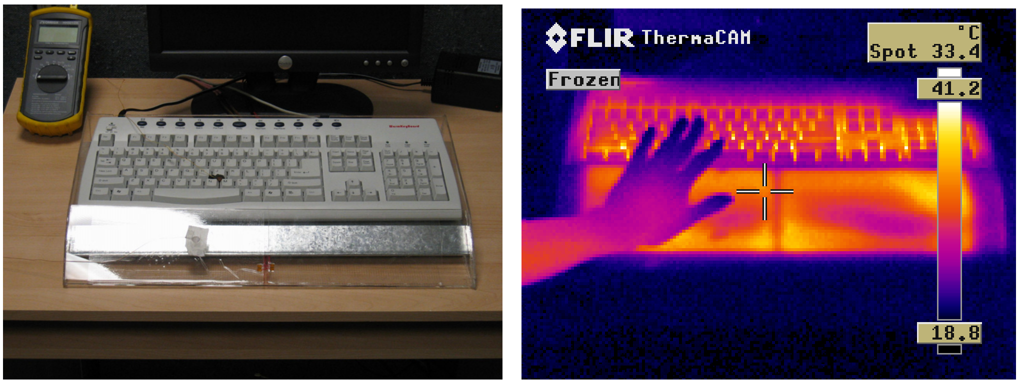
Three pc slot coolers on the bottom of the box provided air crossing through the heat exchanger and the air could be heated. Two thermal-clear heaters were taped on the inside of the palm resting area, to warm up the palms of the hands during typing, as the following IR picture can easily explain. Also in this case it was possible to increase the temperature of the surface by changing the voltage to the thermal-clear heater.



[Figures 2.20-2.22: The hand-warming device #3]



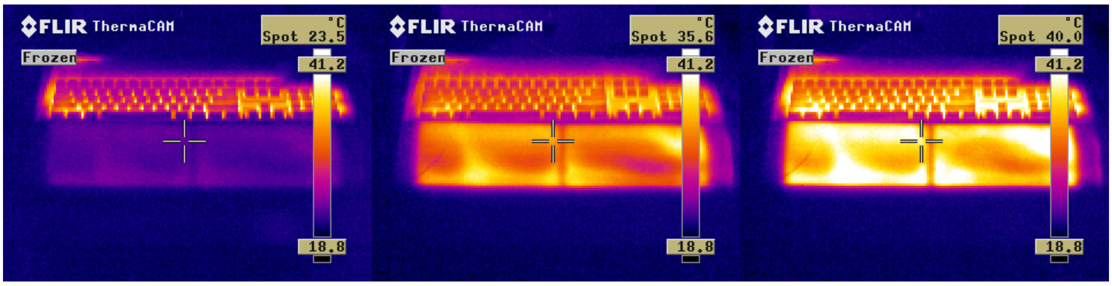
[Figures 2.23-2.24: The hand-warming device #3, IR picture]



[Figures 2.25, 2.26: The effect of hand-warming “shoe” and the heated keyboard, IR picture]

After several modifications we decided for the use of the “shoe” together with a heated keyboard. The use of this last keyboard allowed us to have more uniform temperatures, as seen in the IR picture. [Figure 3.24]

The final prototype, the “shoe”, was made of metal instead of plastic, in order to increase the heat exchange in cooling condition. The “heated tape” was removed from the bottom of the box, lowering the energy demand.



a. b. c.

Potential difference	a) 78 mV	b) 150 mV	c) 222 mV
keyboard temperature	29 °C	34 °C	36 °C
Screen temperature	23.5 °C	35.6°C	40 °C

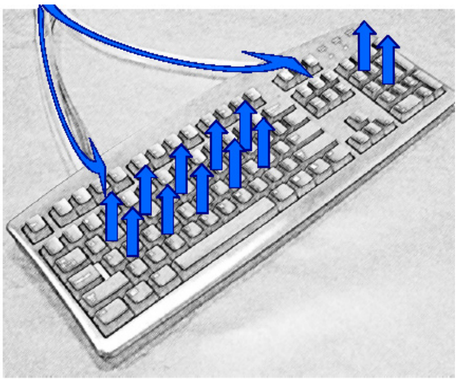
[Table 3.1: Values corresponding to IR pictures

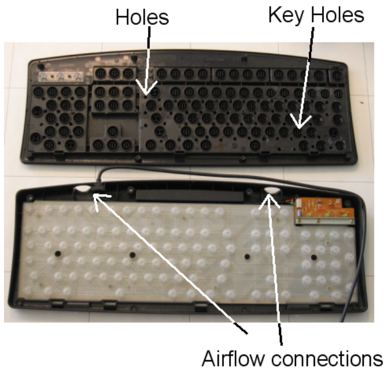
b. Hand-cooling devices

Hands are the most active parts of the body in responding to the body's thermoregulation requirements. In warm conditions, the hands are vasodilatated and the fingertips are the warmest areas of the hands. On the contrary, in cold conditions, the hands are vasoconstricted in order to preserve the heat exchange and keep the core temperature higher.

For this reason during the Human Subject Tests, we made use of a hand-cooling device. During the HST, in warm condition, the occupant could control the air motion from the three pc slot cooler in order to cool down the finger skin temperature. The airflow rate could be adjusted by changing the supply voltage to the fan using the control unit.

A standard keyboard was modified to provide cool air as desired. At the beginning, the keyboard was connected to the cooling system by two tubes in order to have air blowing from the cooling system through the pipes and then from small holes drilled on the topside of the keyboard cooling down the surface. The cooling effect was caused more by the improved turbulence than by the cold air from the system.

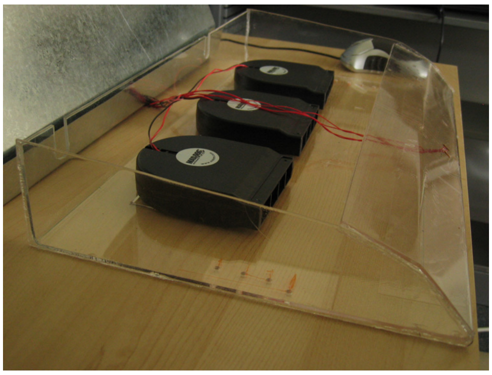


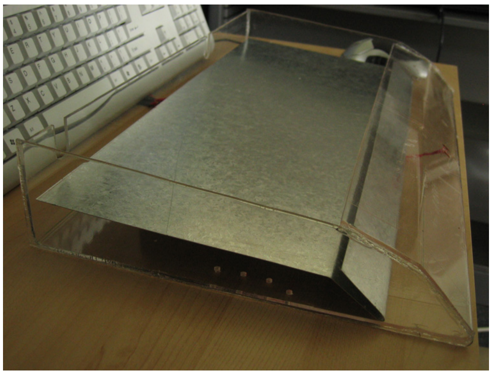


[Figures 2.27, 2.28: the hand cooling device: cold air provided to the keyboard from the conditioning system blows through holes on the topside of the keyboard]

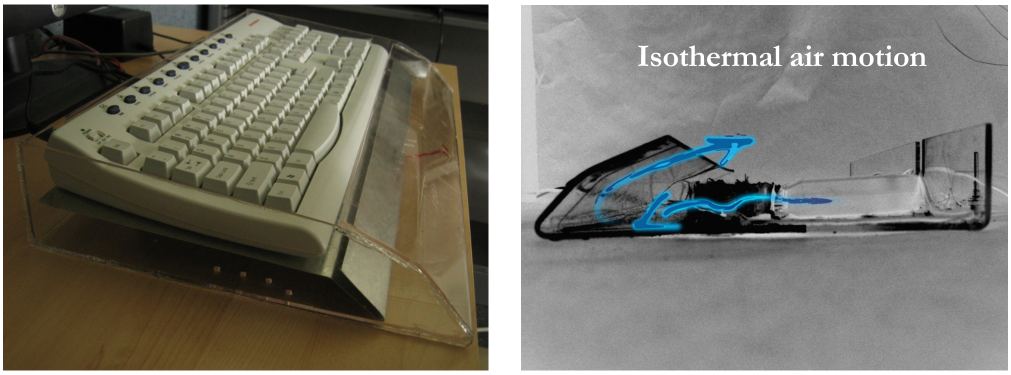
Afterwards we built a second prototype. Instead of modifying the keyboard itself, we moved on to build a box that would host the keyboard.

The hand-warming devices #3 is provided of three pc slot coolers in order to blow isothermal air motion. The pc slot coolers can provide maximum air flow of 35 cfm each. In order to increase the cooling effect, a flap was added between the top side of the three pc slot coolers and the bottom side of the keyboard. In this way a channel has been created to direct the air on the surface of the keyboard. The system allows individual control over the airflow rate by changing the supply voltage to the fan.





[Figures 2.29, 2.30: the hand-cooling device]



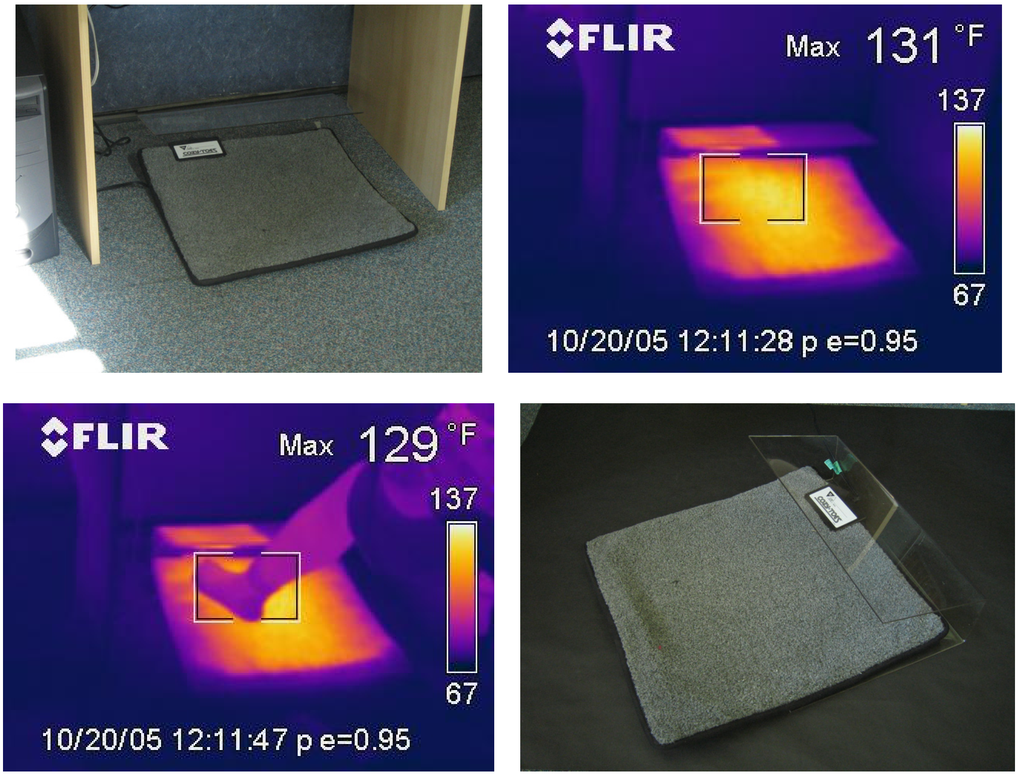
[Figures 2.31, 2.32: pc slot coolers; sketch of the air motion]

[Figures 2.33-2.38: keyboard and effect of the cool air. The left hand was not exposed to the hand-cooling device; the comparison between the two hands shows the effect of the device]

c. Foot-warming devices

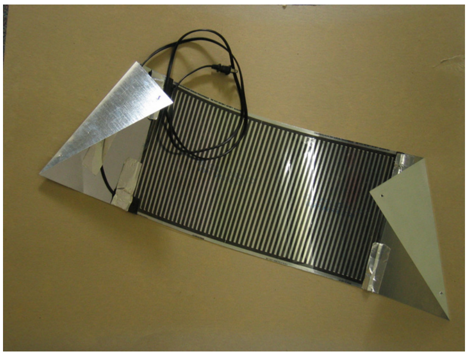
During the HST under cooling (winter) conditions, we used a device to warm up the feet. We developed the prototype in order to have an efficient device, avoiding local discomfort caused by the presence of moisture or strong differences in surface temperatures between the upper and the lower side.

The radiant foot-warming devices are similar to the hand devices. A heating pad will warm up the feet from the bottom and a thermal-clear heater will be attached to a clear screen, in order to warm up the feet from the upper side. This will provide uniform warmth.

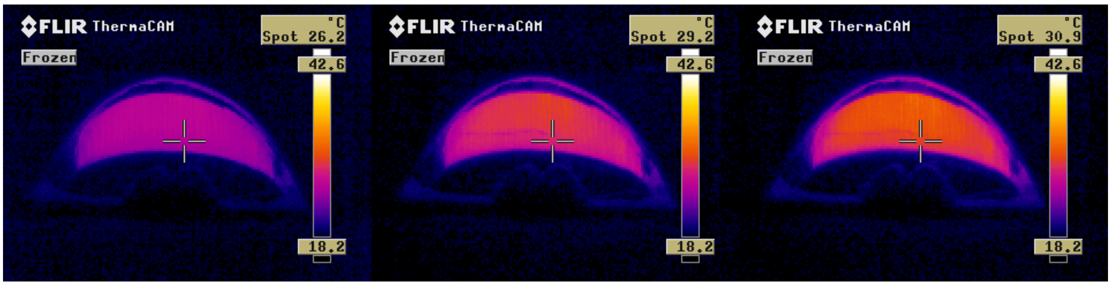


[Figures 2.39-2.42: Radiant foot-warming devices]

After few pilot tests we realized how the first prototype was not providing local comfort because of the shoes. As a matter of fact the warmth from the bottom could produce discomfort for the high humidity level inside the shoes. Moreover, the difference between the top side and the bottom side of the feet could be another cause of discomfort. For this reasons the next prototype consisted in a metal sheet and a heated film taped on it. Same as for the hand warming devices, here it was possible to change the temperature varying the voltage.



[Figures 2.43, 2.44: Radiant foot-warming device and heated film manufactured by Calorique, West Wareham, MA, USA]



a. b. c.

room air temperature	19 °C	a.	b.	c.
hot film		26.2 °C	29.2 °C	30.9 °C
potential difference		299 mV	457 mV	531 mV

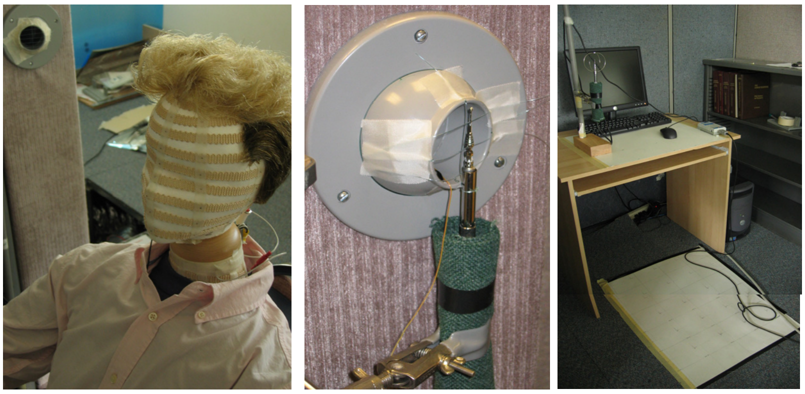
[Table 2.2: IR pictures of heated keyboard at 299 mV, 457 mV, 531 mV]

d. Head-cooling devices in warm conditions

Two towers for each workstation provide cool air from the cooling system to the breathing zone of the occupant. It has been showed that the neck always has a high skin temperature. For this reason, neck and back are particularly susceptible to draft. Moreover, in warm environment, people regard as pleasant and effective at cooling the presence of air movement from the side of the head. [Arens E., 2006; Zhang H., 2003] As seen in the IR pictures below, the airflow is well focused to the breathing zone to improve the comfort level and avoid the eye dryness discomfort.

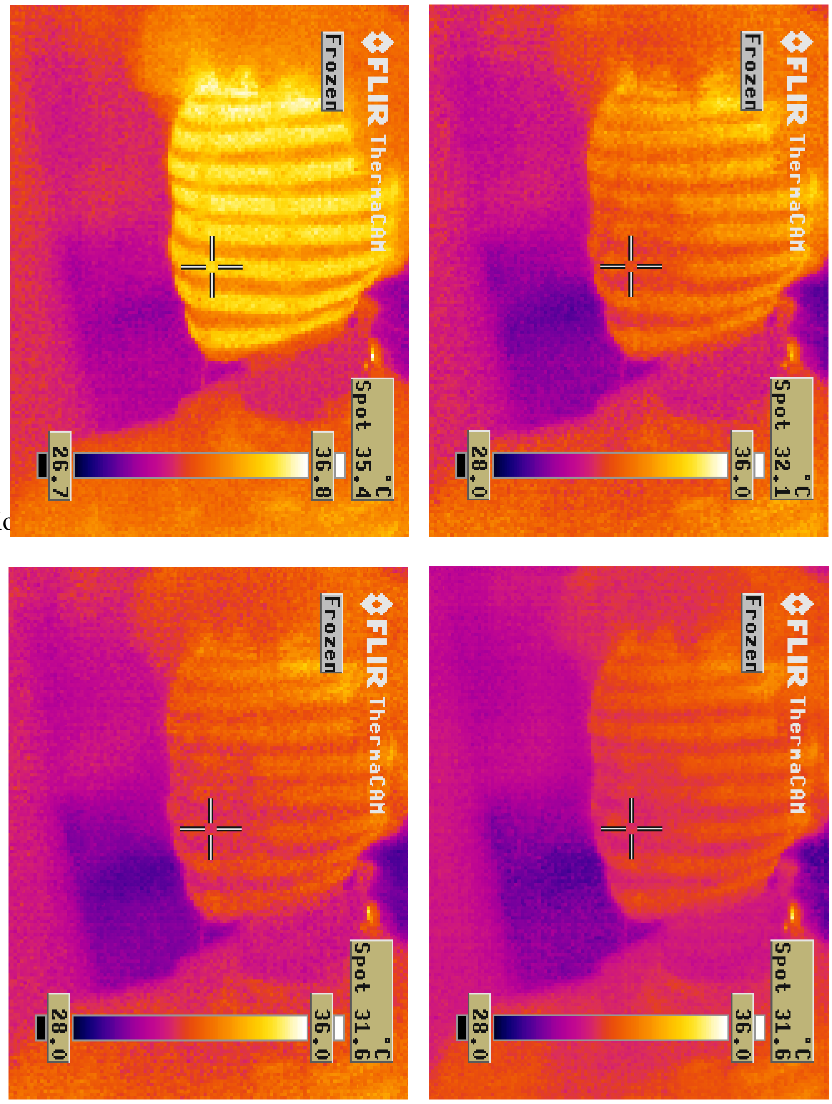
The chamber has a separately controlled cold-air source, located in the floor plenum and connected to the towers. In order to easily control and manage the air volume through the two towers, we decided to modify the Personal Environmental Module (PEM) manufactured by Johnson Controls, Milwaukee, Wisconsin. The mixing box uses a small variable-speed fan to pull supply air from zero or very low pressure plenum under the floor. Each PEM system is capable of providing approximately 40 to 150 cfm (20 to 70 L/s) of air. The system provides also individual control over the airflow rate by changing the supply voltage to the fan that will provide air to the TAC system. The two towers are provided with adjustable nozzles. In this way when the subject is working at the workstation it is possible to direct the air flow to the breathing zone.

[Figures 2.45, 2.46: Personal Environmental Module (PEM) manufactured by Johnson Controls, Milwaukee, Wisconsin, connected to the workstation]



[Figures 2.47-2.49: Outlet and manikin, omni-directional sensor, measurement grid]

The air velocity field in the workstation was characterized before the actual tests, because velocity measurement during testing would have been too intrusive. During the subsequent Human Subject Test, the experimenters we did spot checks of velocity around the head with hand instrumentation, to assure that actual airflows matched the values predicted from the airflow control settings.



No air motion | 602 mV

674 mV | 747 mV

[Figures 2.50-2.53: Air motion cooling effect on the manikin's face. It is possible to notice that the airflow is well focused on the breathing zone. Room air temperature 30°C, airflow temperature 30°C.]

To set the skin temperature to the manikin's face at 36.5 °C we used the data found by Arens, who measured the skin temperatures in different environments [Arens E. 2006]. The skin temperature is not uniform across the different segments of the body, due to a variety of physiological factors. In warm conditions, the skin temperatures are evenly distributed, with variations of 2.7 K. The use of a heated manikin generates a realistic buoyant plume around the shape in order to simulate a real person.

The IR pictures below show the manikin under the cooling effect of the isothermal air motion. To map the air motion in the environment, the workstation was divided into a grid of 5" by 5”. To measure the air velocity field in the breathing zone and in the area around the manikin we used an omni-directional sensor.

Segment	Skin temperature (°C)
Forehead	36.5
Cheek	36.3
Front neck	36.8
Back neck	36.1
Chest	36.1
Back	36.3
Abdomen	36.2
Upper arm	36.4
Lower arm	36.1
Hand	36
Left finger	36.7
Thigh	35.6
Shin	34.4
Calf	34.1
Foot	36.4
Average	35.8

Figure 2.49: Local skin temperatures in warm stable condition. From Arens E., Zhang H., *The skin’s role in human thermoregulation and comfort*, from *Thermal and Moisture Transport in Fibrous Materials*, edited by N. Pan and P. Gibson, 2006

<kurz>			mean velocity	std. deviation	turb. Int%
26~28 (23~30)		1.nose	1.16	0.3	26.2
	26.5	2 cheek L	**0.83**	0.26	31.46
		3 cheek R	0.886	0.3	33.94
		4 forehead	1	0.27	28.49
		5 chin	1.28	0.36	28.06
		6 back head	0.14	0.75	24.95
			1.0312		
30~35 (30~37)		1.nose	1.41	0.33	23.14
	33.5	2 cheek L	**1.1**	0.32	28.42
		3 cheek R	1	0.31	31.41
		4 forehead	1.47	0.28	21.93
		5 chin	1.63	0.41	24.78
		6 back head	0.15	0.04	25.7
			1.322		
46~50 (45~52)		1.nose	2.15	0.487	22.61
	48.5	2 cheek L	**1.71**	0.49	28.78
		3 cheek R	1.6	0.43	27.36
		4 forehead	2.3	0.36	15.54
		5 chin	2.44	0.5	24.47
		6 back head	0.21	0.05	23.45
			2.04		
14~16		1.nose	0.71	0.23	32.37
	15	2 cheek L	**0.48**	0.16	32.83
		3 cheek R	0.5	0.18	37.51
		4 forehead	0.41	0.15	38.36
		5 chin	0.78	0.24	31.81
		6 back head	0.12	0.03	25.27
			0.576		
19~21		1.nose	1.2	0.29	28.53
	20	2 cheek L	**0.63**	0.21	33.5
		3 cheek R	0.65	0.23	35.68
		4 forehead	0.82	0.23	28.76
		5 chin	1.24	0.32	25.86
		6 back head	0.13	0.04	30.14
			0.908		

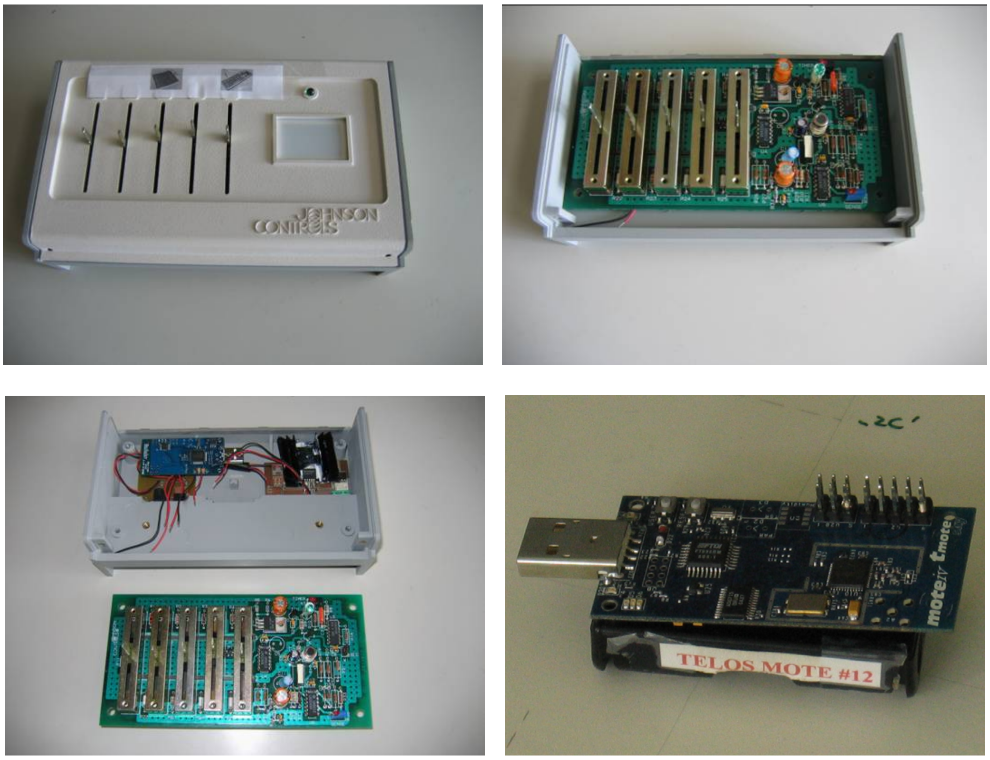
[Table 2.3: Air velocities measured around the manikin's head. Measurements were taken at 1 cm far from the surface]

2.4 The control system: TAC control unit

To give easy and effective control to the four TAC systems, we elaborated a control system starting from the one manufactured by Johnson Controls, Milwaukee, Wisconsin (USA) for the Personal Environmental Module (PEM).

There are sliders on the left panel that adjust the surface temperature of the aluminum palm warmer, the air movement level through the nozzles, and the fans providing cooling air from under the keyboard. For the foot warmer, the control unit on the right adjusts the on/off time of the heating lamp. The keyboard and mouse were turned on with a switch on each unit.

The levels of heating or air motion settings on the TAC controllers were recorded by a wireless sensing device in the control unit, and transmitted every 5 seconds to the monitoring computer.



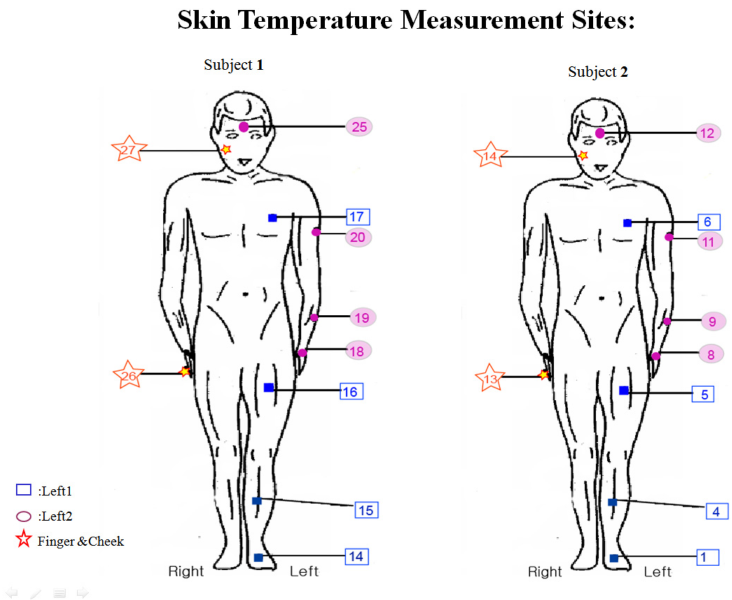
[Figures 2.54-2.57: The modified control system. The mote used to record the changing in voltage for each device]

2.5 Skin Temperature Measurement

For the bare-skin locations we used thermocouples, each connected to an Onset Corp Hobo thermocouple data logger. The eight other locations used more massive thermistor sensors, connected to two 4-channel Hobo temperature loggers (grouped as blue rectangles and pink ovals).

Altogether, each subject had four hobo loggers, in a small fanny pack fastened to the waist. The thermistors were recorded in 10-second intervals and the thermocouples in 5-second intervals.

The core temperature was measured by a wireless transducer (a pill, size of a vitamin capsule) which each subject swallowed before the start of a test to wirelessly transmit core body temperature as it travels through the digestive tract. The sensor's signal passes harmlessly through the body to the CorTemp™ Data Recorder worn on the outside of the body. A receiver/logger (CTC-2000) was put into the pocket of the shirts that subjects wore to wirelessly pick up the signal from the CorTemp™ sensor and convert the signal into digital format. The core temperature data was recorded in 20-second intervals. The thermocouples were taped on the subjects' skin with surgical tape, which allows air to penetrate so that the skin can breathe. Figure 4.17 shows a researcher during a pilot test, wearing sensors on the skin.

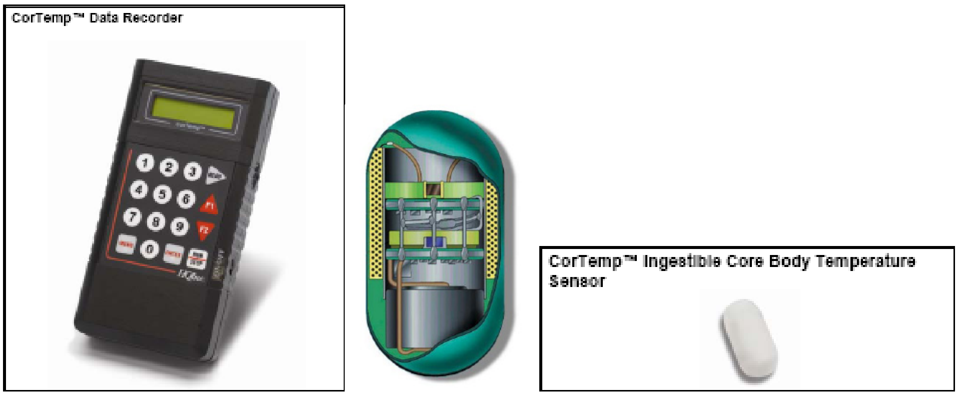


[Figure 2.58. Skin and core temperature sensors and skin temperature measurement locations]

The CorTempTM pill was originally developed for use by the National Aeronautics and Space Administration (NASA) to monitor astronauts for dangerously low or high body core temperatures (http://www.htitech.com/CTSensor.htm). Each silicone-coated capsule contains a telemetry system, a micro battery, and a quartz-crystal temperature sensor (Figure 4.21). Inside the gastrointestinal tract, the crystal sensor vibrates at a frequency in direct proportion to the body temperature surrounding it, producing an electromagnetic flux that is magnified by the sensor electronics and transmitted through the body to the recorder. [Zhang, 2003]

[Figure 2.59: The researcher during a pilot test]

Each pill is 23 mm long and 9 mm in diameter. The pill’s accuracy is 0.1 °C, and resolution is 0.01°C. The associated recorder is 4.72 x 2.23 x 0.98 inches. The CorTempTM pill’s sensors are calibrated by the company using a National Institute of



[Figure 2.60-2.62: CorTemp™ Core Body Temperature Monitoring System]

The advantage of CorTempTM is that it is accurate, unintrusive, and continuously measures body core temperature. A potential disadvantage is that the pill moves along through the digestive tract (it is ultimately eliminated by bowel movement). If the variation of temperature inside the body is small, this changing of the pill’s location will not result in significant error (personal communication with M. Ducharme at the 5th International Meeting on Thermal Manikin and Modeling, 2003). It is known however that internal temperature varies between organs depending on metabolism and blood flow. To avoid this potential inaccuracy, we had subjects swallow the pill at the same time shortly prior to the test with warm water (about 40 minutes before they started the first votes). [Zhang, 2003]

2.6 Measurement of environmental conditions

At each workstation, three Hobo thermistors measured the air temperature at the three standard heights (0.1, 0.6, 1.1m) specified for seated subjects in the ASHRAE and ISO environmental standards. Globe temperature and humidity were measured at 1.1 m.

Another Hobo thermistor measured the air temperature at the outlet of the nozzle, and a thermocouple to measure the surface temperature of the palm warmer. Because the foot warmer was controlled by cycling the heat lamp inside, an illumination-sensing Hobo in the warmer monitored the on/off times of the lamp.

[Figure 2.63. Thermisters and thermocouple to measure workspace environmental conditions and the TAC system temperatures]

The air velocity field in the workstation was characterized before the actual tests, because velocity measurement during testing would have been too intrusive. This was done with a manikin with the head-cooling air jets set at various velocities, as already shown in the previous chapter.

The manikin surface was heated to generate a realistic buoyant plume around the person. During the subsequent human subject tests, the experimenters did spot checks of velocity around the head with hand instrumentation, to assure that actual airflows matched the values predicted from the airflow control settings

3. HUMAN SUBJECT TEST:
METHOD

The present chapter is intended to present the method used to evaluate and measure results from the Human Subject Test. The human subject test was approved by the U.C. Berkeley Committee for the Protection of Human Subjects (C.P.H.S).

3.1 Test conditions

During the time between February and May 2007 we conducted 90 three-hour tests in the Controlled Environment Chamber at the University of California, Berkeley.

We recruited eighteen subjects, 9 male and 9 female, who participated in each of the 5 test conditions listed in Table 4.1.We chose a heterogeneous representing group, all 25-30 years old, some professionals and some students from different departments of UC Berkeley.

During the Human Subject Test we simulated five climate conditions, controlling the chamber air temperature and the window temperature. We simulated two cooler temperatures representing ‘winter’ conditions (18 ºC and 20ºC), two ‘summer’ conditions (28 ºC and 30ºC), and a neutral condition for each season.

We provided each subject with winter and summer clothing appropriate for the tests, in order to have the same clothing index for all subject participating to the tests. Winter clothing consisted of a short-sleeve T-shirt, long-sleeve cotton shirt, cotton long pants, sneakers, underwear, and a pair of thick socks. Summer clothing included a short-sleeve cotton shirt, long cotton pants, underwear, light shoes, and a pair of thin socks. In both summer and winter tests, underwear consisted of brief for women and shorts for men respectively.

	Room air temperature	Effective temperature (ET*)
hot	30ºC (86ºF)	29ºC ±0.1
warm	28ºC (82.4ºF)	27.5ºC ±0.1
neutral	25 or 24.5 ºC (77ºF or 76ºF)	24.2ºC ±0.1
cool	20 (68ºF)	19.9ºC ±0.1
cold	18 ºC (64.4ºF)	18ºC ±0.1

[Table 3.1: Chamber air temperatures and effective temperatures]

Since we provided different clothing for winter and summer conditions, there were two neutral condition temperatures, 24.5ºC and 25ºC.

Each subject performed five sessions of tests, one for each climate condition. Each session lasted three hours and included three control strategies for operating the TAC system, one for each hour: ‘No TAC’, ‘Fixed TAC’, ‘User Control’.

‘No TAC’ means none of the TAC features were enabled.

‘Fixed TAC’ means that the TAC settings were fixed at levels prescribed by the experimental design.

Under ‘User Control’, the subjects were allowed to adjust the levels of heating and/or cooling provided by the TAC system.

In the 18 ºC and 20ºC ‘winter’ condition tests, the heating TAC system was provided: foot warmer, palm warmer, heated keyboard, and heated mouse. In the ‘Fixed TAC’ mode, the aluminum surface of the palm warmer was controlled at 35ºC, and the heated keyboard and mouse were each fixed at 32 ºC. The foot warmer was controlled at the on/off ratio of 4/12 (4 seconds on and 12 seconds off), producing inside the warmer an average radiant flux of 45W, and an internal air temperature of 32 ºC.

In the 28ºC ‘summer’ condition test, air motion was provided through the head and hand ventilation devices, both using re-circulated room air. The 30ºC tests were the same as the 28ºC tests, except that the head cooling airflow in this case was outside air, supplied at 24ºC (6ºC cooler than the room air temperature). Owing to mixing, by the time the air reached the breathing zone of an occupant, the air temperature is around 28ºC.

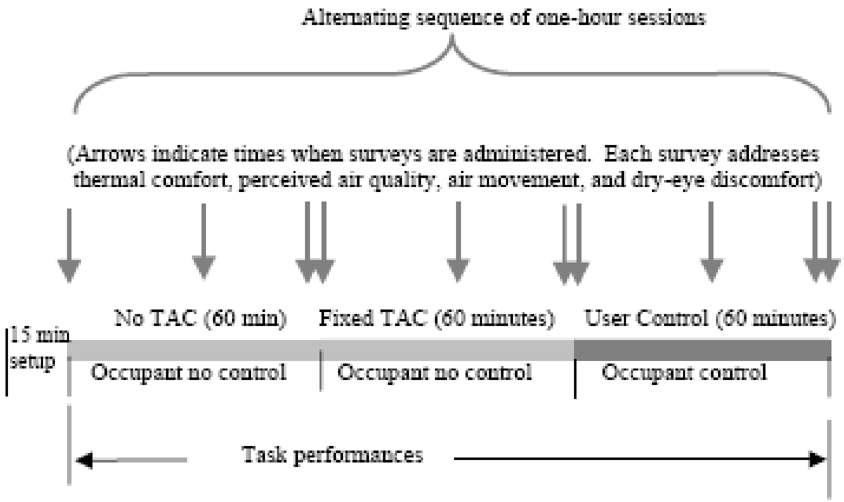
Under neutral conditions, there was no ‘Fixed TAC’ condition, because at neutral we assumed that the occupants would not need any local conditioning. In these conditions we observed few cases where subjects turned on the foot warmer and the head cooling.

3.2 Schedule for human subject tests

Each test took three hours, divided into 3 one-hour sessions, corresponding to three control strategies: No-TAC, Fixed-TAC, and User-Controlled TAC. In order to keep a balanced order in the sequence of sessions for the subjects, we alternated the conditions into the Controlled Environment Chamber.

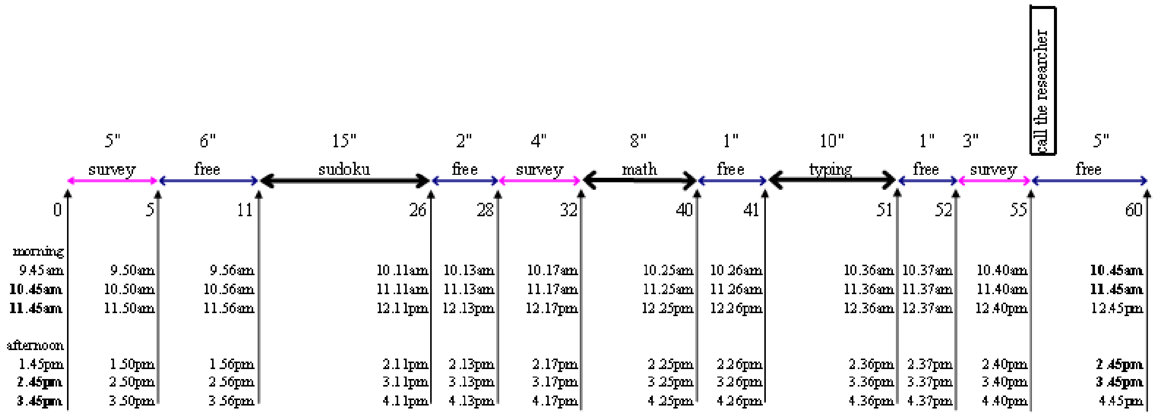
For the neutral condition, in which there was no Fixed- TAC session, the three-hour test was divided into either of the following two sequences: No-TAC, User-Control, No-TAC, or User-Control, No-TAC, User-Control.

During the Human Subject Test the subjective surveys were administered three times each hour, as shown by the vertical arrows in Figure 4.1. At the beginning of each test session the subjects were asked to answer a subjective survey, then a second one appeared after 30 minutes in the middle of the test session, and another one at the end of the session. The researcher could change/adjust the test conditions during the five minutes interval between the last subjective test of a session and the first of the following session. (e.g., put the TAC into its fixed value settings). During the interval between two control strategies we provided a light snack for the subjects and let the subjects stretch and move about.



[Figure 3.1: Plan of each test]

During the Human Subject Tests, surveys and subjects' tasks (Sudoku games, math problems, and typing test; described later) were all pre-scheduled into the computers which the subjects were working on, so they automatically appeared on their screens according to the timeline shown here. We run two sets of tests per day, one in the morning and one in the afternoon.



[Figures 3.3: Scheduled tasks]

3.3 Subjective surveys

The survey questionnaires appeared automatically on the subject's computer screen at the times shown in Figure 4.2. When the subjects answered the surveys and the tasks, their votes were stored in the computer. The subjects took two minutes to answer all the questions in the subjective survey.

The subjective survey addressed thermal sensation and thermal comfort of the occupant during the test. It also addressed few questions about their preferences and local discomfort due to air movement.

3.3.1 Sensation and comfort scales used in our tests

The two most widely used scales for evaluating thermal sensation and comfort are The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) seven point sensation scale, and Bedford's sensation and comfort scale.

The ASHRAE seven-point scale, shown in Table 4.3, has been widely used for thermal sensation assessment in both laboratory and field studies (Arens et al. 1988).

McIntyre (McIntyre 1980) explains why a seven-point (versus three- or 25-point) scale is appropriate for psychological measurement. When people are presented with a set of stimuli that vary in one dimension only, the number of stimuli that can be unambiguously identified is relatively small. Subjects can identify about six different tones and five degrees of loudness without error. Along with McIntyre, Miller (Miller 1956) investigated this range, which he called the "span of absolute judgment." For several different types of stimuli, Miller found that people cannot generally deal with more than about seven levels of sensation without confusion. Because the temperature range for automobiles can be exceptional large in both the warm and cold directions, automobile thermal comfort studies have used scales of nine and more points. Bedford's (Bedford 1936) well-known scale of sensation and comfort (Table 3.3) conflates warmth and comfort but does at least address the issue of comfort. Bedford's scale has also been applied to both field and laboratory studies (Bedford 1936; Lewis, Meese et al. 1983). [Zhang, 2003]

value	description
3	hot
2	warm
1	slightly warm
0	neutral
-1	slightly cool
-2	cool
-3	cold

value	description
3	much too warm
2	too warm
1	comfortably warm
0	comfortable
-1	comfortably cool
-2	too cool
-3	much too cool

[Table 3.2, 3.3. on the left the ASHRAE seven-point scale; on the right the Bedford comfort scale]

Comfort is not necessarily dependent only on sensation; perceptions of comfort may also have to do with expectation, adaptation to conditions, and other factors. Thus, information about sensation alone is not sufficient to evaluate a subject's comfort; direct questions must also be asked about comfort level. Because of the complexity of assessing comfort transient conditions in an asymmetrical environment, we asked subjects separate questions about both thermal sensation and comfort.

The sensation scale used in our tests covers a range from "very cold" to "very hot." It is a continuous scale; subjects can identify any place along the scale as corresponding to their perceptions. Internally, the scale is translated to the numerical values, i.e., "very cold" is –4, "cold" is –3, "cool" is –2, "slightly cool" is –1, "slightly warm" is 1, "warm" is 2, "hot" is 3, and "very hot" is 4. Our scale is thus very similar to the ASHRAE seven-point thermal sensation scale, with "very cold" and "very hot" added to encompass thermal possibilities similar to the extreme conditions found in automobile studies, as referenced below, and studies covering wider sensation range, such as the one carried out by Goto (Goto et al., 2002) examining thermal sensations corresponding to different levels of activity. The transience and asymmetry of conditions in our tests are greater than is typically found in " normal" environments, such as offices. [Zhang, 2003]

A study by Kansas State University for Ford Motors added the gradation "cold/cool" between "cold" and "cool" and "hot/warm" between "hot" and "warm" to expend the scale to nine points

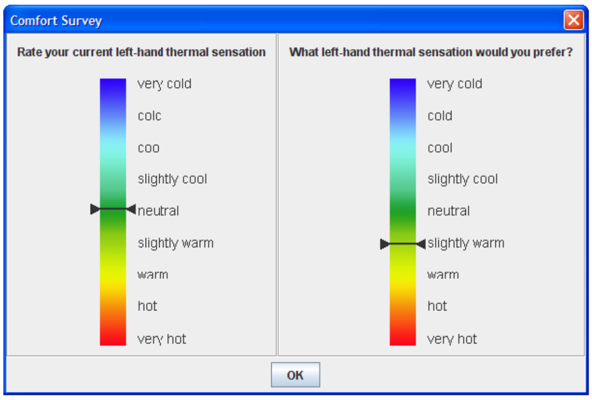
(Guan 2003). The scale is similar to Bedfords' sensation and comfort scale: cold, cold/cool. Comfort/cool, comfort, warm/comfort, hot/warm, hot. A Toyota study expended the scale to 11 points, adding "slightly hot" between "warm and hot," "slightly cold" between "cool" and "cold," and the two extremes of "very hot" and "very cold". A study by Nissan used the same nine points that we use in our study (Hagino and Hara 1992). In addition to Bedford's combined comfort and sensation scale, some studies have applied a specific comfort scale. Hagino (Hagino and Hara 1992) used a seven-point comfort scale: +3 (very comfortable), +2 (comfortable), +1 (slightly comfortable), 0 (neutral), (-1) slightly uncomfortable, (-2) uncomfortable, (-3) very uncomfortable. Our study uses the comfort scale as shown in Figure 4.22, which ranges from very uncomfortable (-4) to very comfortable (+4). In the middle we break the scale, between "just uncomfortable (-0)" and "just comfortable (+0)," which forces subjects to make a broad determination about whether their perceived state falls in the overall category of "comfortable" or "uncomfortable." [Zhang, 2003]

Each question appears on the subject's screen separately and disappears after being answered; thus, the subjects cannot see the other questions or the history of responses while answering the questions each time.

3.3.2 Thermal sensation and preferred thermal sensation

First 9 questions addressed thermal sensation and preferred thermal sensation for 4 local body parts (head, left hand, right hand, foot) and the whole-body. We asked sensation for left hand and right hand separately because the two hands may work on keyboard and mouse separately. Since the two feet are not exposed to different environments, we did not ask questions about them individually. We asked only thermal sensation for leg, arm, and trunk, not the preferred thermal sensation, because TAC does not influence these body parts directly. Therefore, only the left side of the Figure 4.3 was used on these questions.

Subjects registered their votes by clicking on the place that best described their thermal sensations. The scale is continuous and they could click on any place. They could change their votes by dragging the arrow up and down, or by clicking on a different place. The numerical values of the sensation scale are: -4 (very cold), -3 (cold), -2 (cool), -1 (slightly cool), neutral (0), 1 (slightly warm), 2 (warm), 3 (hot), 4 (very hot).



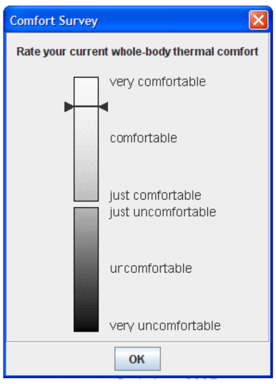
[Figure 3.4. Thermal sensation and preferred thermal sensation questionnaire]

We used paired thermal sensation and preferred sensation surveys because this format not only indicates thermal preference (want to be warmer, no change, cooler) by subtracting the two votes, but it also indicates the thermal sensation that a subject prefers, the magnitude of the preference, and whether neutral is the preferred sensation. This scale pairing was adopted by Humphreys [Humphreys et al. 2006, Zhang, 2003].

3.3.3 Thermal comfort

The following five questions addresses thermal comfort for the 4 local body parts and the whole-body. We used the same comfort scale used by Zhang in previous human subject studies [Zhang 2003, Arens et al. 2006a & b]. It was a continuous scale, from just comfortable (+0) to very comfortable (4), just uncomfortable (-0) to very uncomfortable (-4).

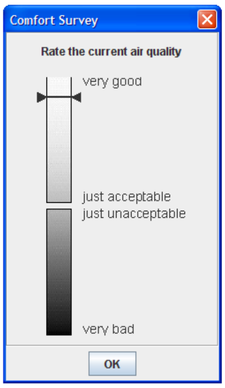
In this scale there is a gap between just comfortable and just uncomfortable to force the subjects to make a decision whether they are on the comfortable side, or on the uncomfortable side. We asked about thermal comfort for the same 4 local body parts, and for the whole-body.



[Figure 3.5. Thermal comfort questionnaire]

3.3.4 Perceived air quality

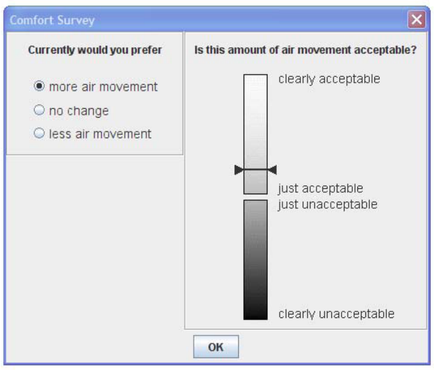
The appearance of the perceived air quality questionnaire is very similar to the comfort scale. The continuous scale runs from just acceptable (+0) to very good (4), just unacceptable (-0) to very bad (-4). Also in this case there is a gap between just acceptable and just unacceptable to force the subjects to make a clear distinction between the acceptable and unacceptable perceived air quality.



[Figure 3.6. Perceived air quality questionnaire]

3.3.5 Acceptance of the air movement and preference

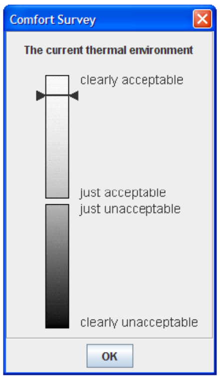
We provided two questionnaires regarding air movement, one on its acceptability, and one on preference for more, less, or the same. The acceptance scale runs from just acceptable (+0) to clearly acceptable (+4), and just unacceptable (-0) to clearly unacceptable (-4). The air movement scale has three choices, less air movement (-1), no change (0), more air movement (1). Both questionnaires have been commonly used when evaluating the effects of air movement on comfort.



[Figure 3.7. Air movement acceptance and preference]

3.3.6 Acceptance of the thermal environment

The subjects were asked to give votes regarding the acceptance of the thermal environments while performing the HST. The numerical values of the scale are the same as the air movement acceptable scale.

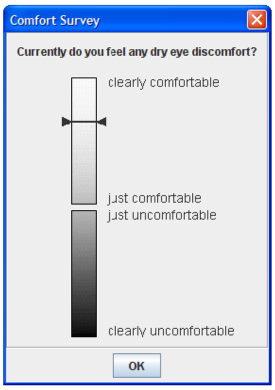


[Figure 3.8 Thermal environment acceptance]

3.3.7 Dry-eye discomfort

Many research showed that air movement could cause dry-eye discomfort to the occupant, for this reason we designed the head ventilation system so that the air does not blow directly onto the face and eyes, as seen in the previous chapter. (Wyon 1987, Wolkoff et al. 2005, Pejtersen et al. 2005).

The purpose of this questionnaire is to examine whether dry-eye discomfort occurs, caused by the use of the head cooling system. The numerical values are the same as the other comfort and acceptable scales.



[Figure 3.9: Dry-eye discomfort questionnaire

3.4 Productivity evaluation

Common approaches to evaluating productivity in laboratory studies include math exercises (normally addition), typing, proof reading, and creative thinking. It often happens in laboratory studies that the differences in the task performances between different environmental conditions are not significant, while in field studies, significant differences are seen. [Niemela R. et al. 2002, Tham et al. 2004, Tanabe et al. 2005].

The lack of response in laboratory studies could mean that the environment did not impact productivity. It could also mean that the methods used in the laboratory studies did not properly represent normal office work, or that the motivation of subjects over the short duration of laboratory tests overwhelms environmental influences that in normal life would have an impact on office work. We looked for ways to evaluate task performances (productivity), over a reasonably long time period, involving both mental and dexterity work, and providing resolution in the level of response.

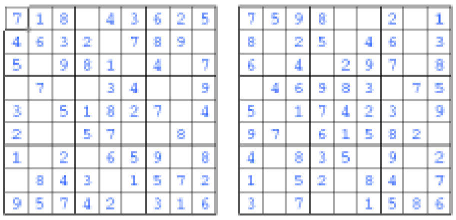
We spent some time exploring the possibility of using the math session of Graduate Record Examination (GRE) or Student Aptitude Testing (SAT) practice tests as a way to evaluate the performance. The advantages are that such tests involve both thinking and typing, cover a reasonable length of time, and are real work being undertaken anyway by university student subjects, for whom the pacing of work and motivation would be realistic.

However, we found that during the one-hour test sessions planned for our experiment, including the time needed for the subjective surveys, we could only arrange to do one session of the GRE test. One session normally only covers 18 – 25 questions, so the resolution was too low (e.g. if one question is wrong, it has large impact on the score). The GRE and SAT tests may be a good approach if the test session is longer (for example, people can do two SAT sessions). It was not a feasible choice for our test.

For the previous reason we chose the following three tasks to evaluate performance. The tasks were chosen in order to evaluate three aspects of the real work: logical thinking, mental performance and dexterity. Each day, every hour for the three hour session, the subjects had to take parallel versions of numerical and logical-based performance tasks representing different aspects of office work, from mathematics to typing. Our intent during the human subject tests was to simulate a regular office work. The tasks were always in the same order and the same difficulty level.

To evaluate logical thinking the subjects were asked to complete Sudoku for 15 minutes/each session (condition). Medium difficulty examples were chosen so that subjects could complete more than one in a session, and not become stuck on any test.

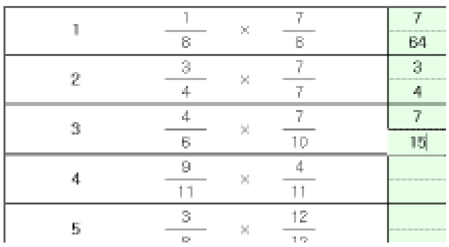
Moreover Sudoku games avoid any bias due to the language skills of subjects. In fact our subjects were of different nationality. This could affect results from any test were language knowledge was requested. Sudoku games do not imply any mathematical or logical bases, avoiding also any bias due to different background in subjects. We evaluate the logical thinking calculating the percentage of right Sudoku games solved in 15 minutes. The values were normalized to the "no TAC value" of each subject for the specific day.



[Figure 3.10: A screen shot of an automated Sudoku of medium difficulty]

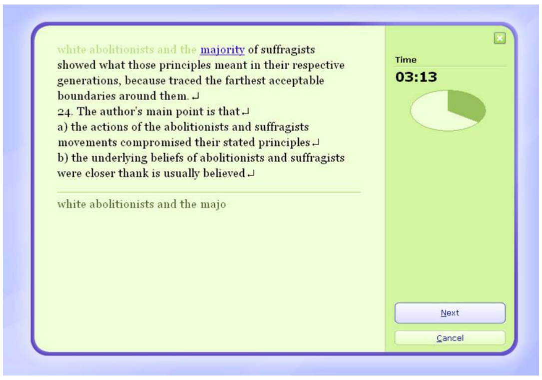
To evaluate the mental performance during the Human Subject Test, the subjects were asked to answer simple math problems for 8 minutes/each session. We chose fraction multiplication for the math problems, because such exercises were neither tedious nor too difficult; always solvable but at varying rates of speed depending on how many mental shortcuts were employed.

We evaluate the tests calculating the rate of right math problems solved and the percentage of mistake in 8 minutes. The values were normalized to the "no TAC value" of each subject for the specific day.



[Figure 3.11: A screen shot of math test sheet]

To evaluate the dexterity of the subjects we chose a typing test to be performed. For 10 minutes the subjects had to type a text as seen in the screen. The typing test was evaluated calculating the gross speed (words per minute) and the accuracy (%). Also here the results were normalized to the "no-TAC" value of each subject for each day of test.



[Figure 3.12: A screen shot of TypingMaster Pro 7.0 English]

At the end of each one-hour test session, we asked the subjects to stretch their bodies during a three-minute break. The researchers also had short conversations with them. We also provided a light snack before the start of the next one-hour session. The break was intended to prevent subjects becoming tired or sleepy, or low in blood sugar, since we could not standardize the meals they had before their arrival to the building.

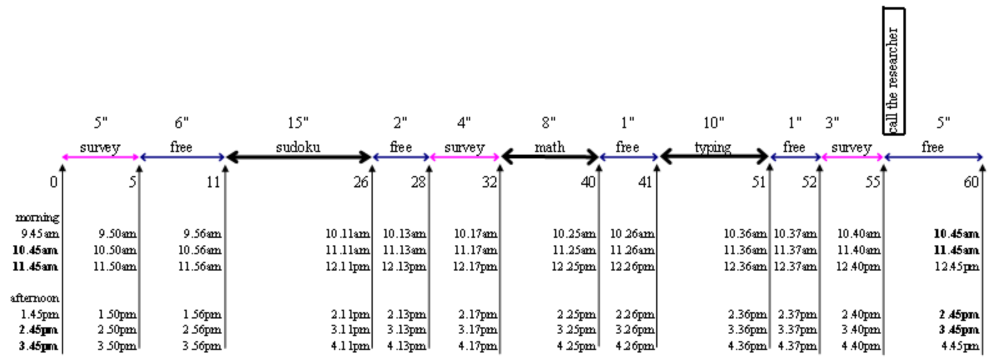
3.5 Test description

3.5.1 Test procedure

Each test takes three to four hours. Upon the subject's arrival, s/he first swallows the core temperature measurement pill with warm water and then we applied the sensors at the different sites on the subject's body. After the thermocouples are placed, the subject sits on the chair in front of the computer and begins to answer subjective survey as they appear on the computer screen. Meanwhile, the data from the 10 skin-temperature thermocouples are recorded, and the recorder takes body core-temperature data.

After 5 minutes the subjective survey appears on the computer's screen and the subject answers the questions. After the subjective survey, the subject has 6 minutes free. During the free time the subject could work freely on the computer. After the 6-minute-break time, the Sudoku game starts and lasts for 15 minutes. At the end of the 15 minutes the Sudoku games switch off automatically saving results. The subject then sees the second session of thermal questionnaire, same of the first one. The thermal questionnaire appears three times per hour: after 5 minutes, in the middle and 5 minutes before the end of each hour. Math tests and typing appears automatically during the second half of each hour.

At the end of the last subjective survey of each hour, the subject ias asked to call the researcher from a pop-up window on the screen. The researcher then changs the condition between no-TAC, fixed-TAC and user-control. At the end of each one-hour test session, we asked the subjects to stretch their bodies during a three-minute break. The researchers also initiated short conversations with them. We also provided a light snack before the start of the next one-hour session. The break was to prevent subjects becoming tired or sleepy, or low in blood sugar, since we could not standardize the meals they had before they arrived for the tests. The subjects could easily move around because we used wireless sensors measuring skin and core temperatures.



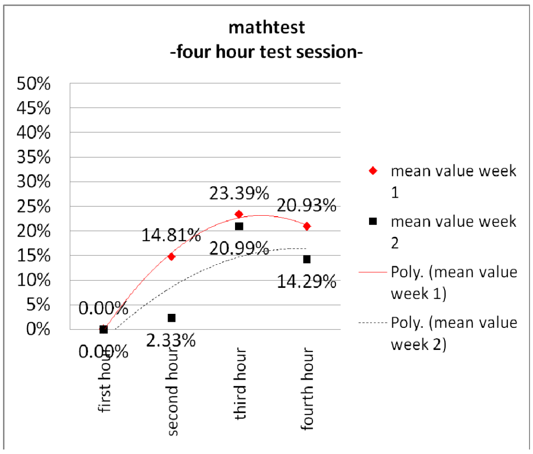
[Figure 3.12: time schedule for the Human Subject Test]

Then the test for that day is completed, and the subject can change clothing and sign for payment.

Normally the measurement time continues for more than 3 hours. The entire test (starting from the arrival of a subject) takes four hours. We run two tests per day with two subjects working at the same time on two workstations, excluding one day when we run only the morning session. In total 18 tests per week.

The first session of Human Subject Test scheduled four-hour tests. After two weeks analyzing results we noticed that the subjects' performances had improvements during the first, second and third hour of test [Figure 4.13]. During the fourth hour we noticed a loss in productivity for almost all the subjects. For this reason we decided to have shorter session of tests, running three-hour sessions instead of four-hour tests.

We also decided to shift the three local conditions (no-TAC, fixed-TAC and TAC-control) in random order to avoid that the subject performances were affected by fatigue or by the performance improvement due to the work sequence (first hour, second hour and third hour). The thermal local conditions (no-TAC, fixed-TAC and user-control) were again switched between the three hours the following week in order to cover all combinations.



[Figure 3.13: Math tests. Median value of four-hour tests]

3.5.2 Subject training sessions carried out prior to testing

Before starting with the Human Subject Test, we first described the test procedure, the typing test and survey questionnaires via a Powerpoint presentation to the subjects in order to avoid the effect of the learning curve.

Then we asked them to practice three 15-minute Sudoku games, and three 8-minutes math solution exercises. After they practiced, they went to the environmental chamber to visit the workstations and to learn how to use the control units of the four TAC systems.

[Figure 3.14, 3.15: The pictures show the researchers explaining the test procedure and the three tasks to the subject during the training sessions.]

4. SUBJECTIVE SURVEY: RESULTS

Air conditioning in office buildings aims to create a uniform and stable environment in order to provide comfort for the occupants, with high energy consumptions. Previous research [Zhang, 2003; Arens, 2006 part II] showed that a non-uniform environment could be more appreciated than uniformity by the occupants, showing the opportunity of lowering energy consumptions keeping high comfort level.

In fact, if it were possible to keep the occupants comfortable in a wider range of temperatures, by the use of efficient TAC systems, it would be possible to save energy in air conditioning systems, having cooler temperatures in winter and warmer in summer.

This research aims to analyze the capability of TAC systems in keeping occupants comfortable in a wide range of temperature, from 18°C to 30°C. In cold conditions, 18°C and 20°C, we used two TAC devices to warm up local body parts that previous research [Zhang, 2003] showed to dictate the comfort level: hands and feet. In warm conditions, 28°C and 30°C, we blown air into the breathing zone from two nozzles placed on the furnishing on both sides of the occupant.

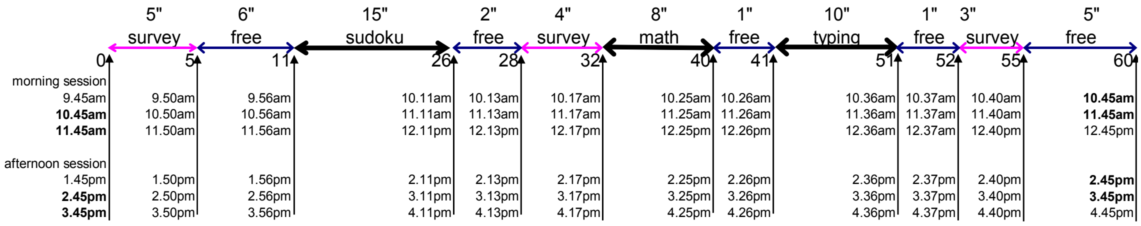
This chapter is intended to present the data from the subjective survey during the HST.

4.1 Thermal sensation and thermal comfort

In the subjective survey all subjects were asked about their whole body and local thermal sensation and thermal comfort in order to evaluate not only the effect of environment on discomfort but also the possibility that the application of local stimuli to selected parts of the body might produce a thermal delight decreasing the overall perception of stress. In the following chapters results from the whole body thermal sensation and comfort will be presented.

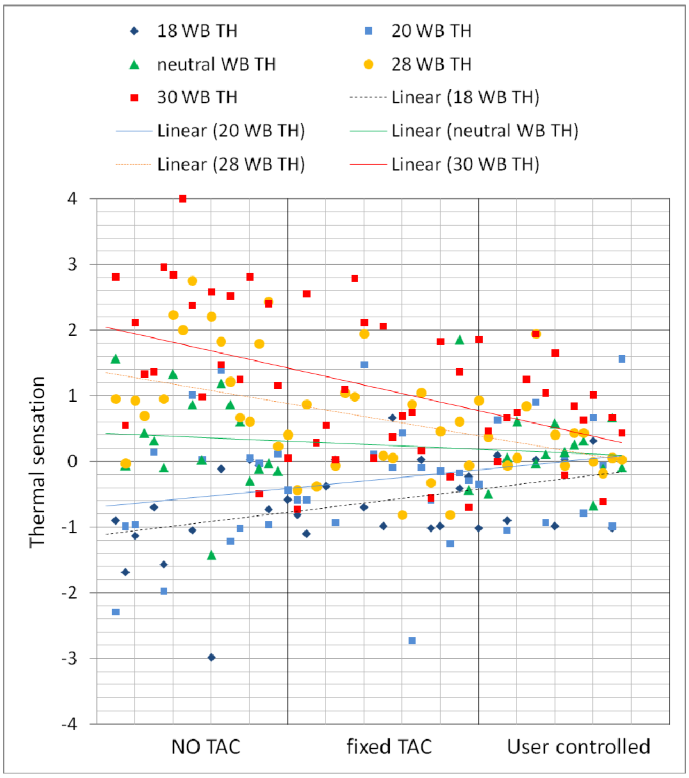
4.1.1 Whole body thermal sensation

During the Human Subject tests the subjective survey appeared automatically on the computer screen on a scheduled time.

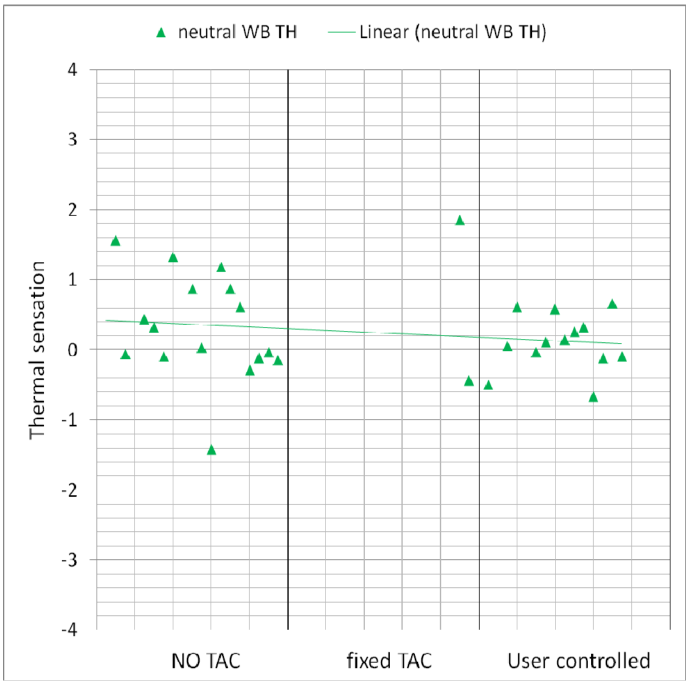


[figure 4.1: Schedule of Human Subject Tests]

We asked the subjects to vote by clicking on the place that best described their thermal sensations. The scale was continuous and they could click on any place. They could change their votes by dragging the arrow up and down, or by clicking on a different place. The numerical values of the sensation scale are: -4 (very cold), -3 (cold), -2 (cool), -1 (slightly cool), neutral (0), 1 (slightly warm), 2 (warm), 3 (hot), 4 (very hot). Votes that are far from the 0 value identify not acceptable thermal sensation (e.g. too hot or too cold).



[figure 4.2: Whole body thermal sensation]



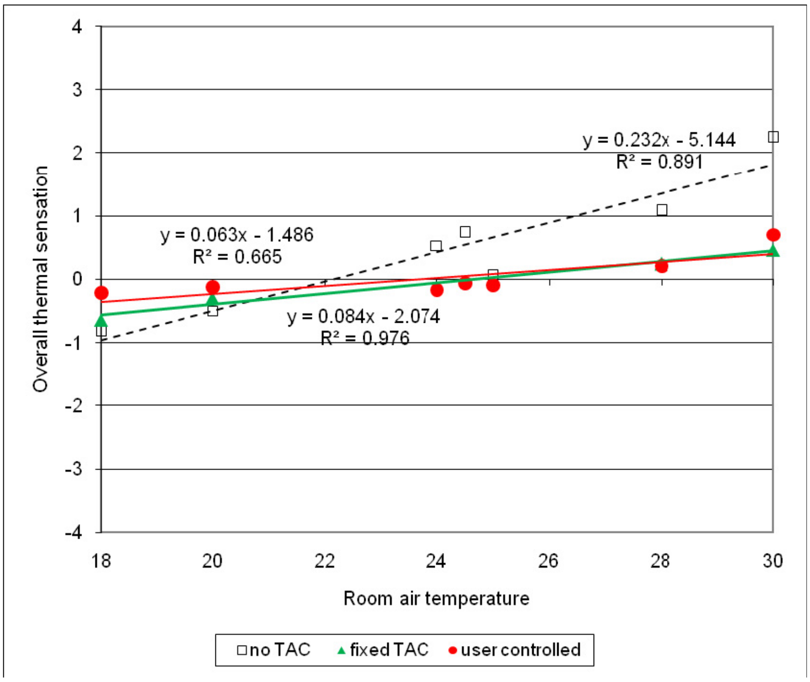
[figure 4.3: Whole body thermal sensation]

Figure 4.2 presents the 18 subjects' median whole-body thermal sensation, for each of the 5 environmental conditions and the three control strategies. It is possible to notice that moving from no-TAC condition to TAC conditions, the whole body thermal sensation improves, in fact subjects' votes moved closer to the center line.

In User-controlled the possibility of adjusting the micro environment, leads to better thermal sensations for all the subjects in all the five conditions (18°C, 20°C, 28°C, 30°C, neutral).

It is interesting to notice the improvement in thermal sensations in neutral conditions. In 24°C and 25°C, since it was neutral condition, we did not apply a fixed-TAC value to the devices. From figure 4.2 it is possible to notice that votes in User-controlled are closer to neutral sensation than in no-TAC.

Figure 4.4 shows the sensation votes in different thermal environment conditions. The slope in no-TAC is steeper than in the other two strategies. This suggests that the use of TAC devices allows a larger percentage of subjects to maintain comfortable conditions over a wider range of room temperatures. Moreover data suggest a stronger effect of local devices in warm conditions than in cold conditions.



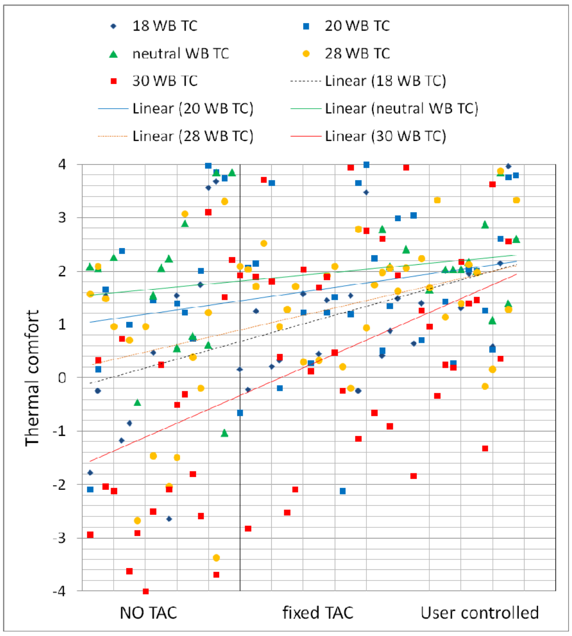
	Overall Thermal Sensation		
room air temperature	**no TAC**	**fixed TAC**	**user controlled**
18	-0.81	-0.64	-0.20
20	-0.49	-0.29	-0.12
24	0.54		-0.16
24.5	0.74		-0.06
25	0.06		-0.09
28	1.09	0.25	0.22
30	2.25	0.46	0.71

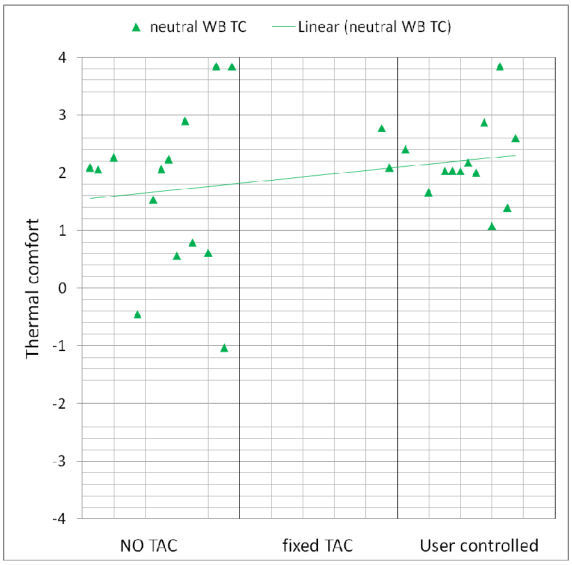
[Figure 4.3 and table 4.1: Whole-body thermal sensation with air temperatures for three control strategies (no-TAC, fixed-TAC, user-controlled)]

4.1.2 Whole body thermal comfort

Subjects registered their votes by clicking on the place that best described their thermal comfort. Again the scale is continuous and they could click on any place, from just comfortable (+0) to very comfortable (4), from just uncomfortable (-0) to very uncomfortable (-4). The scale for thermal comfort differs from the scale for thermal sensation; in fact, in the thermal comfort questionnaire there is a gap between the indication of just comfortable and just uncomfortable, in order to force the subjects to make a clear decision whether they are on the comfortable side, or on the uncomfortable side.

In agreement with data from thermal sensation, it is possible to notice in figures 4.5 and 4.6 that subjects voted higher comfort level moving from no-TAC to TAC strategies (both fixed TAC and user controlled).



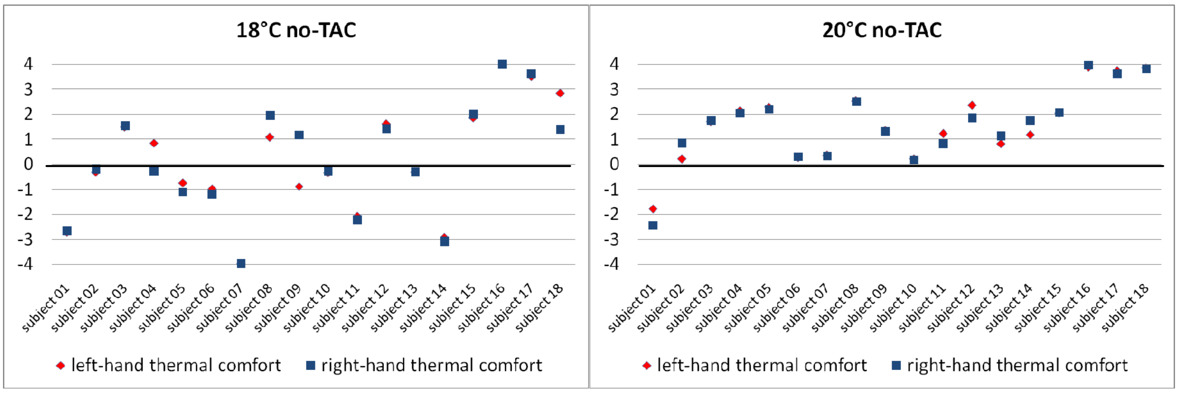


[figure 4.5 - 4.6: Whole body thermal comfort]

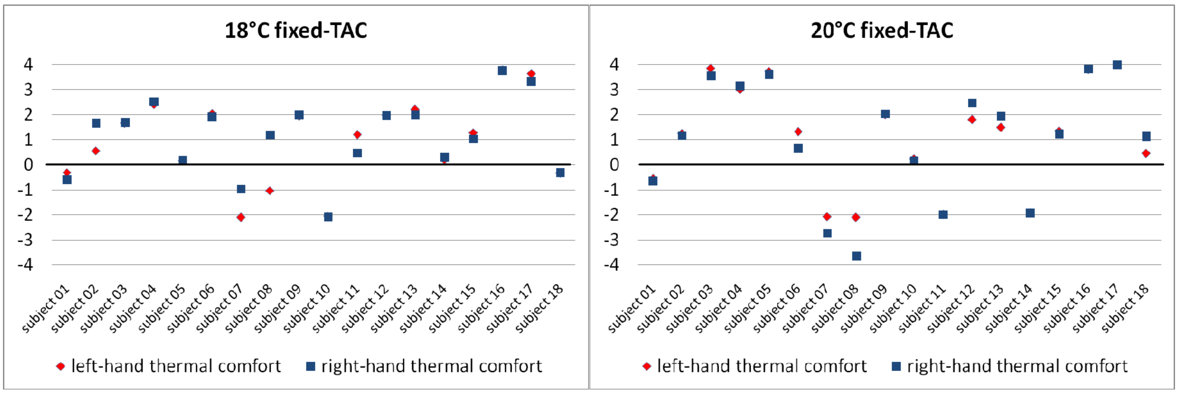
This confirms that TAC systems allowed the subjects to feel comfortable over a large room air temperature range, from 18ºC to 30ºC, and that the local devices have stronger effect in warmer environment than in cold environment.

Figure 4.6 shows the median value of subjects' votes for their whole body thermal comfort in neutral condition. Votes are more concentrated in the upper part of the graph, meaning that, having the possibility of controlling their own environment permitted the subjects to feel more comfortable.

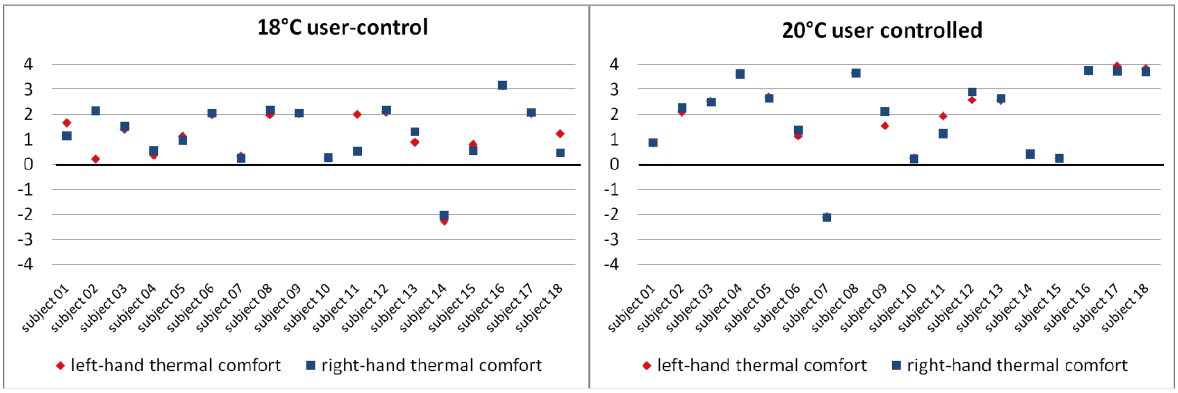
The following graphs show local thermal comfort votes for 18°C and 20°C. In cold conditions we fixed the surface temperature of the palm warmer at 35°C; subjects could not change it. It is possible to notice that in 18°C the fixed temperature increases subjects' comfort level in almost all cases; but we have to consider also that in 20°C, in fixed-TAC strategy, the palm warmer was not always perceived as comfortable, but in some cases increased local discomfort. When, in user-controlled strategy, the subject could control the surface temperature of local devices, comfort level was higher.



[Figure 4.7, 4.8: Local thermal comfort for the 18 subjects in 18°C and 20°C during no-TAC conditions.]

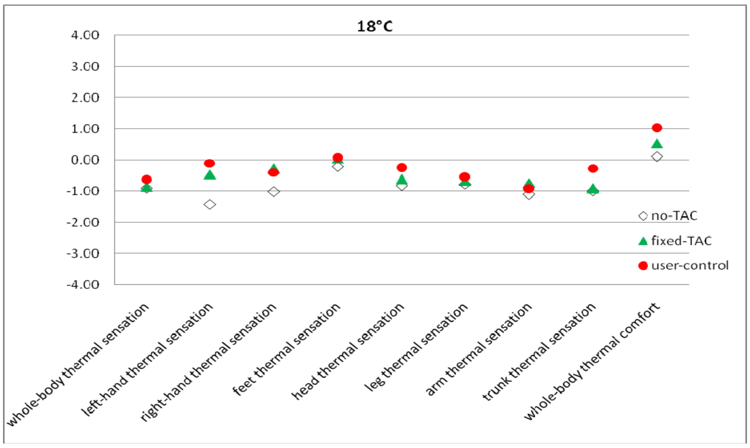


[Figure 4.9, 4.10: Local thermal comfort for the 18 subjects in 18°C and 20°C during fixed-TAC conditions.]



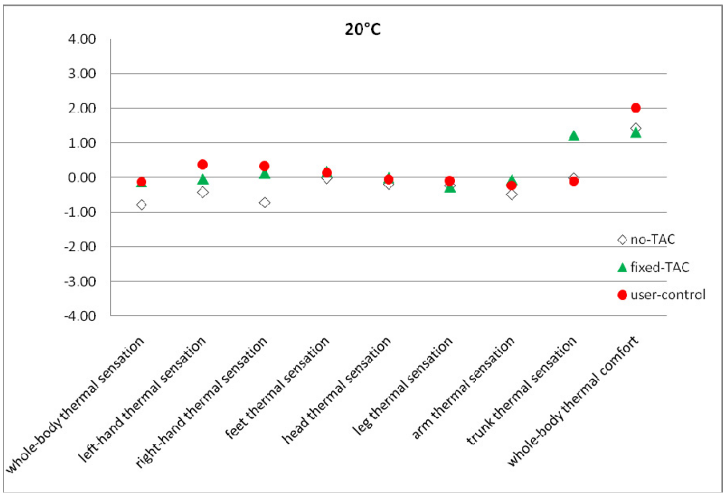
[Figure 4.11, 4.12: Local thermal comfort for the 18 subjects in 20°C during User-control conditions.]

The following figures show the median value of local and overall sensation, and the overall comfort in the five conditions.



	whole-body thermal sensation	left-hand thermal sensation	right-hand thermal sensation	feet thermal sensation	head thermal sensation	leg thermal sensation	arm thermal sensation	trunk thermal sensation	whole-body thermal comfort
no-TAC	-0.91	-1.42	-1.01	-0.20	-0.83	-0.77	-1.10	-1.00	0.12
fixed-TAC	-0.86	-0.45	-0.28	0.06	-0.61	-0.67	-0.72	-0.91	0.55
user-control	-0.64	-0.09	-0.39	0.07	-0.25	-0.55	-0.93	-0.26	1.03

Figure 4.13 and table 4.2: Median values of whole body thermal comfort, whole body and local thermal sensation. In 18°C

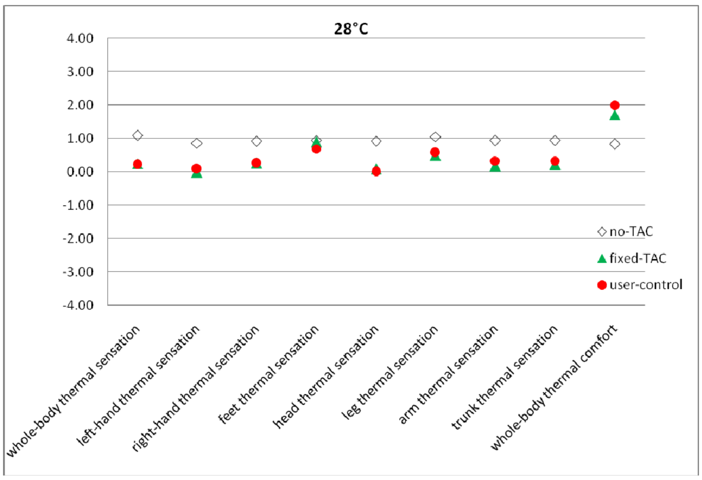


	whole-body thermal sensation	left-hand thermal sensation	right-hand thermal sensation	feet thermal sensation	head thermal sensation	leg thermal sensation	arm thermal sensation	trunk thermal sensation	whole-body thermal comfort
no-TAC	-0.77	-0.42	-0.71	-0.01	-0.19	-0.23	-0.48	-0.01	1.43
fixed-TAC	-0.12	-0.03	0.13	0.17	-0.01	-0.04	-0.26	-0.04	1.23
user-control	-0.12	0.36	0.32	0.13	-0.06	-0.10	-0.22	-0.09	2.01

[Figure 4.14 and table 4.3: Median values of whole body thermal comfort, whole body and local thermal sensation in 20°C]

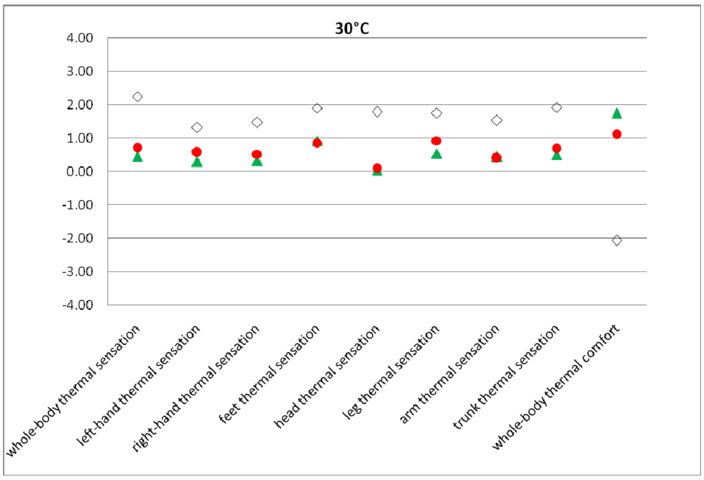
In cold conditions, 18°C and 20°C, the application of palm warmer and feet warmer have effect also on trunk thermal sensation, improving the whole body thermal comfort.

The following figures in warm conditions, 28°C and 30°C, show that the air movement focused on the breathing zones has effect on thermal sensation on all local body parts, improving the whole body thermal comfort.



	whole-body thermal sensation	left-hand thermal sensation	right-hand thermal sensation	feet thermal sensation	head thermal sensation	leg thermal sensation	arm thermal sensation	trunk thermal sensation	whole-body thermal comfort
no-TAC	1.09	0.87	0.93	0.96	0.93	1.06	0.94	0.96	0.84
fixed-TAC	0.25	-0.01	0.26	0.90	0.09	0.49	0.17	0.23	1.72
user-control	0.22	0.09	0.26	0.70	0.00	0.58	0.33	0.33	1.98

[Figure 4.15 and Table 4.3: Median values of whole body thermal comfort, whole body/local thermal sensation. In 28°C]



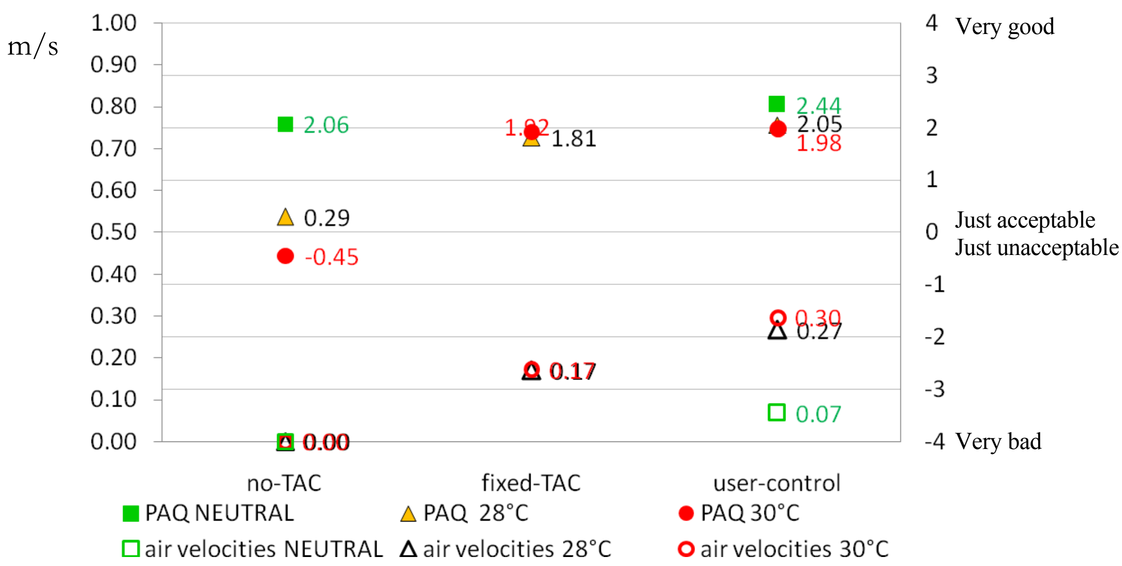
[Figure 4.16 Median values of whole body thermal comfort, whole body and local thermal sensations in 30°C.]

	whole-body thermal sensation	left-hand thermal sensation	right-hand thermal sensation	feet thermal sensation	head thermal sensation	leg thermal sensation	arm thermal sensation	trunk thermal sensation	whole-body thermal comfort
no-TAC	2.25	1.32	1.48	1.91	1.80	1.75	1.54	1.93	-2.06
fixed-TAC	0.46	0.30	0.32	0.93	0.04	0.55	0.45	0.51	1.75
user-control	0.71	0.58	0.52	0.87	0.09	0.93	0.41	0.68	1.11

[Table 4.4: Median values of whole body thermal comfort, whole body and local thermal sensations in 30°C.]

4.2 Perceived air quality (PAQ)

The following graph shows median value of perceived air quality questionnaire. Data show that air movement in breathing zone improves perceived air quality (PAQ) in warm and neutral conditions.



Median values of 18 subjects	PAQ 30°C	air velocities 30°C	PAQ 28°C	air velocities 28°C	PAQ NEUTRAL	air velocities NEUTRAL
no-TAC	-0.45	0.00	0.29	0.00	2.06	0.00
fixed-TAC	1.92	0.17	1.81	0.17		
user-control	1.98	0.30	2.05	0.27	2.44	0.00

[Figure 4.17 and table 4.5: Perceived air quality (PAQ) in the breathing zone]

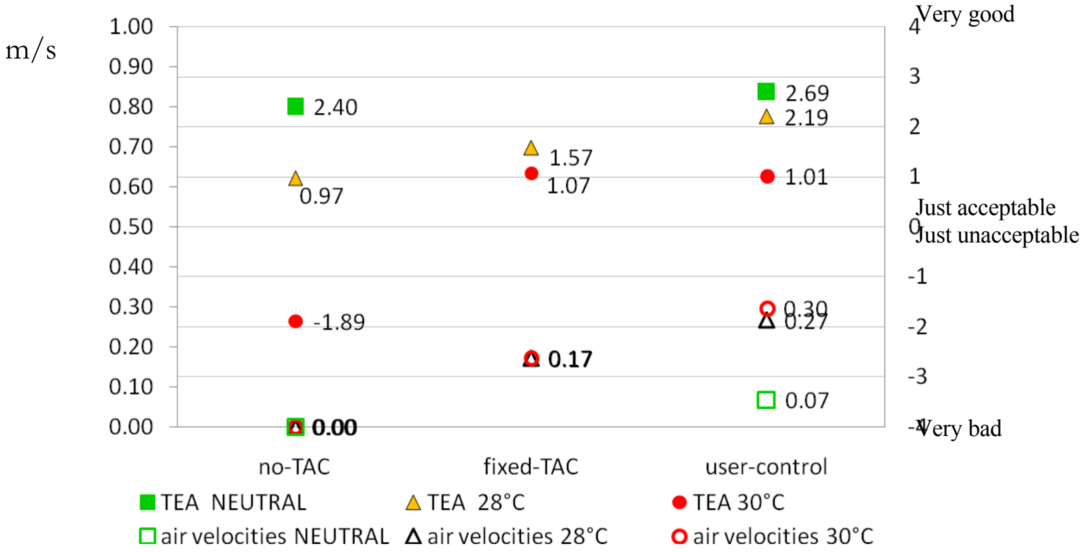
In the 30ºC tests the nozzle air supply was cooler (24ºC right at the outlet of the nozzle, about 28ºC when reaches the breathing zone), and coming from outdoors. For this reason we could attribute the improved perceived air quality (PAQ) to three different causes: air movement availability, lower air temperature in breathing zone, and the freshness of the supply air.

In 28°C condition, the nozzle supply air was entirely re-circulated room air drawn from near the floor. Since the air temperature and freshness were identical to those of the surrounding room air, the improvement in PAQ must be attributed only to air movement.

This is further supported by the curve representing neutral. In this, the PAQ under neutral conditions is increased when subjects increased the air speed. Also in neutral conditions, the air flow is re-circulated room air and no outdoor or cooler air is blown in the breathing zone.

4.3 Thermal environment acceptability and air movement:

During the Human Subject Tests we noticed that air movement in the breathing zone improve the Thermal Environment Acceptability (TEA). In particular, figure 4.18shows that in 30°C votes move from “bad” to “acceptable in fixed-TAC strategy. Same as before, in 30°C we blown fresh air at 24°C, and in 28°C and neutral condition we blown re-circulated air. For this reason there is a stronger improvement in TEA in 30°C than in the other two conditions.



[Figure 4.18: Thermal environmental acceptability (TEA) and air velocities in the breathing zone]

Median values of 18 subjects	TEA 30°C	air velocities 30°C	TEA 28°C	air velocities 28°C	TEA NEUTRAL	air velocities NEUTRAL
no-TAC	-1.89	0.00	0.97	0.00	2.40	0.00
fixed-TAC	1.07	0.17	1.57	0.17		
user-control	1.01	0.30	2.19	0.27	2.69	0.07

[Table 4.6: Thermal environmental acceptability (TEA) and air velocities in the breathing zone]

4.4 Air movement and eye dry discomfort

We have seen before that in 28°C and 30°C conditions, high air movement in the breathing zone increased the perceived air quality. In the subjective questionnaire, we also asked the subjects if they felt eye dry discomfort. Following the analysis of data divided between subjects who wear eye glasses and subjects not wearing eye glasses during the Human Subject Tests.

Analyzing eye dry comfort level data in 28°C and 30°C, it is possible to notice that TAC devices (both fixed-TAC and User-control) improve the shape of the distribution of thermal comfort among the subjects than in no-TAC strategy.

The use of fixed-TAC has as side effect for subjects not wearing eye glasses during the Human Subject Tests, a positive impact on the level of dry eye comfort as well. Subjects wearing eye glasses show lower level of eye dry comfort.

If we compare the distribution of thermal comfort and dry eye comfort at 28°C for fixed-TAC and User-controlled, we can observe improvement in the minimum value of thermal comfort. That means that those subjects who voted very uncomfortable in fixed-TAC conditions felt an improvement just because of the possibility of a further control chance. However, we have to observe as well that the dry eye comfort level decreases all along the distribution for both the subjects wearing glasses and not wearing glasses.

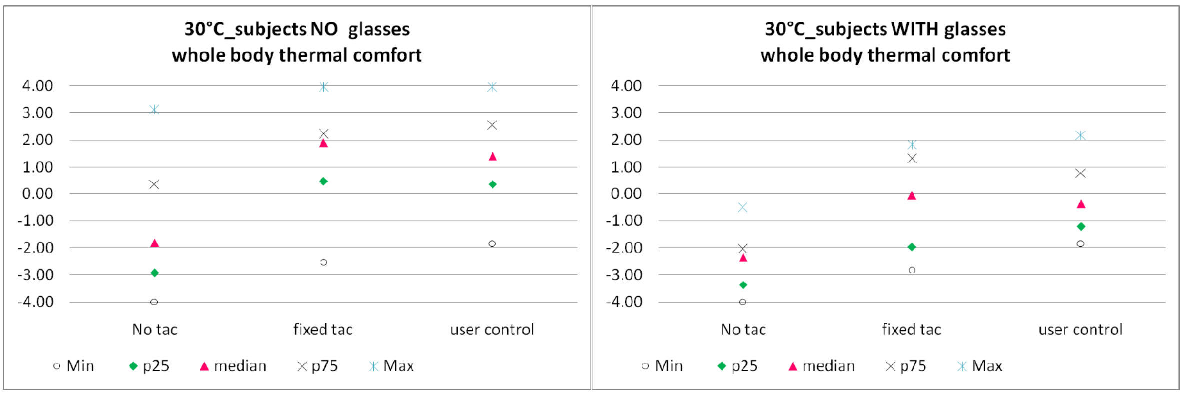
In particular in 30°C condition, dry eye discomfort affects the whole body thermal comfort for the subjects wearing glasses. Probably in extreme warm condition, subjects wearing glasses hardly found the good compromise in air motion to have higher whole body thermal comfort and lower eye dry discomfort.

[Figure 4.20-4.21: Whole body thermal comfort in 28°C for subjects wearing and not wearing glasses]

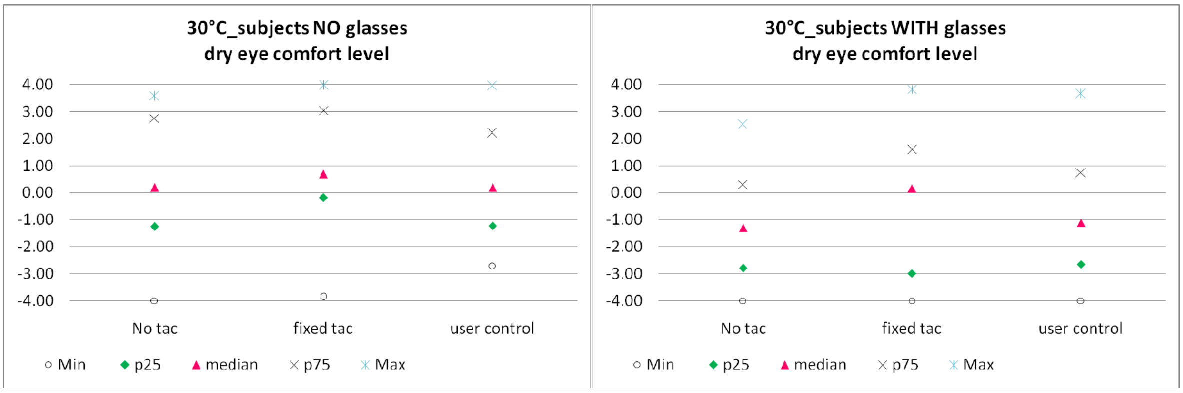
[Figure 4.22-4.23: Dry eye comfort level in 28°C for subjects wearing and not wearing glasses]

	28°C_ALL subjects			**28°C_NO glasses**			**28°C_WITH glasses**		
	whole body thermal comfort			*whole body thermal comfort*			*whole body thermal comfort*		
	No tac	fixed tac	user control	No tac	fixed tac	user control	No tac	fixed tac	user control
Min	-3.36	-0.19	-0.16	-3.36	0.22	-0.16	-3.36	-0.19	0.16
p25	-1.47	0.79	1.37	0.55	1.13	1.83	-1.76	0.64	1.34
median	0.84	1.72	1.98	0.97	1.75	2.06	-0.19	0.97	1.63
p75	1.51	2.05	2.15	1.83	2.09	2.79	0.84	1.72	2.18
Max	3.31	2.79	3.88	3.31	2.79	3.88	1.49	1.92	3.34
	dry eye comfort			*dry eye comfort*			*dry eye comfort*		
	No tac	fixed tac	user control	No tac	fixed tac	user control	No tac	fixed tac	user control
Min	-1.14	-3.22	-3.31	-1.11	-0.51	-2.04	-1.14	-3.13	-3.31
p25	-0.60	-0.33	-0.30	-0.64	-0.17	0.00	-0.98	-1.26	0.07
median	0.07	0.53	0.48	-0.10	1.17	0.45	-0.45	1.17	0.65
p75	2.96	2.37	2.75	3.16	2.56	2.89	1.78	2.32	2.89
Max	3.71	3.71	3.80	3.68	3.71	3.65	3.71	3.60	3.80

[Table 4.7: whole body thermal comfort and dry eye comfort in 28°C for subjects wearing and not wearing glasses]



[Figure 4.24-4.25: Whole body thermal comfort in 30°C for subjects wearing and not wearing glasses]



[Figure 4.26: Dry eye comfort level in 30°C for subjects wearing and not wearing glasses]

	30°C_ALL subjects			30°C_NO glasses			30°C_WITH glasses		
	whole body thermal comfort			*whole body thermal comfort*			*whole body thermal comfort*		
	No tac	fixed tac	user control	No tac	fixed tac	user control	No tac	fixed tac	user control
Min	-4.00	-2.82	-1.83	-4.00	-2.53	-1.83	-4.00	-2.82	-1.83
p25	-2.82	-0.15	-0.20	-2.93	0.48	0.36	-3.36	-1.96	-1.21
median	-2.06	1.75	1.11	-1.81	1.89	1.40	-2.34	-0.06	-0.36
p75	0.11	2.01	2.12	0.33	2.21	2.56	-2.05	1.30	0.77
Max	3.10	3.94	3.94	3.10	3.94	3.94	-0.51	1.81	2.18
	dry eye comfort			*dry eye comfort*			*dry eye comfort*		
	No tac	fixed tac	user control	No tac	fixed tac	user control	No tac	fixed tac	user control
Min	-4.00	-4.00	-4.00	-4.00	-3.86	-2.70	-4.00	-4.00	-4.00
p25	-1.06	-0.32	-1.44	-1.26	-0.19	-1.23	-2.79	-2.98	-2.65
median	0.27	0.65	0.23	0.19	0.68	0.19	-1.29	0.16	-1.11
p75	2.51	2.76	2.14	2.76	3.05	2.21	0.30	1.59	0.75
Max	3.57	3.97	3.94	3.57	3.97	3.94	2.53	3.83	3.65

[Table 4.8: whole body thermal comfort and dry eye comfort in 30°C for subjects wearing and not wearing glasses]

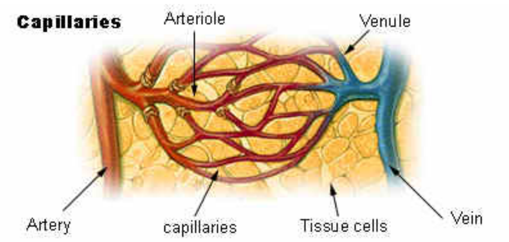
This suggests that blowing air towards the breathing zone from the two sides could cause local discomfort if subjects wear glasses. Probably eye glasses work as deflector, deviating the air flow directly to the eyes. This could increase the air velocity and turbulence close to the eyes, affecting the local comfort. The design of the prototypes shows good effects in increasing global comfort and perceived air quality, avoiding local discomfort to trunk and back, but need to be improved in order to concentrate the air motion to the breathing zone.

4.5 Local skin and core body temperatures

Thermoregulation of the body is part of the homeostatic mechanism designed to keep the organism at optimum operating temperature (core temperature) as it affects the rate of chemical reactions. In human body the optimum value for core temperature is 36.8°C (98.2°F), though it varies regularly in a safe range of temperatures. The variation is due to different causes, first of all the circadian rhythms, but also variations due to women's menstrual cycles, and variation due to the effect of being exposed to different thermal environment.

Thermoregulation is so the ability of the body to keep the core temperature within certain boundaries, even when temperature surrounding is very different. Homeostasis is the dynamic state of stability between the internal environment and the external temperature. In order to avoid hyperthermia if the external temperature rises or hypothermia if the external conditions are extremely cold, the body activates vasodilatation in the first case and vasoconstriction in the second.

Vasodilatation is the mechanism by with arterioles carrying blood to the superficial capillaries under the surface of the skin can swell so that more heat is carried by the blood and is lost to the air. Vasoconstriction is the opposite mechanism. In this case arterioles carrying blood can shrink so that less heat is carried by the blood and lost to the surrounding.



[Figure 4.27: scheme of arterioles in the homeostatic mechanism]

During the human subject tests we measured the local skin temperature of different local body parts and the core temperature. Data measured show that thanks to the thermoregulation of the body, the core temperature in the five environment conditions is always stable, or has very small changing. Also is it possible to notice that in cold condition 18°C, in no-TAC strategy local temperatures decrease because of vasoconstriction. Consequently whole body thermal sensation decreases, comporting a negative value of whole body thermal comfort. When the subject could use the prototypes (fixed-TAC and user-controlled), it is possible to notice that local skin temperatures increase again, comporting a positive whole body thermal comfort value. In warm cases 28°C and 30°C, local body parts increase skin temperatures during no-TAC condition. Then, when the subjects made use of the prototypes (fixed-TAC and user-controlled) local temperatures decrease because of the possibility of losing heat, with consequent improving in thermal comfort and thermal sensation.

Cold condition 18°

18°C	no-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	-0.78	-0.90	-0.71	-1.78	37.44	37.17	31.12	32.25	20.13	21.60	31.15	28.37	32.05	32.25
2	0.06	-1.68	2.67	-0.25	37.09	37.09			17.80	17.89	33.21	32.30	28.52	31.18
3	-1.36	-1.13	1.11	1.55	37.44	37.19	21.86	23.67	29.54	30.67	30.62	28.74	32.56	32.98
4														
5	-0.49	-0.70	-0.16	-1.17	36.85	37.25	27.07	21.63	29.09	28.64	32.61	31.33	34.26	32.05
6	-0.90	-1.57	1.11	-0.19	36.11	36.94	27.97	24.58	33.01	33.01	33.89	32.85	32.82	32.98
7	-0.99	0.09	-0.30	-2.96			26.16	23.89	29.32	30.00	33.47	33.44	35.93	33.91
8	-1.01	-2.87	1.55	1.20			24.58	25.48	30.34	30.34	33.37	33.42	30.82	31.00
9	-0.96	-1.04	2.09	0.48			27.07	21.86	26.61	26.16	33.68	32.95	29.89	29.39
10	-0.81	-0.93	-0.13	-0.25			27.07	24.12	33.01	32.68	34.26	34.02	33.21	33.24
11	-2.03	-2.99	-0.33	-2.64			30.45	29.54	28.64	25.03	35.13	33.97	33.47	32.59
12	0.09	-0.12	2.21	1.55										
13	-1.45	-2.67	0.39	-0.48	37.27	37.47	26.84	24.12	33.01	32.68	34.26	34.02	33.08	33.18
14	-2.20	-2.67	-1.49	-2.09	37.47	37.60								
15	-0.06	0.03	1.29	1.75			26.16	25.48	30.00	29.54	31.82	29.97	31.79	31.59
16	-0.32	-0.06	4.00	3.57	37.81	37.51	30.90	27.74	29.67	31.34	29.74	32.23	32.92	34.23
17	-0.52	-0.72	3.77	3.68	36.64	37.31			29.09	29.54	34.86	33.31	33.60	33.47
18	-0.14	0.09	3.83	2.99	34.98	36.90	30.22	21.86	31.34	31.68	32.74	32.72	32.77	32.74
	no-TAC													
median values	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
	-0.81	-0.93	1.11	-0.19	37.18	37.22	27.07	24.12	29.54	30.00	33.37	32.85	32.82	32.74
↓↑=	↓	**-0.12**	↓	**-1.30**	=	**0.04**	↓	**-2.95**	↑	**0.46**	↓	**-0.52**	=	**-0.08**

[Table 4.9: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in no-TAC strategy for the 18 subjects, in 18°C]

18°C	fixed-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	-0.49	-0.58	0.33	0.16	37.08	37.29	32.25		22.90		33.37		31.94	
2	-0.58	-0.81	-0.33	-0.22	37.10	37.10			19.94	21.18	33.86	34.05	30.62	31.08
3	-0.99	-1.10	1.52	1.49	37.06	36.38	24.12	21.86	30.22	27.97	30.22	30.22	32.69	33.81
4														
5	-0.78	-0.38	-0.16	0.22	37.17	37.08	22.31	24.35	29.09	29.09	31.23	30.65	32.85	32.51
6	-0.75	0.03	0.91	0.33	36.99	36.56	25.26	24.12	33.01	33.01	33.78	36.12	32.48	33.13
7	-0.70	-0.90	0.39	-1.40			21.63	22.08	29.54	29.77	33.29	32.00	32.00	32.43
8	-3.86	-2.84	-2.09	0.65			24.12	22.08	29.67	30.34	33.29	31.92	29.72	30.98
9	0.00	-0.70	2.01	1.57			27.52	26.38	26.84	26.61	33.08	33.73	31.15	30.12
10	-1.88	-1.80	-1.92	-2.01			24.12	22.76	32.68	32.01	34.23	33.00	33.11	32.87
11	0.03	-0.99	4.00	0.45			29.54	30.22	30.22	31.12	32.98	35.16	28.97	33.11
12	-0.06	0.67	2.04	1.46										
13	-0.90	-0.78	1.40	1.14	37.59	37.33	26.84	26.16	33.01	33.01	32.36	33.91	32.90	33.21
14	-1.01	-1.91	1.75	-1.52	37.60	37.48								
15	0.61	0.03	-0.94	1.55			22.08	25.93	27.52	29.77	31.00	32.05	30.60	31.54
16	-1.07	-0.17	3.45	-0.25	37.59	37.51	25.71	27.97	32.01	31.34	32.15	34.18	33.78	34.26
17	-1.01	-0.99	4.00	3.48	37.25	37.33			29.32	30.00	30.85	31.03	33.42	33.68
18	-2.52	-1.19	0.91	1.37	37.04	36.56	25.93	24.80	31.68	31.34	34.60	35.69		32.07
	fixed-TAC													
median values	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
	-0.78	-0.81	0.91	0.45	37.14	37.20	25.26	24.58	29.67	30.17	33.08	33.37	32.24	32.69
↓↑=	=	**-0.03**	↓	**-0.46**	=	**0.06**	↓	**-0.68**	↑	**0.50**	↑	**0.29**	↑	**0.45**

[Table 4.10: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in Fixed-TAC strategy for the 18 subjects, in 18°C]

18°C	user-control													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	-0.90	-0.41	-0.91	0.42	37.14	37.70	32.25	32.70	21.89	22.56	28.44	35.24	32.02	32.64
2	-0.93	-0.23	0.16	0.88	37.12	37.10			18.01	19.82	32.43	34.10	30.55	29.69
3	-1.33	-1.01	1.40	1.26	37.19	37.96	22.76	24.80	30.67	30.22	28.77	30.19	32.95	32.74
4														
5	0.32	0.09	0.33	0.65	37.17	36.90	31.35	28.64	28.19	28.87	31.69	32.85	30.17	32.41
6	0.03	-0.90	3.45	1.40	36.29	36.84	30.45	28.87	32.68	33.01	33.39	34.12	32.64	33.50
7	0.03	-0.58	1.23	1.17			29.77	28.19	27.97	29.77	32.33	33.81	32.48	32.59
8	-0.12	-0.09	2.90	3.48			26.61	25.26	30.01	31.01	32.02	33.60	35.45	31.20
9	0.43	0.03	2.01	2.01			25.03	29.09	26.84	26.84	31.66	33.13	31.51	31.38
10	1.83	-0.96	0.30	-0.33			27.29	26.16	33.01	33.01	32.36	33.91	33.00	33.26
11	-2.99	-0.99	0.51	1.31			29.54	29.77	25.26	28.19	34.20	35.80	32.41	32.59
12	-0.12	0.03	2.21	1.95										
13	-2.03	-0.70	-0.45	0.27	37.46	37.46	24.12	22.99	32.34	32.01	34.02	32.90	33.03	32.79
14	-2.90	-2.29	-2.58	-2.27	37.47	37.69								
15	-0.12	0.32	0.36	0.59			25.26	26.61	29.54	30.00	29.69	29.46	31.31	31.79
16	-0.72	-1.01	3.31	2.15	37.42	37.36	25.93	24.12	31.68	32.01	34.86	36.34	33.91	33.52
17	-1.19	-1.01	3.74	3.97	37.23	37.03			29.32	29.09	33.03	31.18	33.57	33.39
18	-2.38	-1.42	0.25	-0.97	37.10	37.07	22.54	26.84	32.34	31.68	32.77	34.26	32.79	33.11
	user-control													
median values	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
	-0.72	-0.70	0.51	1.17	37.18	37.23	26.61	26.84	29.54	30.00	32.36	33.81	32.64	32.64
↓↑=	=	**0.03**	↑	**0.66**	=	**0.05**	↑	**0.23**	↑	**0.46**	↑	**1.45**	=	**0.00**

[Table 4.11: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in User-control strategy for the 18 subjects, in 18°C]

Cold condition 20°

20°C	no-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	-0.64	-2.29	-0.59	-2.09	36.49	37.86	24.58	22.54	31.12	31.80	32.61	30.19	32.98	33.65
2	-1.97	-0.99	0.25	0.16	37.01	37.24	24.35	22.76	32.68	32.68	33.84	32.61	32.69	32.69
3	-0.64	-0.96	2.64	1.66			27.52	27.29	31.35	31.35	32.85	32.15	31.69	31.59
4	0.32	-0.61	3.08	3.54			28.64	23.89	32.68	32.01	34.94	33.57		
5	0.26	0.14	2.06	2.38	34.28	36.74	31.57	31.12	29.54	30.22	34.47	33.39	32.23	32.41
6														
7	0.43	-0.55	1.31	1.17	36.77	36.89	28.42	26.16	30.00	30.00	33.13	32.79		
8	-0.78	-1.39	2.44	2.47	36.66	37.29	28.19	24.35	31.68	32.34	33.05	32.18	32.15	33.13
9	1.77	1.01	1.26	1.46	37.51	37.69	30.90	28.87	29.32	29.32	33.31	32.95	32.79	32.87
10	0.06	0.03	0.22	0.25			22.76	29.09	33.34	33.68	32.02	32.18		
11	-2.06	-0.93	-2.01	0.19			26.61	29.54	30.90	31.12	33.97	35.13	34.28	34.70
12	1.39	1.39	1.34	1.40			28.87	28.87	33.68	34.68	34.02	34.47	33.76	33.44
13	-0.38	-1.22	2.21	1.23			27.74	29.54	21.49	23.47	33.99	34.26	32.05	31.66
14	-1.71	-1.01	-0.16	0.74					31.01	31.01	28.87	29.89	32.85	33.00
15	0.06	0.06	1.43	2.01			26.61	28.42	30.45	30.45	30.72	30.70	32.77	32.25
16	-0.03	-0.03	4.00	3.97			25.48	30.00	29.01	32.01	29.39	30.62		
17	-0.87	-0.96	3.71	3.86			32.25	33.15	29.54	32.25	33.86	34.41	32.18	33.05
18	-0.96	0.12	1.00	3.74					31.34	31.34	31.82	33.03		
	no-TAC													
median values	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
	-0.38	-0.61	1.34	1.46	36.72	37.27	27.74	28.87	31.01	31.35	33.13	32.79	32.73	32.94
↓↑=	↓	**-0.23**	↑	**0.12**	↑	**0.55**	↑	**1.13**	↑	**0.34**	↓	**-0.34**	↑	**0.21**

[Table 4.12: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in no-TAC strategy for the 18 subjects, in 20°C]

20°C	fixed-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	-0.58	-0.43	0.74	-0.65	36.45	37.40	27.29	25.03	31.35	31.80	33.00	32.48	33.05	33.26
2	-0.72	-0.58	1.63	2.06	37.03	37.10	26.84	25.71	32.34	31.68	34.49	34.20	34.36	34.36
3	-0.38	-0.58	2.84	2.15			29.77	29.77	31.57	31.35	32.43	33.13	31.66	31.43
4	0.41	0.32	3.45	3.42			28.19	30.90	32.34	32.68	34.10	35.02		
5	0.70	0.55	3.65	3.65	36.94	36.95	27.29	25.48	30.22	30.45	33.84	33.37	32.82	32.95
6														
7	0.35	1.04	2.09	-0.48	36.86	36.86	30.90	30.00	29.09	30.00	32.87	33.29		
8	-0.23	1.01	2.87	0.68	37.11	37.18	25.03	29.09	31.34	32.34	32.87	33.73	32.74	33.11
9	0.96	1.48	1.20	1.23	37.57	37.35	31.12	32.47	28.64	29.32	32.00	33.39	32.98	33.00
10	-0.90	0.12	0.22	0.27			29.09	26.38	33.01	33.01	34.86	34.86		
11	-1.10	-2.00	1.29	-1.34			26.16	26.84	30.90	30.67	34.44	33.81	33.94	34.28
12	1.16	-0.09	1.37	1.23			31.35	29.54	34.34	34.34	35.53	34.31	34.18	33.91
13	0.49	0.43	1.69	1.52			29.77	29.32	25.26	25.26	35.37	33.91	31.69	31.26
14	-0.99	-2.72	-0.16	-2.12					31.01	31.01	30.02	29.02	32.67	32.82
15	0.67	-0.09	-0.56	1.20			23.67	27.52	27.97	30.22	31.66	30.93	31.15	32.87
16	-0.12	-0.58	3.25	3.65			28.87	26.16	32.34	31.34	31.97	31.92		
17	-0.46	-0.14	3.45	4.00			30.00	31.35	31.80	32.02	34.05	34.07	33.18	33.05
18	0.23	-1.25	3.94	2.24					31.01	31.01	31.84	32.30		
	fixed-TAC													
median values	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
	-0.12	-0.09	1.69	1.23	36.99	37.14	28.87	29.09	31.34	31.34	33.00	33.39	32.90	33.03
↓↑=	**=**	**0.03**	↓	**-0.46**	↑	**0.16**	↑	**0.22**	**=**	**0.00**	↑	**0.39**	↑	**0.13**

[Table 4.13: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in Fixed-TAC strategy for the 18 subjects, in 20°C]

20°C	user-control													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	-0.41	-0.17	1.57	0.51	37.43	37.33	29.54	27.97	30.67	31.80	32.90	33.11	33.31	33.11
2	0.00	-0.29	2.56	1.34	36.59	36.99	31.57	30.00	31.01	32.68	33.08	34.39	32.87	34.20
3	-1.07	-0.35	1.75	2.99			23.67	31.12	29.32	31.12	29.84	32.54	30.77	31.79
4	-0.06	-0.03	3.22	3.60			30.00	30.90	32.34	32.34	33.00	34.10		
5	0.29	0.64	2.87	3.05	41.78	36.93	30.90	28.87	30.22	30.22	33.24	33.42	32.56	32.61
6														
7	-0.38	-1.42	1.14	-1.14	35.40	36.88	24.80	23.44	30.00	30.00	32.25	31.77		
8	-1.88	-0.03	2.06	3.83	36.42	37.40	24.12	24.58	30.68	31.68	32.05	31.54	31.28	32.72
9	0.93	0.90	1.26	1.43	37.72	37.76	26.38	30.00	29.32	28.64	33.91	33.91	32.85	32.74
10	1.04	-0.93	0.30	0.27			30.45	28.64	33.68	32.68	32.00	34.44		
11	-1.19	-1.57	3.34	2.01			23.89	29.54	29.54	31.12	32.23	34.44	32.67	34.26
12	0.09	0.09	2.12	2.04			28.64	32.47	30.68	34.34	31.97	35.37	30.87	34.44
13	-0.90	0.43	0.62	2.01			29.77	29.77	23.44	25.26	34.20	35.21	30.98	31.61
14	0.23	-0.78	3.02	1.26					31.34	31.34	30.93	30.14	33.03	32.87
15	0.17	0.67	0.10	0.53			25.93	25.03	30.45	30.45	30.75	31.08	32.77	32.72
16	-0.12	-0.06	2.12	2.61			29.77	30.22	32.34	32.01	30.37	32.15		
17	-0.64	-0.99	3.36	3.77			30.22	31.57	31.35	31.35	35.02	34.23	32.90	33.31
18	0.06	1.57	3.60	3.80					30.68	32.01	33.31	33.86		
	user-control													
median values	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
	-0.06	-0.06	2.12	2.01	37.01	37.16	29.54	29.77	30.68	31.35	32.25	33.86	32.72	32.81
↓↑=	=	**0.00**	↓	**-0.12**	↑	**0.15**	↑	**0.23**	↑	**0.67**	↑	**1.61**	=	**0.09**

[Table 4.14: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in User-control strategy for the 18 subjects, in 20°C]

Neutral condition

neutral	no-TAC														
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	1.42	1.57	2.06	2.09	36.32	37.40	32.02	32.92	32.92	33.15	31.89	31.46	35.26	34.20
2	0.14	-0.06	1.92	2.06	37.07	37.12	30.45	31.57	34.01	34.68	33.39	33.70	33.89	34.12
3	0.12	-0.29	3.80	3.83			30.90	32.25	31.57	32.25	33.63	32.98	35.66	35.13
4	-0.03	0.43	3.13	2.27	36.57	36.66	32.02	32.92	28.92	34.34	34.26	33.86	35.74	35.82
5	0.38	0.12	3.86	3.88			33.37	33.60	32.47	32.47	33.73	34.49	34.76	36.25
6	-0.06	-0.09	2.27	1.89	36.87	36.93			34.68	35.01	33.86	33.05	33.63	34.65
7	0.03	1.33	2.09	-0.45	36.80	36.97	31.57	33.15	32.25	33.37	33.00	32.79	34.12	34.41
8	0.12	-0.03	2.90	3.42			28.87	33.37	34.34	34.68	33.68	33.21	33.63	33.63
9	-0.03	0.87	1.66	1.55			32.02	30.45	30.22	30.67	33.63	33.94	36.85	36.34
10	0.03	0.03	2.01	2.06					35.01	35.01	35.48	35.37	32.77	32.98
11	-0.72	-1.42	2.06	2.24	36.42	37.14	32.02	32.70	31.57	34.05	30.93	32.72	32.64	34.15
12	-0.06	1.19	1.86	0.56	36.67	36.94	31.35	33.82	32.34	34.68	30.04	32.61	34.70	35.18
13	1.16	0.87	0.88	2.90	36.92	37.01	30.90	28.42	29.54	32.02	32.15	34.60	32.77	33.94
14	0.64	0.61	0.94	0.79	36.87	37.09	32.25	31.12	32.68	33.68	31.64	33.47	33.81	34.07
15	-0.26	-0.29	0.82	1.57	36.89	36.80	30.67	31.35	32.92	32.92	29.72	29.56	33.89	33.86
16	0.00	-0.12	4.00	4.00	35.27	37.16	32.47	32.02	34.68	34.01	32.85	33.29	34.52	34.33
17	0.00	-0.03	0.82	2.12	37.14	37.00	27.97	27.07	31.35	33.37	33.18	32.07	33.55	34.28
18	0.41	0.17	3.19	3.86	35.83	37.12	32.92	33.15	30.68	34.34	33.18	34.57	33.31	34.57
	no-TAC														
	whole body thermal sensation		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median valeus	0.03	0.07	2.06	2.11	36.80	37.01	31.80	32.48	32.41	33.85	33.18	33.25	33.89	34.31
↓↑=	=	**0.04**	=	**0.04**	↑	**0.21**	↑	**0.68**	↑	**1.44**	=	**0.07**	↑	**0.42**

[Table 4.15: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in no-TAC strategy for the 18 subjects, in neutral condition]

neutral	user-control													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	-0.99	-0.43	1.98	1.98	37.56	37.40	31.35	33.60	32.70	33.37	31.59	31.10	34.23	35.74
2	-0.99	-0.43	2.06	2.04	37.10	37.26	31.57	27.52	34.68	32.34	33.70	32.82	34.28	33.39
3	0.09	-0.17	3.83	3.83			33.15	31.57	32.25	30.45	34.44	33.73	36.04	35.80
4	-0.32	-0.49	2.73	3.51	36.76	36.78	31.57	31.35	30.34	31.68	33.97	33.24	35.77	35.98
5	0.09	-0.17	3.83	3.83			33.15	31.57	32.25	30.45	34.44	33.73	36.04	35.80
6	-0.12	-0.09	2.09	2.50	37.01	37.05			34.68	35.01	32.87	32.61	34.62	34.57
7	0.67	0.61	1.46	1.55	36.99	36.96	29.32	32.47	32.47	31.57	32.90	33.21	33.76	33.31
8	0.03	-0.06	2.90	4.00			30.00	28.42	33.34	34.68	34.44	33.86	33.13	33.47
9	0.00	-0.03	2.01	2.06			29.77	27.07	30.45	28.42	33.94	33.39	33.37	32.56
10	0.09	0.12	2.01	1.95					34.68	34.68	35.34	34.92	32.74	32.87
11	0.03	-0.99	3.25	2.04	37.17	37.08	31.12	32.47	33.82	32.02	32.79	35.18	36.01	33.37
12	-0.09	0.06	2.30	2.18	36.88	36.95	32.70	32.70	34.34	33.34	32.59	34.39	34.84	34.62
13	-0.38	-0.67	2.01	2.01	37.00	37.05	28.87	27.29	31.80	32.47	34.47	33.89	33.31	33.81
14	0.12	-0.12	2.04	2.87	37.25	37.55	29.77	27.52	33.34	32.68	33.37	32.28	33.24	32.85
15	-0.06	-0.67	1.00	1.08	35.80	36.87	31.57	30.00	32.92	32.92	29.84	29.74	33.81	33.97
16	-0.12	-0.12	3.97	3.86	37.12	37.10	32.70	33.60	33.68	34.68	33.11	33.13	34.28	34.70
17	-0.06	0.67	0.19	1.40	37.19	37.12	31.12	29.32	31.80	30.90	34.02	33.29	32.20	36.07
18	0.09	-0.09	3.39	2.61	37.10	37.08	32.92	31.35	33.68	33.68	34.57	33.81	34.07	34.41
	user-control													
	whole body thermal sensation		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median valeus	-0.03	-0.12	2.08	2.12	37.10	37.08	31.46	31.35	33.13	32.58	33.82	33.34	34.15	34.19
↓↑=	**=**	**-0.09**	**=**	**0.04**	**=**	**-0.02**	**↓**	**-0.11**	**↓**	**-0.56**	**↓**	**-0.48**	**=**	**0.04**

[Table 4.16: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in User-control strategy for the 18 subjects, in neutral condition]

Warm condition: 28°C

	no-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	1.88	0.96	1.29	1.57	37.66	37.10	33.82	33.37	33.15	34.05	33.94	33.94	34.73	36.20
2	-0.58	-0.03	2.21	2.09	37.38	37.21			34.34	35.68	34.41	35.37	33.29	35.02
3	0.93	0.93	1.98	1.49	38.65	37.01	30.90	34.72	32.70	34.05	30.57	33.89	33.73	34.57
4	0.96	0.70	2.04	0.97	37.58	36.89			35.34	35.34	32.98	35.32	35.24	35.24
5														
6	0.43	0.96	1.49	0.71	34.97	36.15	32.25	33.37	34.01	35.68	33.47	34.62	34.36	34.68
7	0.96	2.23	0.77	-2.67	36.94	37.16	30.67	34.49	33.15	34.94	33.65	34.55		
8	1.51	2.00	0.97	0.97	33.89	32.75	33.15	34.94	34.34	35.34	34.78	35.37	33.78	35.00
9	2.35	2.75	-0.77	-1.46	36.11	37.23	33.15	33.82	32.02	34.05	33.63	33.81		
10														
11	0.96	2.20	-0.53	-2.04	37.02	37.19	32.70	35.17	33.60	34.72	33.94	35.34	33.16	34.26
12	1.57	1.83	0.39	-1.49	36.93	36.90	32.92	34.05	32.68	33.68	34.10	34.84		
13	1.25	1.22	2.56	3.08	36.92	37.12	31.80	33.37	33.37	34.27	33.76	34.47	34.68	34.84
14	1.28	0.67	0.30	0.39	37.60	37.66	34.05	34.27	34.01	35.68	34.07	34.84	34.36	35.80
15	0.35	0.61	-0.19	-0.19	36.72	36.95	33.15	34.49	33.60	34.27	31.51	31.84	34.33	34.76
16	2.26	1.80	1.63	1.23	37.18	37.32	30.45	31.80	34.01	34.68	33.39	33.50	33.86	34.05
17	2.00	2.43	-0.42	-3.36	36.81	36.89	34.05	34.27	31.80	34.05	35.21	35.42	34.12	34.57
18	0.00	0.23	3.51	3.31	36.83	36.99			30.34	30.01	34.62	34.31	35.26	35.82
	no-TAC													
	whole body thermal sensation		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median values	1.10	1.09	1.13	0.84	36.94	37.06	32.92	34.27	33.49	34.48	33.85	34.58	34.33	34.84
↓↑=	**=**	**-0.01**	↓	**-0.29**	↑	**0.12**	↑	**1.35**	↑	**0.99**	↑	**0.74**	↑	**0.50**

[Table 4.17: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in no-TAC strategy for the 18 subjects, in 28°C]

	fixed-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	0.61	0.41	1.92	2.09	37.39	37.31	32.02	29.54	32.47	32.25	32.77	32.48	32.59	32.95
2	-0.99	-0.43	2.06	2.04	37.37	37.50			34.01	34.34	34.62	34.20	32.59	33.94
3	0.87	0.87	1.63	1.72	36.53	36.95	33.15	33.60	32.25	32.02	34.57	34.49	40.20	37.87
4	0.00	-0.38	2.73	2.53	36.64	36.95			34.68	34.68	35.02	34.84	35.10	35.26
5														
6	-0.43	-0.06	2.06	0.97	36.71	36.63	32.47	30.90	33.34	32.01	32.18	33.76	32.41	32.23
7	0.46	1.04	2.04	1.29	37.09	36.97	33.37	33.60	33.15	33.60	33.47	34.07		
8	0.96	0.99	1.11	1.72	35.59	36.89	33.15	34.49	34.68	35.34	34.15	35.02	34.02	34.76
9	0.99	1.94	0.22	0.30	37.30	37.21	30.00	31.35	31.12	31.35	34.02	33.63	35.88	33.63
10														
11	0.64	0.09	1.37	0.33	36.88	37.16	33.60	32.47	33.37	32.92	34.89	35.02		
12	-0.03	0.06	2.04	1.92	37.03	37.19	33.60	34.49	31.68	32.68	34.76	35.13		
13	-1.04	-0.81	1.11	2.09	35.90	37.28	34.05	29.32	34.27	32.25	34.60	34.18	34.31	32.74
14	1.01	0.87	-0.42	0.22	36.54	37.80	31.57	34.05	34.34	34.34	32.82	33.86	35.64	36.09
15	0.70	1.04	-0.48	-0.19	36.24	36.81	26.84	33.60	32.02	32.25	31.48	31.48	31.13	33.29
16	0.09	-0.32	2.06	2.79	37.15	37.33	32.02	30.00	34.01	33.68	33.52	33.47	33.47	33.84
17	0.90	0.46	-0.36	0.94	36.99	36.92	34.05	33.82	30.22	30.67	35.24	35.24	31.71	32.25
18	-0.17	-0.81	2.41	1.75	37.34	36.91			24.98	33.68	24.53	33.57	24.51	33.37
	fixed-TAC													
	whole body thermal sensation		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median values	0.54	0.25	1.78	1.72	36.94	37.07	33.15	33.60	33.25	32.80	34.08	34.12	33.47	33.63
↓↑=	↓	**-0.29**	=	**-0.06**	↑	**0.13**	↑	**0.45**	↓	**-0.45**	=	**0.04**	↑	**0.16**

[Table 4.18: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in Fixed-TAC strategy for the 18 subjects, in 28°C]

	user-control													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	0.96	0.61	1.69	1.98	36.97	37.45	33.15	32.92	33.82	33.15	33.84	32.54	36.31	33.05
2	0.14	-0.06	1.92	2.06	36.72	37.40			35.68	34.01	35.32	34.68	34.15	33.47
3	0.96	0.93	1.52	1.63	36.95	36.97	33.37	33.60	33.37	32.47	33.91	34.31	37.81	37.84
4	0.43	0.38	2.27	2.06	36.77	36.92			35.68	34.34	35.13	35.26	35.34	35.02
5														
6	0.03	-0.06	2.04	2.24	34.69	36.99	31.57	32.25	34.68	35.01	34.57	34.12	33.97	38.45
7	1.16	0.06	-1.11	1.69	36.60	37.11	32.70	32.92	33.15	33.15	33.21	33.60		
8	-0.12	0.84	2.84	3.34	36.95	36.31	27.97	31.80	34.01	34.01	31.89	34.02	33.50	33.26
9	1.39	1.94	1.17	1.14	37.84	37.31	33.15	32.25	31.35	31.12	32.67	34.07	34.94	35.80
10														
11	0.26	0.41	2.09	1.40	35.30	37.24	34.27	33.15	33.37	32.47	35.18	34.89	32.36	33.89
12	0.03	-0.06	1.63	2.12	36.52	37.07	33.60	33.60	31.68	33.01	34.76	35.00		
13	-0.12	0.43	3.16	1.98	36.74	37.21	34.05	32.25	34.05	34.49	34.39	34.73	34.60	34.70
14	1.10	0.43	0.51	-0.16	37.81	37.72	33.15	33.15	35.34	33.68	33.73	33.55	35.29	36.09
15	-0.49	0.00	-0.13	0.16	36.96	37.15	34.27	31.80	34.27	32.25	32.07	32.61	34.57	33.21
16	0.35	-0.17	3.28	3.88	36.98	37.30	31.80	27.52	34.34	32.68	33.68	32.79	34.02	33.70
17	1.94	0.06	-0.45	1.29	36.66	37.06	33.37	30.90	32.25	30.67	35.32	34.33	33.18	32.69
18	-0.55	0.03	3.34	3.34	36.80	36.92			32.34	34.34	34.23	33.86	35.77	36.12
	user-control													
	whole body thermal sensation		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median values	0.30	0.22	1.81	1.98	36.79	37.13	33.15	32.25	33.92	33.15	34.07	34.10	34.59	34.30
↓↑=	**=**	**-0.09**	↑	**0.17**	↑	**0.34**	↓	**-0.90**	↓	**-0.77**	**=**	**0.03**	↓	**-0.29**

[Table 4.19: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in User-control strategy for the 18 subjects, in 28°C]

Warm condition: 30°

30°C	no-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	1.88	2.81	-1.43	-2.41			33.82	34.94	34.72	35.62	33.57	35.02	35.29	35.61
2	0.09	0.55	-0.56	0.33	37.17	37.23	34.49	34.72	35.34	36.34	34.60	35.96	35.45	35.90
3	1.80	2.12	-1.63	-2.04			35.62	35.39	34.05	34.05	35.72	35.61	33.81	33.34
4	1.39	1.33	-0.36	-2.12	37.05	37.12	34.05	34.49	33.34	36.01	35.10	35.37	35.29	35.66
5	1.86	1.36	-0.13	0.74	36.67	34.63								
6	2.81	2.96	-3.48	-3.62	37.69	36.55	33.37	34.94	31.35	34.49	33.18	35.05	35.96	39.72
7	1.94	2.84	-1.60	-2.90	36.99	36.94	34.72	34.94	34.49	35.39	34.02	35.08	35.21	35.45
8	3.39	4.00	-2.12	-4.00	37.11	36.71	34.72	35.17	35.34	36.01	35.21	35.88	35.29	35.32
9	2.38	2.38	-1.57	-2.50	38.30	37.57								
10	0.93	0.99	-0.30	0.25	37.73	37.35	33.82	35.39	35.68	36.34	33.50	34.55	34.81	35.32
11	2.46	2.58	-0.62	-2.09	37.23	37.51	33.82	34.49	34.72	35.39	35.50	35.32	36.25	35.90
12	1.39	1.48	0.27	-0.51	36.90	37.12	34.05	34.49	35.01	35.68	35.32	35.34	35.26	35.34
13	2.35	2.52	-0.30	-0.30	37.50	37.42	34.27	35.17	35.34	35.68	35.37	35.74		
14	1.94	1.25	-1.95	-1.81	37.72	37.93	30.67	34.72	35.01	35.68	34.97	35.58	35.21	35.90
15	1.48	2.81	-0.16	-2.58	35.77	36.88	32.70	35.17	32.02	34.94	33.26	35.29	33.70	37.84
16	-0.49	-0.49	3.57	3.10	36.97	37.25	30.67	31.80	30.01	35.68	32.56	34.44	34.84	34.18
17	1.86	2.41	-2.15	-3.68	37.43	37.33	34.72	34.94	33.37	31.57	35.00	34.97	33.68	32.77
18	0.46	1.16	2.15	1.52	36.93	36.90	32.07	34.72	32.92	34.94	34.81	35.37	35.53	36.88
	no-TAC													
	whole body thermal sensation		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheek T°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median value	1.86	2.25	-0.59	-2.06	37.14	37.18	33.94	34.94	34.61	35.65	34.89	35.33	35.26	35.61
↓↑=	↑	0.39	↓	-1.47	=	0.03	↑	1.01	↑	1.04	↑	0.44	↑	0.35

[Table 4.20: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in no-TAC strategy for the 18 subjects, in 30°C]

30°C	fixed-TAC													
subject *ID* #	**whole body thermal sensation**		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	1.48	0.06	-0.36	2.21			34.27	31.35	34.27	33.60	33.63	33.55	35.08	33.78
2	-1.01	-0.72	2.06	1.92	37.37	37.17	34.27	33.37	34.01	33.34	32.48	33.55	33.99	34.36
3	2.23	2.55	-2.04	-2.82			35.39	35.62	35.17	35.17	35.69	35.50	34.68	34.60
4	1.94	0.29	0.48	1.89	37.40	37.08	33.82	32.25	33.68	32.68	33.63	35.00	34.68	34.60
5	0.38	0.55	3.86	3.71	36.95	37.06								
6	0.96	0.03	0.22	1.81	36.81	36.93	34.72	34.72	33.37	33.60	34.89	34.26	37.29	37.40
7	0.96	1.10	1.11	0.39	34.11	37.15	33.60	34.05	33.37	33.15	34.62	34.97	34.60	34.41
8	0.93	2.78	-2.21	-2.53	37.08	34.25	34.49	35.17	34.01	34.68	34.84	35.21	34.20	34.76
9	1.94	2.12	-0.91	-2.09	37.43	37.39								
10	0.12	0.06	0.25	2.04	37.45	37.50	34.94	33.82	35.34	34.68	35.08	34.97	34.33	34.78
11	1.91	2.06	2.04	0.13	35.35	37.33	34.27	34.27	32.70	33.60	32.28	35.53	35.00	36.17
12	0.00	0.38	1.86	1.69	36.83	36.88	33.37	33.60	31.01	33.68	33.76	36.42	33.91	34.60
13	0.90	0.70	1.05	1.89	37.63	37.66	34.27	31.80	34.68	32.68	35.48	35.45		
14	1.83	0.75	-0.85	0.48	37.92	37.66	34.05	32.70	34.68	34.01	33.50	34.92	34.28	34.47
15	0.96	0.17	-1.95	-0.25	36.88	36.91	34.05	33.82	33.37	33.60	35.18	35.37		
16	0.84	-0.55	3.57	3.94	37.11	37.12	33.60	34.05	34.01	33.68	30.34	30.29	30.27	30.29
17	2.26	1.83	-2.04	-1.14	37.95	37.36	32.47	32.92	33.15	34.94	35.48	35.02	34.52	35.24
18	0.35	-0.23	1.75	2.76	37.12	36.99	34.05	33.15	31.12	31.35	33.21	34.39	35.48	32.87
	fixed-TAC													
	whole body thermal sensation		**whole body thermal comfort**		**core T°C**		**finger T°C**		**cheekT°C**		**feet T°C**		**front T°C**	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median value	0.96	0.46	0.36	1.75	37.12	37.14	34.16	33.71	33.85	33.60	34.19	34.98	34.56	34.60
↓↑=	↓	-0.49	↑	1.39	=	0.02	↓	-0.45	↓	-0.24	↑	0.79	=	0.04

[Table 4.21: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in Fixed-TAC strategy for the 18 subjects, in 30°C]

30°C	user-control													
subject *ID* #	whole body thermal sensation		whole body thermal comfort		core T°C		finger T°C		cheek T°C		feet T°C		front T°C	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
1	1.74	1.36	0.56	-0.65			32.92	34.27	35.17	34.72	35.18	34.23	34.89	33.99
2	-1.80	-0.70	3.19	2.61	37.31	37.40	34.49	34.27	36.01	35.01	35.18	35.37	35.53	34.70
3	1.19	1.86	0.27	-0.91			33.82	35.39	33.37	34.27	34.36	35.72	38.76	34.12
4	-0.20	0.46	1.05	1.92	37.17	37.24	33.82	33.15	34.68	32.68	35.45	35.16	33.81	33.73
5	1.25	0.00	1.40	3.94	35.02	36.77								
6	0.99	0.67	-1.23	-1.83	35.84	36.85	34.72	33.60	34.72	32.47	35.10	34.52	37.84	36.34
7	1.39	0.75	0.42	1.26	36.87	36.23	33.60	34.27	34.05	33.37	34.86	34.97	34.65	34.23
8	1.57	1.25	-1.43	0.97	35.16	36.91	31.12	34.72	33.01	33.34	35.08	34.84	32.51	33.81
9	1.86	1.94	-1.23	-0.33	37.56	37.45								
10	0.12	1.04	0.19	0.25	37.38	37.52	35.17	35.62	36.01	36.67	34.44	35.24		
11	0.99	1.65	-0.27	0.19	37.37	37.21	33.60	33.60	34.72	33.82	35.32	35.05	35.56	52.31
12	0.23	-0.20	2.09	2.18	36.32	37.32	34.05	34.05	35.01	34.34	35.40	35.29	35.13	34.89
13	0.55	0.84	0.39	1.40	37.48	37.63	32.47	33.37	33.68	33.68	35.66	35.56		
14	1.62	0.64	-1.34	1.46	37.93	37.96	34.72	29.32	35.68	34.01	35.48	35.16	35.90	34.18
15	0.72	1.01	-2.50	-1.31	36.89	36.91	34.05	34.05	33.37	33.37	35.10	35.29	33.37	37.73
16	-0.78	-0.61	3.83	3.62	37.09	37.00	34.49	34.94	34.34	36.01	30.34	32.02	30.34	33.99
17	1.65	0.67	-0.91	0.36	36.94	37.57	33.15	34.72	30.90	29.77	34.97	29.39	31.94	29.61
18	0.12	0.43	3.28	2.56	36.84	36.98	34.72	34.27	34.49	34.27	34.92	34.86	36.80	36.91
	user-control													
	whole body thermal sensation		whole body thermal comfort		core T°C		finger T°C		cheek T°C		feet T°C		front T°C	
	start	end	start	end	start	end	start	end	start	end	start	end	start	end
median value	0.99	0.71	0.33	1.11	37.02	37.23	33.94	34.27	34.59	33.92	35.10	35.10	35.01	34.20
↓↑=	↓	-0.28	↑	0.78	↑	0.21	↑	0.34	↓	-0.67	=	0.00	↓	-0.81

[Table 4.22: Whole body thermal comfort, whole body thermal sensation and body temperatures for all subjects in User-controlled strategy for the 18 subjects, in 30°C]

5. PRODUCTIVITY: RESULTS

A discomfortable environment leads to a high rate of absenteeism in office buildings causing economic losses. The improving of the comfort level in the office environment shows a decrease in the rate of absenteeism, thus an improvement in profits. Does a comfortable environment increase also the personal productivity of the occupant?

Previous human subject tests run at UC Berkeley in 2003 (Zhang, 2003) showed that in warm conditions head and hands dictate overall discomfort and in cool conditions feet and hands are the local body parts that dictate the overall discomfort.

In the previous chapter we showed the results from the subjective surveys, concluding that TAC devices improve local and overall comfort for a large range of temperatures. In the present chapter we will present the results of the productivity tests, trying to understand if thermal delight could lead to a direct improvement in subjects' productivity.

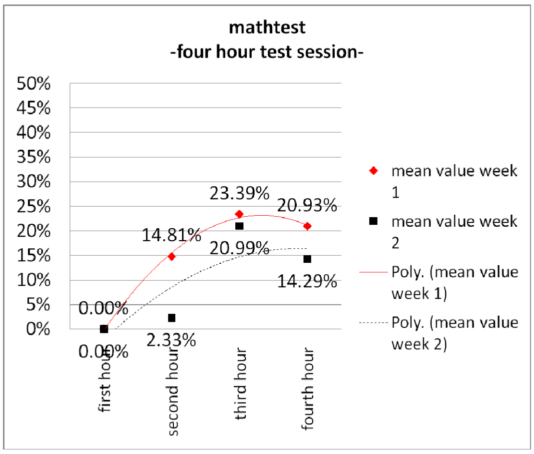
5.1 Measurements of productivity and performance

In order to evaluate the productivity and the mental performance of the subject during the human subject tests, we decided to use three speed based tests. Performance was measured in terms of speed (how many right answers the subject gave per unit of time). The choice for the speed based test was bound by the time availability.

People are highly motivated during a short-term experiment, so it may be very difficult to measure the difference in actual performance. For this reason the subjects were unaware about being tested about productivity. During the training session we explained to them that they were performing tasks in order to simulate real office work and evaluate they acceptability of the environment. We choose to let them know about being tested for energy saving and comfort purposes, but not about the productivity.

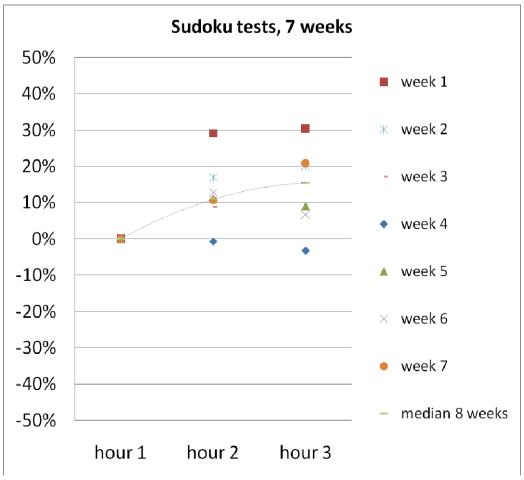
The first session of Human Subject Test scheduled four-hour tests. After two weeks we noticed in the results that the subjects' performance had an improvement during the first, second and third hour of test. During the fourth hour we noticed a loss in productivity for almost all the subjects. For this reason we decided to have shorter sessions of tests, running three-hour sessions. [Figure 5.1]

We also decided to shift the three local conditions (no-TAC, fixed-TAC and TAC-control) randomly in order to avoid that the subject performance was affected by fatigue or by the performance improvement due to the work sequence. The thermal local conditions (no-TAC, fixed-TAC and user-control) were again switched between the three hours the following week in order to cover all the combinations.



[Figure 5.1: Math tests. Median value of four-hour tests]

Figure 5.2 highlights the positive effect of work sequence in the three hour sessions for 7 weeks (2 four-hour sessions, 5 three-hour sessions) on subjects' productivity.



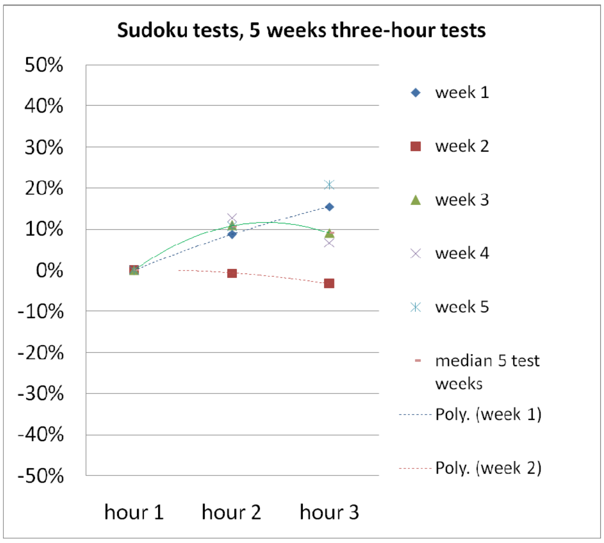
[Figure 5.2: Sudoku tests. 7 week test results]

The comparisons between conditions were always within-subject comparisons, to eliminate any bias due to individual differences in the ability to perform office work, and considering the median value of the 18 subjects.

5.2 The effect of the learning curve and tiredness

The following figure compares the median value of subjects' results week by week. Results from Sudoku tests, week by week, were compared in order to evaluate the possible effect of a learning curve and tiredness in performing tasks.

We can observe that during the second week of three-hour tests the subjects showed a decreasing performance, while in the third week of three-hour tests the performance increased again. We have to consider that the second week of three-hour tests was in fact the fourth week of tests (two weeks of four-hour tests plus two weeks of three hour tests). After the second week of three hour tests there was Spring Break, so we had to stop the tests and the subjects had time to recover. Even if the subjects had to participate to the tests for just one day (morning or afternoon) per week, the possibility of repeating the same task for four weeks with no stops could have caused tedium and a consequent loss in interest in performing the tasks. Moreover, right before Spring Break it was end of semester time and this could have caused tiredness in students.



[Figure 5.3: Sudoku tests. 5 week test results]

From a theoretical point of view it would have been better to run the tests with a higher number of subjects, each of them performing a limited number of tests, so as to decrease the potential bias due to tiredness and the improving ability in performing the tests. However, in this way we would have lost the possibility to track the impact of fixed-TAC and user-control versus the benchmark situation of no control (as we said, the comparisons between conditions were always within-subject comparisons). We had to find a compromise between these two needs.

Ideally, we could have run the tests using a higher number of human subjects performing the same sequence of tasks. That would have increased the statistical significance of our results, reducing the potential bias of tiredness and learning curve without limiting the possibility to track the impact of fixed and customized control devices. Unfortunately that was not possible for budget reasons. Therefore, in future, it will be very important to set up the time schedule of tasks in order to lower the bias of both the effects.

5.3 Mental performance: Math tests

To evaluate the mental performance we asked the subject to solve some easy math problems like fraction multiplications for 8 minutes/each hour. Performance was evaluated counting the number of right answers and the percentage of mistakes. The results are normalized on the no-TAC value for each person.

The following pictures show the median values of the 18 subjects for the math test, normalized to the 'no-TAC' value. In neutral conditions for winter and summer (24ºC, 25ºC) we did not apply fixed TAC systems, we alternated the 'no-TAC' condition to the "TAC control" (see chapter 3).

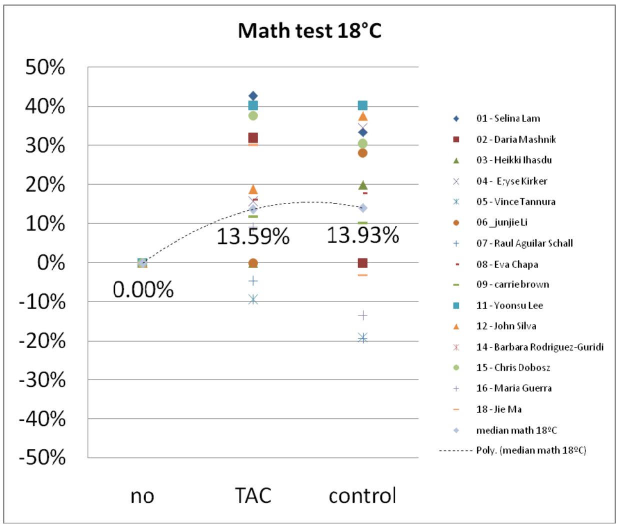
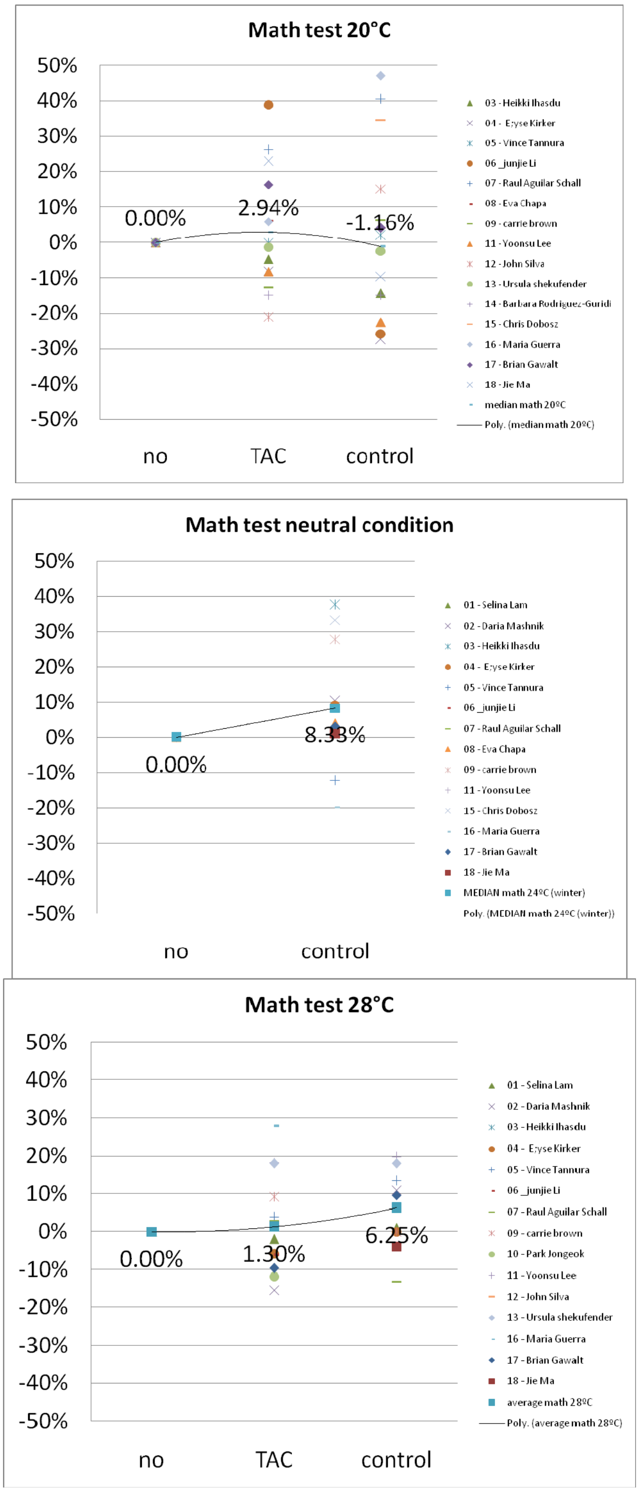
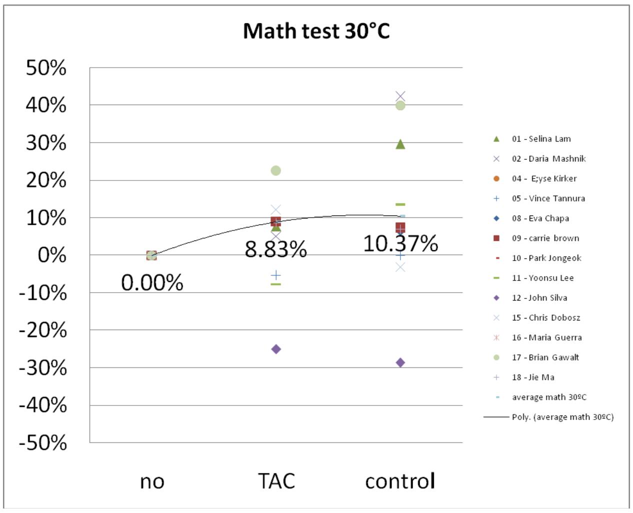


Figure 5.4: Math tests. Comparison between the no-TAC, fixed-TAC and user controlled in 18°C ambient condition. The data are normalized to the no-TAC values.]



[Figure 5.5-5.7: Math tests. Comparison between the no-TAC, fixed-TAC and user controlled in 18°C, 20°C and neutral ambient condition. The data are normalized to the no-TAC values.]



[Figure 5.8: Math tests. Comparison between the no-TAC, fixed-TAC and user controlled in 28°C 30°C and neutral ambient condition. The data are normalized to the no-TAC values.]

Data show an interesting positive trend of the productivity in the Math tests. The magnitude of the improvement in productivity is not completely uniform among the different temperature conditions, but that could easily depend on the small sample of our subjects and the consequent sensitivity of the final number. A bigger number of subjects would have permitted a more reliable comparison of the results.

Although the empirical evidence is more mixed, data show a comparative advantage of User-controlled versus Fixed-TAC. At least on a marginal basis, a user control improves the subjects' productivity. The only exception to this evidence is represented by the results obtained at the temperature of 20°C, where we see a decreasing performance between fixed-TAC and user-control (-1.16& vs. 2.94%).

A possible explanation of this result might be identified in the high sensitivity characterizing the control unit of the user-control device. In Fixed-TAC we set up the palm warmer surface temperature for the subjects at 35°C.

During user-control strategy, subjects were allowed to adjust the temperature of palm warmer and feet warmer to the best fitting temperature.

After few tests, we noticed that in some cases subjects had not the proper sensitivity in adjusting the temperature. In this way the surface temperature of the palm warmer device was too high to touch it, consequently affecting the results during the productivity tests and creating local discomfort. While at 18°C the high temperature perceived might represent an overall comfort improvement to the sensation of cold, at 20°C the perception of a high temperature might decrease the subject comfort, depending on his sensitivity to cold and hot, as seen in chapter 3.

One other possible explanation of this result might be identified in the loss of time implied by the willing to control the temperature.

As we said before, we opted for the use of speed tests. A possible bias associated to this kind of tests is that every unit of time used to adjust the temperature might impact on the final subject performance (spending one minute of out ten to adjust the temperature has a different cost of spending one minute out of sixty!). In other words, there might be a possible positive correlation between the employ of user-control devices and the percentage of mistakes done in performing the tasks. In order to avoid this bias, we did some preliminary training sessions to all the subjects, but we can truly exclude the possibility of the bias in measuring the subjects' productivity.

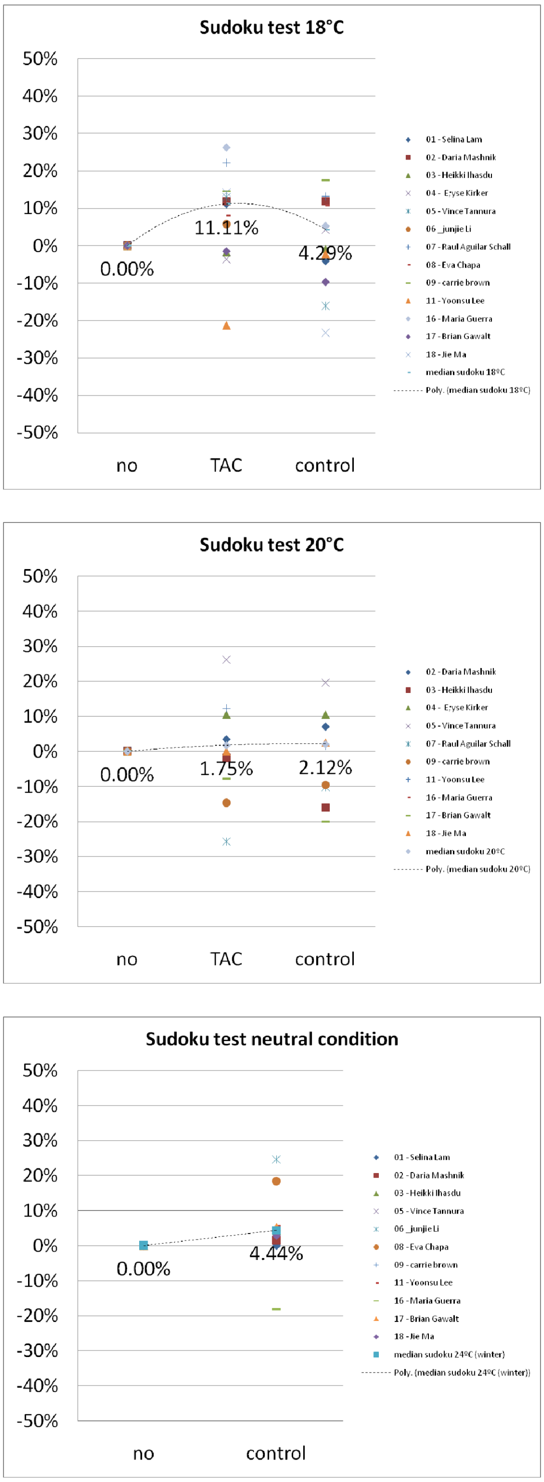
Comparing the changes in productivity at the temperature conditions of 18°C and 20°C, at the temperature 20°C we observe a less compelling improvement of productivity between fixed TAC and user-control. Theoretically this is the condition where the marginal benefit of a user-control device is greater (18°C is cold, 20°C is not so cold, everything depends on the subject sensitivity). The same can be observed comparing the changes in productivity at the temperature conditions of 28°C and 30° C. Where the user-control might be better exploited (30°C), the empirical evidence supporting the user-control device is weak.

5.4 Logical thinking: Sudoku games

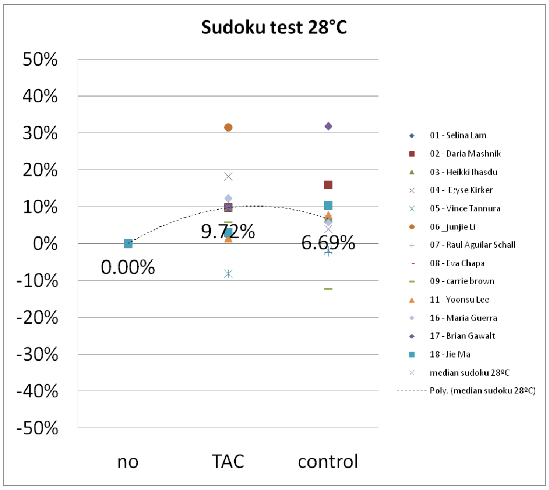
Performance was measured calculating the percentage of Sudoku games solved per unit of time. The results are normalized on the no-TAC value for each person.

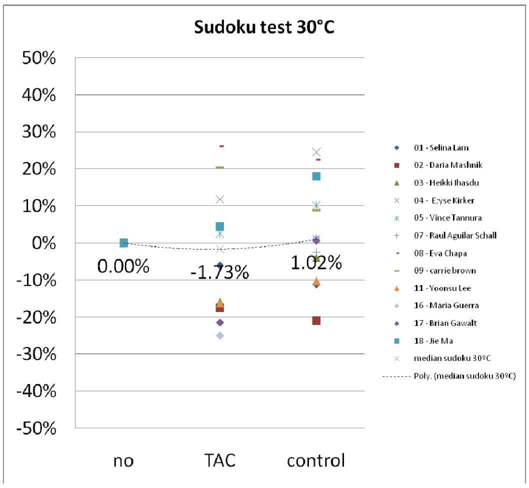
The following pictures show the median value of the 18 subjects. Although the empirical evidence is more mixed than in the Math tests, data from the Sudoku tests show agreement with the results we obtained in the Math tests. In particular, with the only exception of the results obtained at the temperature of 30°C, data show an improvement between no-TAC and fixed-TAC strategies.

We do not find strong evidence in favor of user-control towards fixed TAC, but it is worth observing that we did the Sudoku tests before the Math tests. Considering the difficulty described before in managing the control unit, it is possible that a learning process in managing it could have helped in obtaining more significant results in the Math tests.



[Figure 5.9-5.11: Sudoku tests. Comparison between the no-TAC, fixed-TAC and user controlled in all five conditions. The data are normalized to the no-TAC value.]

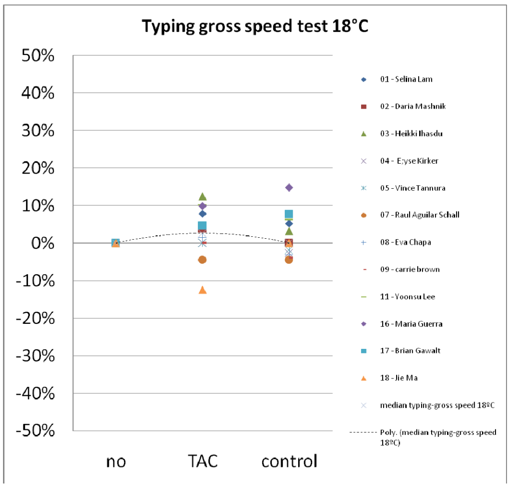


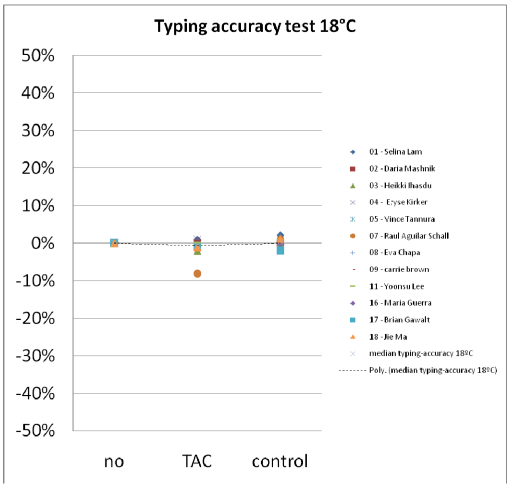


[Figure 5.12-5.13: Sudoku tests. Comparison between the no-TAC, fixed-TAC and user controlled in all five conditions. The data are normalized to the no-TAC value.]

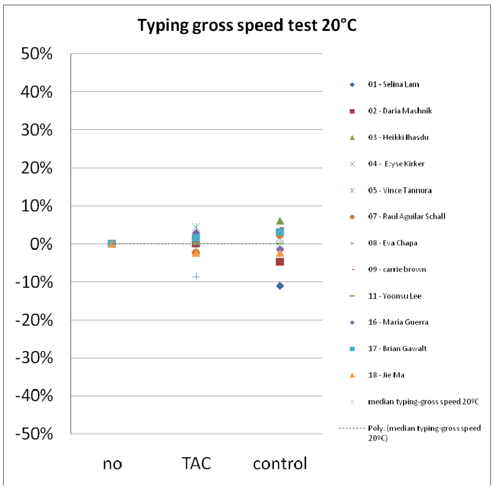
5.5 Dexterity: Typing tests

To evaluate dexterity we choose to use a typing test. The subject was asked to type for 10 minutes/each hour. The score was calculated in gross speed (word per minute, wpm) and accuracy (% of right words typed). The data from the typing tests show very small improvements in typing accuracy.

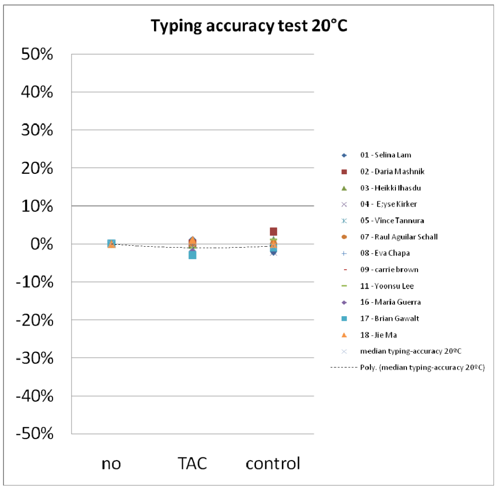




[Figure 5.14-5.15: typing test. Comparison of typing gross speed (wpm) and accuracy (%) between the no-TAC, fixed-TAC and user controlled in 18°C]



[Figure 5.16: Typing test. Comparison of typing gross speed (wpm) between the no-TAC, fixed-TAC and user controlled in 20°C]



[Figure 5.17: Typing test. Comparison of typing accuracy (%) between the no-TAC, fixed-TAC and user controlled in 20°C]

In this test, differences in typing rate among all the conditions seem to be poorly significant. Typing does not appear to be a sensitive method for evaluating performance in this range of environmental conditions.

CONCLUSIONS

1) The use of TAC devices (Fixed-TAC and User-controlled) improves the whole body thermal sensation across all the environmental conditions, from cold to warm. When the subjects made use of TAC devices, their votes moved closer to the neutral sensation (whole body thermal sensation close to 0). Also in neutral condition, we registered an improvement when the subjects had control of their own microenvironment. This result is in accordance with the recent evidence from laboratory research suggesting that diversified environments could produce higher levels of thermal comfort than possible for the best-controlled neutral and uniform environments [Zhang, 2003].

It is worth noting that in neutral conditions, where the environment was uniform and stable at neutral condition (24°C and 25°C), subjects made use of local devices. It is interesting to mention that few subjects made use of local devices in order to cool down the air in the breathing zone and warming up the feet at the same time.

2) Subjects in no-TAC condition were more sensitive to the environment than in fixed-TAC and user-controlled strategies; we can say that the use of TAC devices allows a larger percentage of subjects to maintain comfortable conditions over a wider range of room temperatures. As for the whole body thermal sensation, even whole body thermal comfort shows improvement moving from no-TAC to TAC strategies. Also in neutral condition, we registered a positive effect of local devices on whole body thermal comfort. The following graphs (figure 6.1-6.5) synthesize the correlation between TAC device strategies applied during the Human Subject Tests and the effects on acceptability together with productivity. It is possible to notice that the local devices were more effective in extreme conditions (18°C, 28°C and 30°C) than in mild and neutral.

4) Subjects showed higher rate of thermal environment acceptability (TEA) when air motion was blown during TAC strategies. The airflow was well focused on the breathing zone, thanks to the design of the prototypes. We registered a positive effect in perceived air quality (PAQ) due to the air motion, even blowing re-circulated air at low velocities (case of neutral condition and 28°C, figure 4.17). At 30°C, we blew cooler and fresher air from outside. In

neutral condition and at 28°C we blew re-circulated room air. This difference is probably the reason why we registered a stronger positive effect on PAQ and TEA in 30°C.

5) The positioning of the head cooler device on the occupant's sides gave better thermal comfort levels, but the design needs to be improved in order to limit the eye dry discomfort in the subjects wearing glasses.

6) Data show an improvement in subjects' productivity between no-TAC and fixed-TAC strategies across all the tests, with the only exception of the typing test, which proved to be not significant in measuring the productivity.

7) Although the empirical evidence is more mixed about, at least on a marginal basis, a User-controlled device should improve the subjects' productivity in comparison with fixed TAC. Unfortunately, we experienced some problems in measuring the productivity in the user-control strategy (subjects' difficulty in managing the control unit of the User-controlled device; possible correlation between the employ of User-controlled devices and the percentage of mistakes done in performing tasks); that could have limited the significance of our results. Moreover, it is worth noting that the limited number of subjects performing the tests might have reduced the ability to measure marginal difference in the productivity. In other words, a small sample of subjects might be enough to measure macro-changes in the productivity, not enough to detect micro-changes.

8) The above-mentioned results are coherent with the empirical evidence obtained by the thermal comfort tests. In particular, the results on thermal comfort show that there is a strong improvement between no-TAC and TAC strategies (Fixed-TAC and User-controlled).

9) All of the subjects participated to training sessions before running the tests in order to reduce the effect of learning on the results' significance. The effect of tiredness must be properly considered in scheduling the tasks and structuring the tests. The best solution would be probably to test a large number of subjects for just three times. Then consider the first two sessions as training session and use data only from the third test.

10) In our analysis we focused on the measurement and evaluation of potential "direct" improvements in the productivity. We do not have to forget all the possible indirect improvements that can be induced on productivity through an improvement of the overall subjects' comfort. In fact, it is quite likely that better working conditions might encourage the

worker, on the medium to long term, to work more efficiently because of the psychological positive effect of a supportive working environment.

Human psychology matters. As well known performance is affected by the working environment, personal motivation and by the ability to perform a job. Discomfort due to unsatisfactory indoor environmental quality can result in reduced performance and lost productivity in a variety of ways. Very important are losses due to increased absenteeism of varying duration and less than optimal job performance.

As Wargocki et al. specified that a minor 1% increase in office work could offset the annual costs of ventilating the building. Moreover, every 10% reduction in the percentage dissatisfied with air quality seems to increase the performance of office work by roughly 1% and a reduction of indoor air temperatures above 22°C by 1°C can roughly increase the performance of office work by 1% [Wargocki, 2006]. Unfortunately, to verify such a kind of effect our tests should have to be performed on a regular basis within a real working environment in order to track the changes through time due to a better working environment.

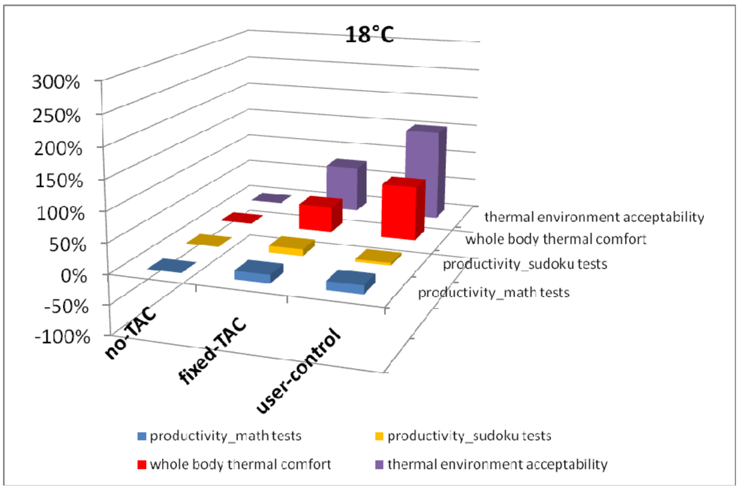
11) We asked ourselves the possible reason behind the differences in the performance of the three selected tests. In other words, why the empirical evidence is stronger, although similar, in the Math test than in Sudoku test? Why typing test did not work in measuring the productivity in our tests? About typing, our impression is that the test was too simple to measure the changes in productivity. Few mistakes for every subject, independently of the environment, are not an optimal situation to track changes in productivity.

About Math/Sudoku, the explanation we gave ourselves appears to be more subtle and challenging for a potential future research. While Math tests are straightforward and the main difficulty in solving them is time, the same does not apply for Sudoku tests. Solving Sudoku tests requires logic but also imagination. Without a time limit every subject would be easily able to solve the math tests, we cannot say the same for Sudoku. To track changes in productivity in Sudoku tests is less straightforward than in Math tests.

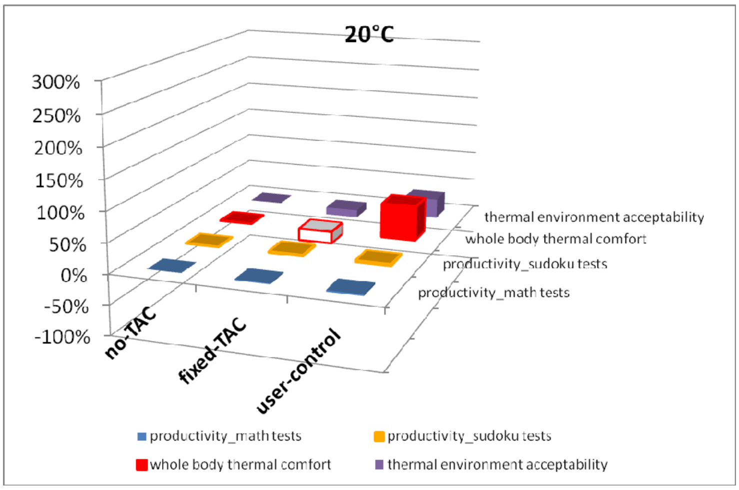
We think that TAC devices are more effective on a very repetitive job, as the Math tests we used during Human Subject Tests. It seems that creative thinking, as required in Sudoku games, is less dependent on a comfortable environment.

12) Results from subjective survey and productivity tests suggest that local devices could be used not only in office environment, but in also every situation where manual labour is

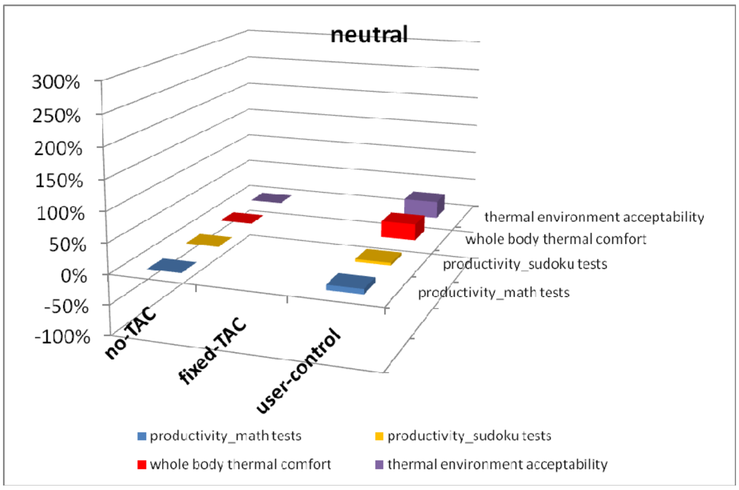
required. In fact, results suggest that local devices increase attention and concentration on the task that the subject is performing. This suggests also that local devices could reduce the possibility of industrial injury.



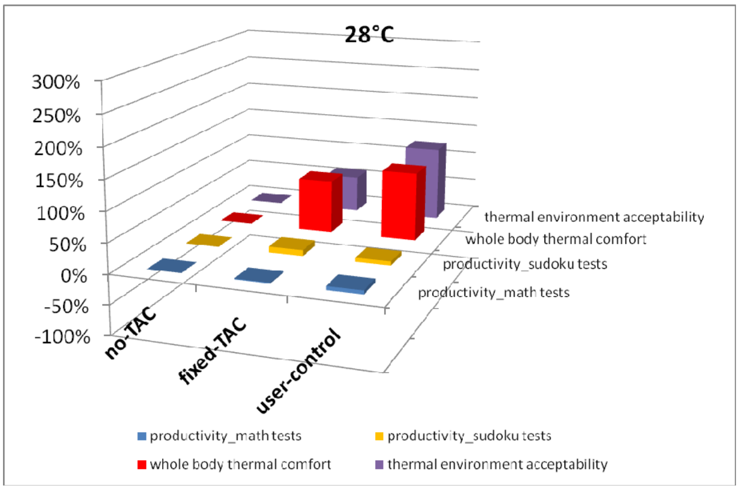
[figure 6.1: Synthetized results of math tests, Sudoku tests, whole body thermal comfort and thermal acceptability fot the three strategies (no-TAC, fixed-TAC, user-control) in 18°C condition]



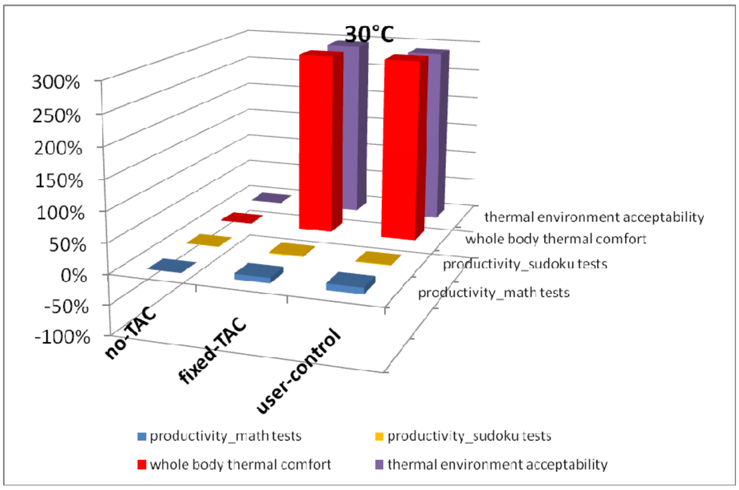
[figure 6.2: Synthetized results of math tests, Sudoku tests, whole body thermal comfort and thermal acceptability fot the three strategies (no-TAC, fixed-TAC, user-control) in 20°C condition]



[figure 6.3: Synthetized results of math tests, Sudoku tests, whole body thermal comfort and thermal acceptability fot the three strategies (no-TAC, fixed-TAC, user-control) in neutral condition]



[figure 6.4: Synthetized results of math tests, Sudoku tests, whole body thermal comfort and thermal acceptability fot the three strategies (no-TAC, fixed-TAC, user-control) in 28°C condition]



[figure 6.5: Synthetized results of math tests, Sudoku tests, whole body thermal comfort and thermal acceptability fot the three strategies (no-TAC, fixed-TAC, user-control) in 30°C condition]

APPENDIX *A*: SUBJECTIVE SURVEY DATA

	18°C	whole-body thermal sensation	whole-body thermal sensation preferred	left-hand thermal sensation	left-hand thermal sensation preferred	right-hand thermal sensation	right-hand thermal sensation preferred	feet thermal sensation	feet thermal sensation preferred	head thermal sensation	head thermal sensation preferred	leg thermal sensation	arm thermal sensation
	subject # **median**	**-0.91**	**0.00**	**-1.42**	**0.01**	**-1.01**	**0.06**	**-0.20**	**0.03**	**-0.83**	**-0.10**	**-0.77**	**-1.10**
	1	-0.90	0.90	-2.64	1.42	-2.78	0.99	-1.74	1.19	-0.64	1.97	-0.70	-0.75
	2	-1.68	-0.14	-1.13	-0.09	-1.16	0.03	-0.06	-0.06	-0.99	-0.35	-0.64	-1.77
	3	-1.13	-0.26	-1.71	-0.35	-1.54	-0.35	-1.10	-0.23	-0.84	-0.29	-1.10	-1.57
	4	-0.87	-0.03	-1.88	-0.03	-2.35	-0.03	-0.03	0.03	-0.64	0.06	0.03	-1.07
	5	-0.70	1.10	-0.81	0.93	-0.87	0.93	-0.84	1.10	-0.84	0.96	-1.07	-1.13
	6	-1.57	-0.20	-1.94	0.06	-2.00	-0.17	-1.01	-0.03	-1.39	-0.12	-1.97	-1.77
	7	0.09	0.03	2.78	-0.12	2.81	0.06	0.00	-0.09	0.06	0.03	-0.58	0.00
	8	-2.87	0.84	-2.87	0.87	-0.96	0.09	0.41	0.17	0.03	0.06	-0.96	-1.94
no	9	-1.04	0.00	-1.83	0.09	-0.93	0.03	0.06	0.03	-1.04	-1.01	0.03	-1.39
	10	-0.93	0.12	-0.99	1.01	0.96	1.10	-0.81	0.17	-0.90	-0.14	-0.78	-0.84
	11	-2.99	2.00	-2.93	1.94	-2.93	1.83	-1.94	0.03	-2.43	-0.38	-1.01	-1.48
	12	-0.12	-0.26	-0.81	-0.09	-1.01	0.41	-0.93	0.32	-0.93	0.23	-0.75	-1.07
	13	-2.67	0.23	-2.29	0.17	-2.29	-0.12	-0.81	0.32	-0.64	0.14	-1.04	-1.68
	14	-2.67	0.09	-3.04	-0.09	-2.87	0.06	-0.12	-0.14	-0.81	-0.14	-0.43	-1.51
	15	0.03	-0.93	-0.20	-0.81	-0.09	-0.84	-0.03	-0.84	0.03	-0.96	0.06	0.12
	16	-0.06	-0.09	-0.78	-0.12	-0.87	0.06	-0.29	-0.26	0.00	-0.09	-0.87	-0.67
	17	-0.72	-1.01	-0.87	-0.96	-1.01	-0.90	0.14	-0.96	-1.01	-0.84	-0.96	-0.93
	18	0.09	0.00	-0.41	0.14	-0.93	0.09	0.00	0.32	-0.09	0.23	-0.41	-0.70
	median	**-0.86**	**0.14**	**-0.45**	**0.03**	**-0.28**	**0.04**	**0.06**	**0.04**	**-0.61**	**0.03**	**-0.67**	**-0.72**
	1	-0.58	1.16	-0.58	0.96	-0.61	1.01	-0.06	0.93	0.03	0.90	-0.52	-0.35
	2	-0.81	0.49	-0.96	0.35	-0.17	0.20	-0.09	-0.06	-0.87	0.12	0.00	-0.52
	3	-1.10	-0.14	-0.99	-0.06	-0.96	-0.03	-0.58	-0.03	-0.87	0.09	-0.96	-0.93
	4	0.43	0.29	0.41	0.03	0.14	0.00	1.57	-0.03	0.00	-0.03	0.38	0.41
	5	-0.38	0.93	-0.20	1.07	-0.17	1.13	-0.06	1.04	-0.09	1.07	-0.20	-0.29
	6	0.03	0.09	-0.03	-0.09	-0.06	0.09	0.49	-0.09	0.00	0.00	0.14	-0.35
	7	-0.90	-0.03	-1.88	0.03	-0.67	0.00	-0.06	0.03	-0.03	0.03	-0.70	-1.36
	8	-2.84	0.00	-3.13	0.03	-3.36	-0.09	-1.07	-0.20	-1.16	-1.04	-0.96	-2.35
TAC	9	-0.70	-0.06	1.77	0.87	0.96	0.99	0.00	0.06	-0.99	-0.90	0.06	-0.52
	10	-1.80	0.96	-2.20	1.04	-1.88	1.13	-1.97	0.99	-1.94	1.01	-1.86	-1.77
	11	-0.99	0.32	0.96	1.88	0.09	1.86	0.99	1.10	-1.91	-0.06	-0.64	-0.38
	12	0.67	0.20	-0.14	0.00	0.06	-0.06	1.42	0.67	-0.06	0.03	0.09	-0.12
	13	-0.78	0.46	0.90	0.52	0.46	0.41	0.38	0.41	-0.67	0.12	-0.70	-1.28
	14	-1.91	-0.03	-0.96	-0.06	-0.90	-0.03	0.14	0.03	-0.99	0.03	-1.07	-1.30
	15	0.03	-0.70	0.03	-0.93	-0.12	-1.01	0.49	-0.43	0.58	-0.72	0.70	0.72
	16	-1.01	-0.14	-0.32	-0.12	-0.38	-0.06	0.12	0.06	-0.03	0.00	-1.04	-1.88
	17	-0.99	-0.99	-1.04	-1.19	-0.87	-1.10	-1.01	-0.96	-0.55	-0.87	-1.07	-1.04
	18	-1.19	0.32	-1.94	0.29	-0.84	0.43	1.36	0.70	-1.07	0.20	-0.99	-2.20
	median	**-0.64**	**0.04**	**-0.09**	**0.07**	**-0.39**	**0.12**	**0.07**	**0.12**	**-0.25**	**0.01**	**-0.55**	**-0.93**
	1	-0.41	0.87	1.01	1.01	-0.49	1.04	-0.46	0.87	-0.46	0.99	-0.26	-0.35
	2	-0.23	0.09	-0.38	0.03	0.81	0.84	0.46	0.78	-0.14	0.26	-0.41	0.06
	3	-1.01	-0.14	-0.99	-0.17	-0.87	-0.17	-0.38	0.00	-0.99	-0.06	-0.90	-0.96
	4	-1.39	0.09	-1.19	0.03	-1.45	-0.06	1.62	0.72	-0.03	-0.03	-0.46	-1.91
	5	0.09	0.96	0.43	0.96	0.55	0.93	0.52	1.30	-0.09	0.90	-0.03	-0.52
	6	-0.90	-0.06	-0.06	0.14	0.06	0.09	0.00	0.09	-0.29	0.00	-1.04	-1.36
	7	-0.58	0.03	1.01	-0.03	0.96	-0.03	0.06	-0.03	0.06	0.03	-0.64	0.09
control	8	-0.09	-0.09	-1.36	0.32	-1.16	0.52	0.09	0.17	-0.52	-0.58	0.00	-0.93
	9	0.03	0.06	-0.03	-0.03	0.43	0.52	0.00	0.12	0.06	-0.81	0.61	0.52
	10	-0.96	0.03	0.96	0.14	-0.06	-0.12	0.09	0.06	-0.99	-0.06	1.10	-0.93
	11	-0.99	0.84	0.93	1.86	-1.19	2.14	0.90	0.87	-1.07	0.03	-0.99	-1.25
	12	0.03	0.09	0.17	0.41	0.00	0.35	0.20	0.23	0.32	0.46	0.26	-0.06
	13	-0.70	-0.06	0.26	0.17	-0.29	0.14	-0.93	0.12	-0.20	0.09	-0.96	-1.33
	14	-2.29	0.26	-2.09	-0.06	-1.91	0.03	1.22	-0.06	-0.72	0.06	-1.04	-1.74
	15	0.32	-0.84	-0.12	-1.22	0.00	-1.04	-0.06	-1.30	-0.12	-1.01	-0.23	-0.14
	16	-0.17	-0.09	-0.43	-0.06	-0.49	-0.03	-0.14	-0.17	-0.09	-0.06	-0.64	-0.81
	17	-1.01	-0.99	-1.57	-0.96	-1.45	-1.07	-0.43	-0.96	-1.04	-1.04	-1.01	-1.16
	18	-1.42	0.70	-1.83	0.12	-1.48	0.32	0.72	0.20	-1.59	0.09	-1.33	-2.46

18°C	subject #	trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	median	**-1.00**	**0.12**	**-0.30**	**-0.23**	**0.88**	**1.88**	**1.94**	**0.00**	**2.05**	**0.33**	**1.73**
	1	-0.70	-1.78	-2.70	-2.64	-0.56	-0.71	-0.27	1.00	-0.79	-1.52	-0.68
	2	-1.25	-0.25	-0.30	-0.19	0.65	0.39	1.72	0.00	1.14	-0.97	0.45
	3	-1.25	1.55	1.49	1.55	1.75	1.83	3.71	0.00	3.86	3.83	3.88
	4	0.03	1.23	0.85	-0.27	2.82	2.73	3.08	0.00	3.10	1.37	3.57
	5	-1.04	-1.17	-0.74	-1.11	-0.91	-0.85	3.31	0.00	3.80	-0.39	4.00
	6	-1.51	-0.85	-1.00	-1.20	-3.97	0.22	0.45	-1.00	-0.53	0.53	-0.33
	7	0.00	-2.96	-3.97	-3.97	0.71	1.92	2.12	0.00	2.30	-2.18	1.98
	8	-2.99	1.20	1.08	1.95	0.94	3.22	3.71	0.00	3.91	0.85	3.71
no	9	-0.90	0.48	-0.88	1.17	2.04	1.95	2.18	0.00	2.06	0.33	2.06
	10	-0.96	-0.25	-0.33	-0.27	-0.33	-0.27	0.19	-1.00	0.19	-0.19	0.22
	11	-1.77	-2.64	-2.06	-2.21	0.82	0.33	0.25	-1.00	-0.74	-2.06	-0.36
	12	-1.04	1.55	1.60	1.43	1.83	1.57	1.52	1.00	1.72	1.81	1.49
	13	-2.52	-0.48	-0.30	-0.30	0.42	0.79	0.85	0.00	0.82	-0.36	0.56
	14	-2.26	-2.09	-2.90	-3.08	0.16	2.09	-0.53	-1.00	-0.13	-3.02	-0.62
	15	0.06	1.75	1.86	2.01	1.92	1.92	1.75	0.00	2.04	1.75	0.10
	16	-0.20	3.57	4.00	4.00	3.68	3.80	3.97	0.00	3.94	4.00	4.00
	17	-0.52	3.68	3.51	3.62	1.75	3.22	3.65	0.00	3.65	3.71	3.71
	18	0.03	2.99	2.84	1.40	3.28	3.74	3.80	0.00	3.80	0.33	3.71
	median	**-0.91**	**0.55**	**1.24**	**1.43**	**1.43**	**1.94**	**2.19**	**0.00**	**2.21**	**1.11**	**2.19**
	1	-0.41	0.16	-0.30	-0.59	1.00	0.82	0.91	0.00	0.77	1.11	0.19
	2	-0.99	-0.22	0.56	1.66	1.57	-0.10	1.95	0.00	1.69	-0.22	1.20
	3	-1.16	1.26	1.66	1.69	1.83	1.17	3.74	0.00	3.71	1.72	3.88
	4	0.00	2.53	2.41	2.53	0.85	2.87	3.16	0.00	3.45	2.38	3.28
	5	-0.17	0.22	0.16	0.19	0.45	0.59	2.84	0.00	2.53	0.71	4.00
	6	-0.32	0.33	2.04	1.92	2.04	2.09	1.14	0.00	1.63	2.15	2.87
	7	-0.96	-1.40	-2.09	-0.97	1.17	2.04	2.24	0.00	2.30	-1.60	2.21
	8	-2.32	0.65	-1.03	1.20	0.71	3.54	3.42	0.00	3.45	0.62	3.83
TAC	9	-0.58	1.57	1.95	2.01	2.04	2.04	2.15	0.00	2.15	2.15	2.18
	10	-1.94	-2.01	-2.04	-2.06	-2.01	-2.18	0.36	-1.00	-0.25	-3.80	0.13
	11	-0.87	0.45	1.20	0.48	2.06	1.78	1.34	0.00	1.60	0.45	0.56
	12	0.14	1.46	1.98	1.98	0.85	1.89	0.68	1.00	0.27	1.78	1.23
	13	-1.30	1.14	2.21	2.01	2.01	1.49	2.50	0.00	2.27	2.44	0.82
	14	-1.22	-1.52	0.19	0.30	0.45	1.98	0.22	0.00	1.57	-1.86	-0.13
	15	0.41	1.55	1.29	1.03	1.29	1.00	1.49	0.00	1.37	1.11	-0.10
	16	-1.71	-0.25	3.77	3.77	3.28	2.67	4.00	0.00	3.88	-0.22	3.97
	17	-0.12	3.48	3.62	3.34	3.86	3.97	3.88	0.00	4.00	4.00	3.97
	18	-1.19	1.37	-0.33	-0.30	3.54	2.64	3.80	0.00	3.54	3.86	3.80
	median	**-0.26**	**1.03**	**1.31**	**1.23**	**2.05**	**1.83**	**1.86**	**0.00**	**2.14**	**1.86**	**2.14**
	1	-0.29	0.42	1.66	1.14	0.62	0.65	1.49	0.00	1.81	1.20	0.27
	2	-0.17	0.88	0.22	2.15	1.89	1.75	2.24	0.00	2.04	1.14	2.12
	3	-0.87	1.49	1.40	1.52	1.75	1.75	3.74	0.00	3.77	2.09	3.91
	4	0.03	0.77	0.36	0.56	2.35	3.22	2.99	0.00	3.31	3.54	3.48
	5	-0.23	0.65	1.14	0.97	1.60	0.59	2.73	0.00	2.93	2.04	3.86
	6	-0.81	1.40	1.98	2.06	2.12	1.49	1.31	0.00	0.39	1.72	0.13
	7	-0.03	1.17	0.33	0.25	2.06	2.09	2.06	0.00	2.76	1.03	2.21
control	8	-0.12	3.48	1.98	2.18	3.45	2.99	3.74	0.00	3.77	3.54	3.39
	9	0.84	2.01	2.04	2.06	2.04	2.04	1.66	1.00	2.04	2.01	2.15
	10	-0.87	-0.33	0.27	0.27	0.16	1.98	0.27	0.00	0.22	-0.33	0.30
	11	-0.55	1.31	2.01	0.53	3.28	0.36	0.48	-1.00	0.48	1.31	0.30
	12	0.14	1.95	2.09	2.18	2.12	1.92	1.49	0.00	2.24	2.21	0.94
	13	-1.16	0.27	0.88	1.31	-0.27	0.71	1.20	0.00	1.92	0.45	1.08
	14	-2.23	-2.27	-2.27	-2.04	-0.56	2.24	0.19	-1.00	-0.16	-2.30	-1.14
	15	-0.09	0.59	0.79	0.56	0.79	0.25	0.42	0.00	1.55	1.20	0.48
	16	-0.84	2.15	3.13	3.16	3.71	3.57	4.00	0.00	4.00	2.06	4.00
	17	0.00	3.97	2.04	2.09	2.21	3.68	3.91	0.00	3.94	3.94	3.97
	18	-2.99	-0.97	1.23	0.48	2.93	0.16	3.74	0.00	3.39	3.60	3.77

20°C		whole-body thermal sensation	whole-body thermal sensation preferred	left-hand thermal sensation	left-hand thermal sensation preferred	right-hand thermal sensation	right-hand thermal sensation preferred	feet thermal sensation	feet thermal sensation preferred	head thermal sensation	head thermal sensation preferred	leg thermal sensation	arm thermal sensation
subject #	median	**-0.77**	**0.03**	**-0.42**	**0.07**	**-0.71**	**0.01**	**-0.01**	**0.03**	**-0.19**	**0.00**	**-0.23**	**-0.48**
	1	-2.29	1.42	-2.03	0.99	-2.17	0.87	-2.52	1.80	-1.62	2.00	-2.43	-2.29
	2	-0.99	0.09	-0.96	0.12	-1.10	-0.06	-0.26	0.29	-1.13	0.17	-0.43	-1.01
	3	-0.96	0.12	-0.90	0.00	-0.87	0.06	-0.41	0.03	-0.29	-0.12	-0.55	-0.41
	4	-0.61	-0.06	-1.39	0.00	-1.16	0.00	-0.03	0.03	-0.23	0.00	0.00	-0.06
	5	0.14	0.14	0.35	0.23	0.49	0.55	0.52	0.49	0.52	0.49	0.55	0.26
	6	-1.97	0.03	-1.86	0.20	-2.12	0.09	-1.01	0.06	-1.97	0.09	-1.86	-1.04
	7	-0.55	0.03	0.46	-0.03	0.67	0.06	0.03	0.03	0.00	0.00	-0.58	-0.38
	8	-1.39	-0.99	-1.88	-1.19	-1.88	-0.81	-0.87	-0.72	-0.06	-0.09	-1.01	-1.04
no	9	1.01	0.06	-0.38	0.93	-0.64	0.81	0.96	-0.06	0.84	-0.90	1.01	1.59
	10	0.03	-0.03	-0.03	0.12	0.17	0.00	0.06	-0.03	0.00	0.14	0.09	0.03
	11	-0.93	0.09	0.52	1.83	0.41	1.77	0.38	0.93	-0.87	-0.93	-0.64	-1.04
	12	1.39	0.32	1.13	-0.03	-0.03	0.00	1.94	0.20	0.49	0.14	0.96	-0.14
	13	-1.22	0.00	-1.04	0.12	-0.78	0.03	0.26	0.32	-0.52	0.23	0.41	-0.55
	14	-1.01	0.00	-0.46	0.06	-0.58	-0.09	-0.41	-0.06	-0.20	0.00	-0.41	-0.84
	15	0.06	-0.70	0.72	-0.41	0.49	-1.07	-0.03	-0.70	-0.09	-0.81	-0.03	0.49
	16	-0.03	-0.09	-0.03	-0.09	-0.09	-0.03	-0.12	0.03	-0.17	-0.09	-0.06	-0.03
	17	-0.96	-1.04	-1.04	-0.93	-0.99	-0.90	0.00	-0.96	-0.96	-1.01	-0.70	-1.01
	18	0.12	0.17	-0.35	0.09	-1.19	0.17	1.07	0.78	0.06	0.12	0.00	-0.78
	median	**-0.12**	**0.01**	**-0.03**	**0.10**	**0.13**	**0.09**	**0.17**	**0.03**	**-0.01**	**0.00**	**-0.04**	**-0.26**
	1	-0.43	1.57	-0.46	1.86	-0.43	1.22	-0.29	1.54	-0.64	1.04	-0.41	-0.43
	2	-0.58	0.03	-0.29	0.46	0.20	0.35	0.96	0.99	-0.03	0.03	0.09	-0.61
	3	-0.58	0.00	0.12	0.09	0.52	0.09	0.41	0.06	-0.41	0.00	-0.46	-0.70
	4	0.32	-0.03	0.38	0.03	0.67	-0.06	2.32	0.03	0.00	0.00	0.03	-0.03
	5	0.55	0.46	0.61	0.55	0.55	0.64	0.46	0.78	0.20	0.32	0.43	0.43
	6	-0.93	0.09	-0.06	0.00	-1.04	-0.03	1.77	-0.03	-1.07	-0.14	-0.87	-0.84
	7	1.04	0.00	2.00	0.00	2.32	-0.03	0.90	0.03	0.46	0.00	0.46	0.58
	8	1.01	-0.78	2.09	-0.93	1.83	-0.93	-0.06	-0.06	0.72	-0.99	-0.06	-0.09
TAC	9	1.48	0.03	1.91	0.96	1.30	1.39	0.99	0.00	1.33	-0.84	0.90	1.10
	10	0.12	-0.06	-0.03	0.12	0.06	0.00	-0.06	-0.03	0.00	0.14	0.00	-0.03
	11	-2.00	0.93	-1.91	1.97	-2.35	1.94	0.00	0.96	-2.14	0.06	-0.96	-1.07
	12	-0.09	-0.03	-0.06	-0.26	-0.12	0.09	-0.14	0.03	1.19	0.06	0.00	-0.09
	13	0.43	0.52	0.61	0.41	0.70	0.49	0.70	0.32	0.12	0.14	0.55	0.67
	14	-2.72	0.32	-2.75	0.17	-2.84	0.32	-0.81	0.06	-0.72	-0.23	-1.33	-1.39
	15	-0.09	-0.55	-0.03	-0.72	0.03	-0.84	-0.03	-0.96	0.12	-0.75	-0.03	-0.09
	16	-0.58	-0.09	-0.55	-0.06	-0.26	-0.03	-0.29	-0.17	-0.17	-0.14	-0.43	-0.72
	17	-0.14	-0.72	0.26	-0.20	0.20	-0.20	0.35	-0.58	-1.10	-1.16	-0.99	-0.93
	18	-1.25	0.14	-1.97	0.43	-1.48	0.23	-0.32	0.38	-0.03	0.09	-0.58	-0.78
	median	**-0.12**	**0.04**	**0.36**	**0.07**	**0.32**	**0.06**	**0.13**	**0.01**	**-0.06**	**-0.01**	**-0.10**	**-0.22**
	1	-0.17	0.29	0.41	1.04	0.35	1.25	1.88	1.74	-0.64	0.64	-0.61	-0.67
	2	-0.29	-0.23	-0.23	-0.14	0.84	0.90	-0.29	-0.09	-0.14	0.09	-0.14	-0.09
	3	-0.35	0.09	0.75	0.32	0.72	0.23	0.00	0.00	-0.52	0.09	-0.61	-0.29
	4	-0.03	0.03	0.35	0.06	0.29	0.00	0.20	0.06	-0.03	0.00	0.00	-0.03
	5	0.64	0.58	0.64	0.58	0.46	0.43	0.46	0.52	0.78	0.70	0.43	0.41
	6	-1.04	0.06	0.03	-0.03	0.72	-0.12	0.96	0.00	0.03	-0.06	-0.49	-1.07
	7	-1.42	0.06	-1.45	0.03	-1.51	0.09	-0.06	-0.03	0.09	-0.03	-0.93	-0.96
	8	-0.03	0.00	-0.17	-0.12	0.00	-0.17	-0.14	-0.14	-1.01	-1.07	-0.06	-0.09
control	9	0.90	-0.09	0.99	0.87	1.86	1.39	0.93	0.03	0.96	-0.96	0.90	0.96
	10	-0.93	0.99	1.83	2.03	0.03	0.03	0.06	0.06	-0.99	-1.10	-0.87	-0.96
	11	-1.57	1.01	0.96	1.97	-0.93	1.97	0.58	0.99	-1.59	-0.87	-0.64	-0.55
	12	0.09	-0.03	0.12	0.09	0.14	0.03	0.00	-0.03	0.09	0.06	0.12	-0.14
	13	0.43	0.38	0.38	0.43	0.43	0.29	1.10	0.61	0.35	0.38	0.61	0.32
	14	-0.78	0.00	-0.93	0.00	-0.99	-0.12	-0.06	0.03	-0.09	-0.03	-0.06	-0.70
	15	0.67	-0.70	1.62	-0.75	1.19	-0.81	1.33	-0.67	0.29	-0.96	0.84	0.90
	16	-0.06	0.03	-0.12	0.03	0.00	-0.14	-0.20	-0.06	-0.75	0.06	-0.81	-0.78
	17	-0.99	-0.93	-0.96	-0.84	-1.01	-1.01	-0.55	-0.93	-0.99	-1.01	-0.70	-0.81
	18	1.57	1.42	1.04	1.07	1.59	1.74	1.94	2.00	0.41	0.38	0.67	0.03

20°C			trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**-0.01**	**1.43**	**1.53**	**1.75**	**1.95**	**2.02**	**1.95**	**0.00**	**2.22**	**1.57**	**1.50**
	1		-2.32	-2.09	-1.78	-2.44	-1.72	-1.55	1.55	0.00	1.75	-2.35	-1.31
	2		-0.58	0.16	0.22	0.85	0.13	1.86	1.20	0.00	1.43	-0.22	1.29
	3		-0.70	1.66	1.72	1.75	2.30	2.04	3.80	0.00	3.83	1.46	3.86
	4		-0.03	3.54	2.15	2.04	2.79	3.54	3.10	0.00	3.28	3.54	3.62
	5		0.43	2.38	2.30	2.21	2.18	2.15	3.08	0.00	2.99	2.84	3.48
	6		-1.01	1.00	0.27	0.30	0.36	0.36	0.36	-1.00	0.48	0.27	-3.94
	7		0.03	1.17	0.36	0.33	1.98	1.98	2.06	0.00	2.24	1.11	1.98
	8		-1.97	2.47	2.53	2.50	2.67	2.79	3.48	0.00	3.65	2.93	2.32
no	9		1.71	1.46	1.34	1.31	1.26	1.00	1.92	1.00	1.86	1.89	1.60
	10		0.14	0.25	0.22	0.19	0.22	0.16	0.19	0.00	0.25	0.33	0.30
	11		0.14	0.19	1.23	0.82	2.04	2.53	1.69	0.00	2.41	0.82	1.40
	12		0.35	1.40	2.35	1.86	0.88	1.72	1.92	1.00	-0.48	1.69	1.26
	13		-0.61	1.23	0.82	1.14	1.92	1.75	1.31	0.00	2.21	1.05	0.97
	14		-1.10	0.74	1.17	1.75	1.83	3.31	1.98	-1.00	0.39	2.09	-1.43
	15		0.06	2.01	2.04	2.06	1.92	2.01	1.60	-1.00	0.88	1.40	0.59
	16		0.00	3.97	3.88	3.97	3.83	4.00	3.97	0.00	3.97	3.83	3.88
	17		-0.58	3.86	3.74	3.62	2.30	3.80	4.00	0.00	3.86	3.91	3.88
	18		0.23	3.74	3.86	3.83	3.65	3.80	3.65	0.00	3.62	3.88	3.88
		median	**-0.04**	**1.23**	**1.33**	**1.20**	**1.42**	**1.46**	**1.85**	**0.00**	**1.76**	**1.44**	**1.11**
	1		-0.38	-0.65	-0.56	-0.65	-0.71	-0.79	1.63	0.00	1.55	-1.14	-0.33
	2		-0.38	2.06	1.26	1.17	3.16	1.43	0.65	1.00	0.36	1.60	1.31
	3		-1.04	2.15	3.86	3.57	2.73	2.82	3.86	0.00	3.80	2.44	3.80
	4		0.00	3.42	2.99	3.16	-1.43	3.34	2.82	0.00	3.48	3.45	3.65
	5		0.49	3.65	3.74	3.62	3.45	3.68	3.71	0.00	3.68	3.80	3.97
	6		-0.09	-0.19	1.31	0.65	-0.13	1.29	1.11	0.00	0.48	0.97	0.27
	7		0.06	-0.48	-2.06	-2.73	0.59	2.06	1.92	0.00	2.09	-0.53	1.81
	8		-0.32	0.68	-2.09	-3.62	0.79	1.37	0.65	1.00	1.17	1.29	-1.98
TAC	9		1.86	1.23	2.01	2.04	1.17	0.68	1.81	1.00	1.86	1.78	1.95
	10		0.03	0.27	0.25	0.16	0.27	0.27	0.36	-1.00	0.33	0.27	0.33
	11		-1.36	-1.34	-1.98	-1.98	2.01	1.14	0.10	-1.00	1.05	-0.82	0.36
	12		0.49	1.23	1.81	2.47	1.78	0.68	0.27	1.00	-0.16	1.31	0.79
	13		-0.58	1.52	1.49	1.95	1.20	1.29	2.04	0.00	2.27	0.65	0.91
	14		-1.74	-2.12	-1.89	-1.92	1.46	3.57	1.69	-1.00	1.08	-2.82	-1.31
	15		0.06	1.20	1.34	1.23	1.37	1.49	1.89	-1.00	1.66	1.57	0.79
	16		-0.87	3.65	3.80	3.83	3.91	3.71	3.94	0.00	4.00	4.00	4.00
	17		0.00	4.00	4.00	4.00	2.30	4.00	3.91	0.00	3.97	3.94	3.91
	18		0.09	2.24	0.45	1.14	2.01	2.93	3.54	0.00	3.62	3.62	3.74
		median	**-0.09**	**2.01**	**2.31**	**2.38**	**2.19**	**2.18**	**2.21**	**0.00**	**2.28**	**1.91**	**2.06**
	1		-0.64	0.51	0.85	0.88	1.57	0.62	1.08	0.00	1.89	0.77	-0.33
	2		-0.38	1.34	2.09	2.27	1.14	1.75	2.21	0.00	1.75	0.51	1.00
	3		-0.32	2.99	2.53	2.50	3.48	2.27	3.80	0.00	3.77	3.19	3.80
	4		-0.06	3.60	3.62	3.62	3.51	3.71	2.67	0.00	3.39	3.48	3.68
	5		0.35	3.05	2.70	2.64	3.10	3.36	3.39	0.00	3.48	3.62	4.00
	6		-0.87	0.71	1.14	1.37	2.04	1.78	2.01	0.00	1.43	-0.13	0.62
	7		-0.12	-1.14	-2.09	-2.12	1.29	2.04	2.21	0.00	2.01	-1.69	2.18
	8		-0.03	3.83	3.65	3.65	2.47	4.00	3.97	0.00	4.00	3.45	3.91
control	9		0.87	1.43	1.55	2.12	1.57	1.40	2.09	1.00	2.04	2.09	1.95
	10		-0.87	0.27	0.27	0.22	0.25	0.25	0.16	0.00	0.19	0.27	0.42
	11		-0.06	2.01	1.92	1.23	4.00	3.57	2.99	0.00	3.02	1.40	2.99
	12		0.09	2.04	2.58	2.90	1.57	1.86	0.79	1.00	0.36	2.04	1.14
	13		0.67	2.01	2.56	2.64	0.74	2.09	2.18	0.00	2.53	1.78	0.79
	14		-0.49	1.26	0.39	0.42	2.35	3.74	1.78	-1.00	0.39	0.39	0.33
	15		0.17	0.53	0.25	0.25	0.10	0.25	1.98	-1.00	1.26	0.56	1.14
	16		-0.96	2.61	3.74	3.77	3.31	3.05	4.00	0.00	3.97	2.87	3.97
	17		-0.99	3.77	3.91	3.74	3.05	3.86	3.83	0.00	3.97	3.80	3.83
	18		0.93	3.80	3.83	3.71	3.97	3.88	3.83	0.00	3.74	3.80	3.91

24°C			whole-body thermal sensation	whole-body thermal sensation	left-hand thermal sensation	left-hand thermal sensation	right-hand thermal sensation	right-hand thermal sensation	feet thermal sensation	feet thermal sensation	head thermal sensation	head thermal sensation	leg thermal sensation	arm thermal sensation
	subject #	**median**	**0.54**	**-0.48**	**0.46**	**-0.49**	**0.41**	**-0.45**	**0.48**	**-0.20**	**0.20**	**-0.06**	**0.20**	**0.20**
	1													
	2													
	3		0.12	0.03	0.00	-0.09	0.00	0.00	0.67	0.03	0.03	0.06	0.43	0.12
	4													
	5													
	6													
	7													
	8		0.96	-0.99	0.93	-0.90	0.81	-0.90	0.29	-0.43	0.38	-0.17	-0.03	0.29
	9													
	10													
	11													
NO	12													
	13													
	14													
	15													
	16													
	17													
	18													
	subject #	**median**	**-0.16**	**-0.07**	**-0.19**	**0.03**	**-0.03**	**-0.03**	**0.35**	**0.00**	**-0.10**	**-0.04**	**0.49**	**-0.13**
	1													
	2													
	3		-0.17	0.00	-0.38	0.03	-0.14	0.00	0.67	-0.03	-0.09	0.06	0.38	-0.20
	4													
	5													
	6													
	7													
	8		-0.14	-0.14	0.00	0.03	0.09	-0.06	0.03	0.03	-0.12	-0.14	0.61	-0.06
	9													
	10													
	11													
CONTROL	12													
	13													
	14													
	15													
	16													
	17													
	18													
	subject #	**median**	**-0.16**	**0.01**	**0.46**	**-0.14**	**0.49**	**-0.01**	**0.20**	**-0.04**	**-0.04**	**-0.46**	**0.04**	**0.06**
	1													
	2													
	3		-0.29	-0.09	-0.06	-0.03	0.03	0.06	0.20	0.00	-0.03	0.03	-0.03	0.06
	4													
	5													
	6													
	7													
	8		-0.03	0.12	0.99	-0.26	0.96	-0.09	0.20	-0.09	-0.06	-0.96	0.12	0.06
	9													
	10													
	11													
NO	12													
	13													
	14													
	15													
	16													
	17													
	18													

	24°C		trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**-0.04**	**2.82**	**2.18**	**2.24**	**1.82**	**3.00**	**2.80**	**0.50**	**2.56**	**2.99**	**2.73**
	1												
	2												
	3		-0.03	3.88	3.80	3.83	2.96	3.80	3.68	0.00	3.65	3.77	3.86
	4												
	5												
	6												
	7												
	8		-0.06	1.75	0.56	0.65	0.68	2.21	1.92	1.00	1.46	2.21	1.60
	9												
NO	10												
	11												
	12												
	13												
	14												
	15												
	16												
	17												
	18												
	subject #	**median**	**0.00**	**3.71**	**3.60**	**3.90**	**3.55**	**3.90**	**3.88**	**0.00**	**3.78**	**3.90**	**3.29**
	1												
	2												
	3		0.06	3.83	3.86	3.97	3.25	3.88	3.80	0.00	3.71	3.86	3.88
	4												
	5												
	6												
	7												
	8		-0.06	3.60	3.34	3.83	3.86	3.91	3.97	0.00	3.86	3.94	2.70
	9												
CONTROL	10												
	11												
	12												
	13												
	14												
	15												
	16												
	17												
	18												
	subject #	**median**	**-0.16**	**3.62**	**2.90**	**2.95**	**2.82**	**3.73**	**3.45**	**0.50**	**3.35**	**3.22**	**3.22**
	1												
	2												
	3		-0.26	3.83	3.83	3.74	3.57	3.86	3.80	0.00	3.80	3.65	3.74
	4												
	5												
	6												
	7												
	8		-0.06	3.42	1.98	2.15	2.06	3.60	3.10	1.00	2.90	2.79	2.70
NO	9												
	10												
	11												
	12												
	13												
	14												
	15												
	16												
	17												
	18												

24.5°C			whole-body thermal sensation	whole-body thermal sensation preferred	left-hand thermal sensation	left-hand thermal sensation preferred	right-hand thermal sensation	right-hand thermal sensation preferred	feet thermal sensation	feet thermal sensation preferred	head thermal sensation	head thermal sensation preferred	leg thermal sensation	arm thermal sensation
	subject #	**median**	**-0.06**	**-0.03**	**0.00**	**-0.03**	**0.16**	**0.03**	**0.43**	**0.01**	**-0.01**	**0.03**	**0.30**	**0.06**
	1		1.39	0.93	1.51	0.93	1.54	0.99	1.62	0.90	1.59	0.99	0.90	0.99
	2		-0.03	-0.06	-0.41	-0.17	-0.03	-0.03	-0.12	-0.14	-0.03	-0.09	-0.09	0.00
	3													
	4		-0.75	0.00	-0.38	0.00	0.29	0.03	0.03	-0.03	-1.22	0.00	-0.03	0.23
	5													
	6													
	7		0.52	0.00	1.07	-0.06	1.19	0.00	0.14	0.06	0.00	0.06	0.03	0.03
	8													
CONTROL	9		-0.09	-0.06	-0.06	0.00	0.55	0.03	0.99	-0.12	-0.96	-0.87	0.87	0.84
	10		0.06	0.06	0.12	0.06	-0.06	0.06	0.03	0.09	0.00	0.09	0.12	-0.03
	11		-0.99	-0.67	1.94	1.88	1.42	1.97	1.77	1.86	-1.94	-1.10	0.75	0.96
	12		0.06	0.03	0.06	-0.12	0.03	0.14	0.06	-0.06	0.12	0.17	-0.23	0.09
	13		-0.67	-0.43	-0.81	-0.46	-0.90	-0.55	0.72	0.20	0.09	0.12	0.49	0.03
	14		-0.12	-0.20	-0.32	-0.20	-0.26	-0.23	0.93	-0.06	-0.81	-0.75	0.93	-0.06
	15													
	16													
	17													
	18													
	subject #	**median**	**0.74**	**-0.03**	**0.57**	**0.03**	**0.48**	**-0.01**	**0.96**	**0.06**	**0.42**	**0.03**	**0.64**	**0.62**
	1		1.57	0.96	1.65	0.93	1.57	0.87	1.74	0.84	1.54	0.99	1.04	0.90
	2		-0.06	-0.12	-0.14	0.12	-0.14	-0.03	0.00	-0.03	-0.06	-0.06	-0.06	-0.12
	3													
	4		0.43	-0.03	0.58	0.03	0.49	-0.06	0.72	0.03	-0.03	0.00	0.35	0.61
	5													
	6													
	7		1.33	0.06	2.17	-0.03	2.23	0.09	0.96	0.03	0.75	0.09	0.64	0.64
	8													
NO	9		0.87	0.00	0.55	0.03	0.96	-0.09	0.96	-0.03	1.01	-0.90	1.28	0.99
	10		0.03	-0.03	0.14	-0.09	0.09	0.17	0.09	0.06	0.03	0.14	0.06	-0.03
	11		-1.42	-0.03	0.00	0.99	-0.03	0.93	-0.75	1.16	-1.13	-0.46	-0.46	0.32
	12		1.19	-0.12	1.28	-0.03	1.25	-0.12	1.48	0.06	1.36	0.06	1.07	0.90
	13		0.87	0.35	-0.20	-0.35	0.03	-0.14	1.13	0.81	0.55	0.23	0.93	0.58
	14		0.61	-0.03	0.87	0.03	0.46	0.00	1.42	0.09	0.29	0.00	0.64	0.75
	15													
	16													
	17													
	18													
	subject #	**median**	**0.20**	**0.01**	**0.01**	**0.04**	**0.10**	**0.03**	**0.36**	**0.00**	**-0.06**	**0.07**	**0.10**	**0.04**
	1		1.86	0.99	1.86	0.93	1.94	0.90	1.94	0.96	1.91	0.81	1.01	0.87
	2		-0.43	-0.55	-0.09	0.06	-0.09	-0.14	0.00	0.12	-0.14	0.12	-0.09	0.00
	3													
	4		-0.49	-0.49	-0.35	-0.35	-0.23	-0.55	-0.06	-0.03	-0.67	-0.64	-0.03	-0.03
	5													
	6													
	7		0.61	0.00	1.01	-0.03	0.99	-0.03	0.14	0.00	-0.06	0.03	0.06	0.06
	8													
CONTROL	9		-0.03	0.03	0.00	0.00	0.12	0.20	1.04	0.00	-0.99	-0.90	1.07	1.01
	10		0.12	0.00	0.00	0.12	0.00	0.09	0.03	-0.06	-0.03	0.14	-0.03	0.14
	11		0.58	0.03	1.36	1.28	0.38	0.41	1.01	1.04	-1.51	-0.70	0.09	0.03
	12		0.14	0.03	0.03	0.17	0.12	0.03	-0.09	-0.06	0.14	0.23	0.12	-0.23
	13		0.26	0.23	0.17	0.00	0.09	0.03	0.58	0.43	0.49	0.46	0.41	0.99
	14		0.32	-0.09	-0.06	0.03	-0.17	-0.09	1.10	-0.06	-0.06	-0.06	1.01	-0.12
	15													
	16													
	17													
	18													

24.5°C

	subject #		trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**0.04**	**2.06**	**2.12**	**2.19**	**2.17**	**2.15**	**2.19**	**0.00**	**2.05**	**2.11**	**1.04**
	1		0.84	2.79	2.84	2.82	2.76	2.61	2.53	0.00	2.58	1.92	2.32
	2		-0.06	2.09	1.92	2.09	2.27	2.21	1.40	0.00	1.55	2.09	-0.25
	3												
	4		0.03	2.41	2.96	2.50	2.90	1.69	2.35	-1.00	1.37	2.12	3.39
	5												
	6												
	7		0.03	1.66	-0.36	-0.39	1.31	2.04	1.92	0.00	2.04	1.29	2.38
	8												
CONTROL	9		0.90	2.04	2.12	2.01	1.29	2.99	2.04	0.00	3.54	2.12	0.51
	10		0.06	2.04	2.09	1.95	2.06	1.95	3.68	0.00	3.86	3.86	3.71
	11		1.04	2.04	3.02	2.96	3.13	1.43	1.11	-1.00	1.26	2.06	0.39
	12		-0.09	2.18	2.12	2.30	2.04	2.09	1.95	0.00	2.06	2.24	1.57
	13		0.32	2.01	1.86	2.01	2.73	2.41	2.61	0.00	2.87	2.35	0.51
	14		-0.06	2.87	2.90	3.16	-0.53	3.74	2.35	-1.00	2.04	2.01	-0.36
	15												
	16												
	17												
	18												

	subject #		trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**0.61**	**2.06**	**1.79**	**1.69**	**1.34**	**1.83**	**0.92**	**1.00**	**1.47**	**1.92**	**0.66**
	1		1.01	2.09	2.09	2.09	2.06	2.06	2.35	0.00	2.09	2.24	0.77
	2		0.00	2.06	1.92	2.09	1.86	1.98	-0.25	1.00	-0.19	0.36	-2.04
	3												
	4		0.03	2.27	1.60	1.46	0.79	2.21	1.81	1.00	1.43	1.20	3.60
	5												
	6												
	7		0.32	-0.45	-2.04	-2.38	0.51	1.03	-0.48	1.00	-1.29	-0.74	0.79
	8												
NO	9		1.39	1.55	1.66	1.40	1.08	1.00	2.09	1.00	1.89	1.92	2.06
	10		0.17	2.06	1.92	1.83	2.06	1.92	0.33	0.00	3.71	3.91	3.80
	11		0.55	2.24	1.92	1.95	1.60	1.75	1.52	1.00	1.52	2.04	0.22
	12		0.99	0.56	0.36	1.20	0.36	0.74	-0.25	1.00	-0.45	1.92	0.45
	13		0.99	2.90	2.82	2.73	2.12	1.72	2.12	1.00	2.32	2.56	0.56
	14		0.67	0.79	0.19	1.55	-0.56	3.19	0.22	1.00	0.45	0.39	0.22
	15												
	16												
	17												
	18												

	subject #		trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**0.09**	**2.05**	**2.08**	**2.08**	**2.05**	**2.08**	**2.12**	**0.00**	**2.38**	**2.32**	**0.46**
	1		0.99	1.98	2.04	2.01	2.06	2.04	2.15	0.00	2.04	1.72	0.42
	2		-0.12	2.04	1.98	2.21	2.04	2.12	0.33	0.00	0.53	1.72	-0.22
	3												
	4		-0.03	3.51	3.45	3.48	3.51	3.51	2.32	0.00	3.51	3.80	3.74
	5												
	6												
	7		0.09	1.55	-0.36	-0.36	1.40	2.04	2.09	0.00	2.61	2.06	2.41
	8												
CONTROL	9		1.48	2.06	2.09	2.01	1.46	2.70	2.27	0.00	3.65	2.61	1.26
	10		0.09	1.95	1.92	2.06	1.98	2.01	0.42	1.00	0.33	0.30	0.25
	11		0.43	1.03	2.06	1.98	3.91	1.26	1.95	0.00	2.30	2.76	-0.25
	12		-0.17	2.27	2.12	2.09	2.15	2.04	2.24	0.00	2.32	2.47	0.65
	13		0.67	3.42	2.90	2.90	2.61	3.08	2.53	0.00	2.82	3.22	0.51
	14		-0.09	2.53	2.73	2.79	-0.97	3.34	1.66	0.00	2.44	2.18	-0.85
	15												
	16												
	17												
	18												

	25°C	whole-body thermal sensation	whole-body thermal sensation preferred	left-hand thermal sensation	left-hand thermal sensation preferred	right-hand thermal sensation	right-hand thermal sensation preferred	feet thermal sensation	feet thermal sensation preferred	head thermal sensation	head thermal sensation preferred	leg thermal sensation	arm thermal sensation
	subject # median	**0.06**	**-0.14**	**-0.06**	**-0.09**	**0.00**	**-0.09**	**0.29**	**-0.20**	**0.00**	**-0.12**	**0.03**	**-0.06**
	1												
	2												
	3												
	4												
	5												
	6	0.06	-0.14	-0.03	0.00	-0.20	-0.03	-0.26	-0.20	-0.23	-0.03	-0.03	-0.20
	7												
	8												
NO	9												
	10												
	11												
	12												
	13												
	14												
	15	-0.17	-1.10	-0.61	-1.01	0.00	-0.99	0.29	-0.84	0.03	-0.87	0.03	-0.12
	16	-0.09	-0.12	-0.06	-0.09	-0.06	-0.09	0.03	-0.09	-0.12	-0.12	-0.03	-0.06
	17	1.28	-0.99	-0.09	-0.93	0.00	-1.04	1.91	-0.96	0.67	-1.10	1.83	0.58
	18	0.17	0.14	0.43	0.41	0.67	0.61	0.78	0.81	0.00	0.17	0.75	0.12
	subject # median	**-0.09**	**-0.04**	**-0.16**	**-0.06**	**-0.16**	**-0.01**	**-0.03**	**0.00**	**-0.09**	**-0.13**	**0.01**	**-0.19**
	1												
	2												
	3												
	4												
	5	0.41	0.41	0.41	0.38	0.38	0.58	0.55	0.52	0.41	0.46	0.46	0.29
	6	-0.09	0.00	0.00	0.00	0.06	0.03	0.00	0.06	-0.03	-0.12	0.06	-0.96
	7												
	8												
CONTROL	9												
	10												
	11												
	12												
	13												
	14												
	15	-0.67	-1.01	-0.87	-0.96	-0.61	-0.96	-0.70	-1.04	-0.78	-0.87	-0.17	-0.26
	16	-0.12	-0.09	-0.12	-0.12	-0.09	0.00	-0.06	-0.06	-0.14	-0.14	-0.09	0.03
	17	0.67	-0.96	-0.67	-0.93	-0.81	-1.01	0.99	-0.99	-0.09	-1.07	0.75	-0.12
	18	-0.09	0.20	-0.20	0.12	-0.23	-0.03	-0.64	0.23	-0.09	-0.03	-0.03	-0.72
	subject # median	**-0.10**	**0.04**	**-0.14**	**-0.10**	**-0.01**	**-0.06**	**0.25**	**-0.03**	**0.04**	**-0.10**	**0.07**	**-0.03**
	1												
	2												
	3												
	4												
	5	0.32	0.43	0.49	0.46	0.43	0.35	0.23	0.35	0.46	0.46	0.43	0.49
	6	-0.09	0.14	-0.09	-0.06	0.06	-0.03	0.06	0.00	-0.96	-0.06	0.00	-0.58
	7												
	8												
NO	9												
	10												
	11												
	12												
	13												
	14												
	15	-0.29	-0.93	-0.20	-0.78	-0.09	-0.93	-0.12	-0.81	0.12	-0.93	-0.03	0.09
	16	-0.12	-0.06	-0.09	-0.14	0.06	-0.09	0.26	-0.06	-0.03	-0.14	-0.06	-0.03
	17	-0.03	-0.99	-0.99	-0.99	-1.07	-0.96	0.96	-1.07	-0.06	-1.04	0.38	-0.03
	18	-0.14	0.14	-1.39	0.26	-0.81	0.20	0.49	0.00	0.14	0.12	0.14	-0.12

25°C

	subject #		trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**0.06**	**1.60**	**1.57**	**1.03**	**0.68**	**0.65**	**2.38**	**0.00**	**3.08**	**1.81**	**2.61**
	1												
	2												
	3												
	4												
	5												
	6		0.00	1.60	0.74	0.53	0.68	0.48	2.38	1.00	1.26	1.81	1.72
	7												
	8												
NO	9												
	10												
	11												
	12												
	13												
	14												
	15		0.06	0.62	1.20	0.13	0.10	0.65	2.06	0.00	3.45	1.03	1.03
	16		0.06	3.86	3.83	3.88	1.89	3.86	3.74	0.00	3.86	3.83	3.80
	17		0.52	-1.03	1.57	1.03	-2.04	-0.88	2.15	1.00	-1.86	-1.31	3.10
	18		-0.03	3.86	2.04	2.56	1.40	3.57	3.48	0.00	3.08	3.68	2.61

	subject #		trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**-0.04**	**2.56**	**2.95**	**2.96**	**1.72**	**3.38**	**3.18**	**0.00**	**2.89**	**3.47**	**3.12**
	1												
	2												
	3												
	4												
	5		0.00	3.86	3.71	3.65	3.80	3.83	3.94	0.00	3.88	3.88	3.97
	6		-0.41	2.50	2.06	2.06	2.32	3.10	0.94	0.00	2.82	3.22	-0.79
	7												
	8												
CONTROL	9												
	10												
	11												
	12												
	13												
	14												
	15		-0.09	1.08	0.97	1.66	1.11	1.89	1.86	-1.00	2.12	1.86	0.77
	16		0.00	3.86	3.94	3.94	3.71	3.97	3.83	0.00	3.91	3.83	3.86
	17		-0.14	1.40	2.84	2.73	0.27	1.95	2.79	0.00	2.32	2.35	2.50
	18		0.14	2.61	3.05	3.19	0.94	3.65	3.57	0.00	2.96	3.71	3.74

	subject #		trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
	subject #	**median**	**-0.01**	**2.41**	**2.21**	**2.31**	**1.75**	**2.92**	**2.74**	**0.50**	**3.38**	**3.23**	**3.36**
	1												
	2												
	3												
	4												
	5		0.00	3.80	3.86	3.83	3.86	3.83	3.83	1.00	3.88	3.91	4.00
	6		-0.41	1.89	1.86	2.06	2.04	2.12	0.45	1.00	0.45	2.79	-0.71
	7												
	8												
NO	9												
	10												
	11												
	12												
	13												
	14												
	15		-0.75	1.57	1.66	1.55	1.46	0.51	1.98	0.00	1.37	1.23	0.68
	16		-0.03	4.00	3.94	3.97	3.39	4.00	3.80	0.00	3.91	4.00	4.00
	17		0.00	2.12	2.56	2.56	0.10	2.04	2.90	1.00	3.13	3.02	3.10
	18		0.09	2.70	0.62	2.04	1.40	3.71	2.58	0.00	3.62	3.45	3.62

28°C			whole-body thermal sensation	whole-body thermal sensation preferred	left-hand thermal sensation	left-hand thermal sensation preferred	right-hand thermal sensation	right-hand thermal sensation preferred	feet thermal sensation	feet thermal sensation preferred	head thermal sensation	head thermal sensation preferred	leg thermal sensation	arm thermal sensation
	subject #	**median**	**1.09**	**-0.01**	**0.87**	**0.01**	**0.93**	**-0.01**	**0.96**	**0.00**	**0.93**	**-0.01**	**1.06**	**0.94**
	1		0.96	1.01	0.99	0.99	1.01	1.01	1.01	0.99	0.93	0.93	0.96	0.93
	2		-0.03	-0.06	-0.41	-0.17	-0.03	-0.03	-0.12	-0.14	-0.03	-0.09	-0.09	0.00
	3		0.93	0.00	0.93	0.03	0.99	-0.14	0.72	0.06	0.93	0.00	0.70	0.96
	4		0.70	0.00	0.61	-0.03	0.55	0.03	1.54	0.06	0.29	0.00	0.72	0.43
	5													
	6		0.96	0.03	-0.23	0.03	-0.09	-0.03	0.38	-0.06	0.70	-0.14	0.14	0.14
	7		2.23	0.03	2.14	0.03	2.55	0.12	2.09	-0.03	2.43	0.00	1.91	1.88
	8		2.00	-1.88	1.91	-1.97	1.97	-1.88	2.72	-1.10	1.13	-1.80	2.26	1.86
no	9		2.75	-0.03	2.32	0.00	2.67	0.00	2.55	0.09	2.78	-0.06	2.52	2.46
	10													
	11		2.20	0.49	0.81	0.09	1.25	0.12	0.90	0.64	2.49	-0.03	0.90	1.36
	12		1.83	-0.12	1.80	0.09	1.91	0.03	1.80	0.14	1.86	0.03	1.83	1.86
	13		1.22	0.75	0.26	0.32	0.87	0.61	0.90	1.01	0.90	0.75	1.54	1.04
	14		0.67	-0.12	1.16	-0.03	0.29	-0.03	1.28	-0.06	0.41	0.03	1.16	0.84
	15		0.61	-1.01	0.55	-0.96	0.70	-0.99	0.78	-1.19	0.70	-0.99	1.88	0.52
	16		1.80	-0.06	-0.09	-0.09	-0.12	-0.09	0.87	-0.20	0.96	-0.32	-0.03	-0.06
	17		2.43	-1.07	1.22	-1.01	1.86	-0.99	2.75	-0.90	2.87	-0.93	2.09	1.01
	18		0.23	0.20	0.23	0.23	0.00	0.06	-0.12	0.03	0.06	0.14	-0.09	0.06
	subject #	**median**	**0.25**	**-0.12**	**-0.01**	**-0.06**	**0.26**	**-0.09**	**0.90**	**-0.01**	**0.09**	**-0.10**	**0.49**	**0.17**
	1		0.41	0.52	0.43	0.52	0.38	0.43	0.38	0.26	0.32	0.38	0.38	0.29
	2		-0.43	-0.55	-0.09	0.06	-0.09	-0.14	0.00	0.12	-0.14	0.12	-0.09	0.00
	3		0.87	-0.03	0.58	-0.03	0.67	0.00	0.96	0.00	0.52	0.00	0.90	0.64
	4		-0.38	-0.41	-0.03	0.00	-0.03	0.00	0.64	0.00	-0.70	-0.55	-0.43	-0.41
	5													
	6		-0.06	-0.03	-0.09	0.00	0.09	-0.03	0.06	-0.20	-1.16	0.00	-0.46	-0.52
	7		1.04	0.00	1.04	-0.06	1.13	-0.03	1.04	-0.09	0.35	-0.03	1.01	0.03
	8		0.99	-1.10	1.36	-1.10	1.30	-0.99	2.64	-1.10	1.39	-0.72	0.72	0.87
TAC	9		1.94	0.12	0.96	-0.06	1.86	0.52	1.91	-0.09	1.88	-0.87	1.86	1.94
	10													
	11		0.09	0.43	-0.03	-0.17	-0.70	0.72	0.90	0.90	-1.91	-0.09	0.32	0.49
	12		0.06	0.03	-0.09	0.17	-0.14	-0.17	1.45	0.09	-0.09	-0.06	-0.06	-0.09
	13		-0.81	-0.55	-1.01	-0.58	1.13	0.14	0.90	0.93	-1.13	-0.41	0.93	0.90
	14		0.87	-0.06	1.36	-0.03	1.22	-0.14	1.54	-0.03	0.17	-0.12	1.10	0.75
	15		1.04	-0.90	0.61	-0.96	0.43	-0.93	0.87	-0.84	0.90	-0.78	0.61	0.61
	16		-0.32	-0.26	-0.32	-0.32	-0.20	-0.14	0.26	0.35	0.29	-0.26	-0.03	0.06
	17		0.46	-1.01	0.00	-0.87	0.14	-0.87	1.74	-0.93	0.00	-1.04	1.30	-0.03
	18		-0.81	-0.17	-1.22	-0.84	-0.96	-0.72	-0.03	-0.14	-1.57	0.06	0.06	-1.25
	subject #	**median**	**0.22**	**-0.03**	**0.09**	**0.00**	**0.26**	**0.00**	**0.70**	**-0.01**	**0.00**	**-0.07**	**0.58**	**0.33**
	1		0.61	0.55	0.43	0.43	0.49	0.43	0.49	0.41	0.52	0.41	0.61	0.64
	2		-0.06	-0.12	-0.14	0.12	-0.14	-0.03	0.00	-0.03	-0.06	-0.06	-0.06	-0.12
	3		0.93	-0.03	0.61	0.00	0.70	0.12	0.90	0.00	0.72	-0.06	0.72	0.67
	4		0.38	0.00	0.38	0.00	0.46	-0.03	0.70	0.03	-0.49	-0.41	0.55	0.46
	5													
	6		-0.06	0.09	0.09	0.00	-0.09	-0.14	-0.09	0.00	-0.12	0.12	-0.35	-0.09
	7		0.06	0.09	0.09	0.09	0.96	0.06	0.43	-0.03	0.00	0.00	0.00	0.03
	8		0.84	-0.64	1.04	0.03	0.03	-0.14	-0.09	-0.20	-0.17	-1.01	0.00	-0.06
control	9		1.94	-0.03	0.96	-0.09	1.97	0.03	1.91	-0.06	0.96	-1.01	1.88	1.86
	10													
	11		0.41	-0.03	-0.03	0.00	0.06	0.00	0.96	0.52	-0.96	-0.64	0.93	1.01
	12		-0.06	-0.06	-0.14	0.00	0.03	0.03	1.28	0.14	-0.06	-0.03	0.06	-0.06
	13		0.43	0.35	-1.10	-1.07	0.38	0.38	0.70	0.64	1.10	0.55	1.19	0.20
	14		0.43	-0.12	0.67	-0.06	0.41	-0.09	0.96	-0.09	0.09	-0.17	1.04	0.72
	15		0.00	-0.93	0.20	-0.87	0.96	-0.90	0.84	-0.90	0.06	-0.90	0.93	0.96
	16		-0.17	-0.12	-0.20	-0.14	-0.09	0.00	0.55	-0.09	-0.03	-0.09	-0.12	-0.12
	17		0.06	-1.01	-0.03	-0.96	0.14	-1.01	0.90	-1.07	0.00	-0.87	0.90	-0.06
	18		0.03	0.17	0.06	0.09	-0.12	0.00	0.12	0.14	0.52	0.35	0.09	0.72

28°C

	subject #	median	trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
			0.96	**0.84**	**1.53**	**1.47**	**0.62**	**1.00**	**0.29**	**1.00**	**-0.23**	**0.97**	**0.07**
	1		0.96	1.57	1.55	1.52	1.57	1.63	0.25	1.00	-0.42	1.43	0.25
	2		-0.06	2.09	1.92	2.09	2.27	2.21	1.40	0.00	1.55	2.09	-0.25
	3		0.96	1.49	1.75	1.60	1.37	1.40	2.61	1.00	0.94	2.32	3.71
	4		0.26	0.97	1.89	1.83	-0.33	2.56	1.75	0.00	3.54	1.29	3.68
	5												
	6		-0.06	0.71	1.52	1.43	0.65	0.45	-0.27	1.00	-0.22	1.14	-0.85
	7		2.35	-2.67	-2.12	-2.38	-2.76	-1.20	-2.06	1.00	-2.15	-2.32	-0.71
	8		1.74	0.97	0.97	0.97	0.59	1.43	-0.33	1.00	-0.25	0.79	-1.11
no	9		2.84	-1.46	-0.27	-0.36	-0.88	-1.34	0.33	1.00	-1.89	-2.01	2.21
	10												
	11		2.03	-2.04	1.72	1.63	1.60	-1.34	-1.23	1.00	-1.72	-1.89	-0.45
	12		2.03	-1.49	-1.52	-1.78	-1.72	-1.46	-1.89	1.00	-1.52	-0.74	0.79
	13		0.72	3.08	2.24	2.61	2.35	2.15	1.34	1.00	2.12	2.64	-0.56
	14		0.93	0.39	-0.62	-0.25	-1.81	1.95	-1.37	1.00	-1.60	-1.66	-0.10
	15		0.96	-0.19	-0.30	-0.82	-1.72	-0.53	-0.42	0.00	3.45	-0.48	-1.14
	16		0.81	1.23	2.09	2.21	1.57	0.59	0.45	1.00	1.60	2.90	3.57
	17		2.49	-3.36	-0.97	-1.29	-3.19	-2.67	2.73	1.00	-2.76	-2.24	2.76
	18		0.17	3.31	3.22	3.51	2.79	3.10	2.06	0.00	1.78	3.13	3.62

	subject #	median	trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
			0.23	**1.72**	**1.85**	**1.78**	**1.24**	**1.83**	**1.81**	**0.00**	**1.07**	**1.57**	**0.53**
	1		0.35	2.09	2.06	2.12	2.06	2.09	1.55	-1.00	2.12	2.30	-0.10
	2		-0.12	2.04	1.98	2.21	2.04	2.12	0.33	0.00	0.53	1.72	-0.22
	3		0.84	1.72	1.83	1.89	1.57	1.57	3.28	0.00	2.70	2.27	3.60
	4		0.00	2.53	2.58	2.58	1.66	3.25	2.70	0.00	3.31	3.28	3.71
	5												
	6		-0.35	0.97	1.66	2.09	2.06	0.39	1.66	-1.00	-0.42	1.20	-0.13
	7		0.03	1.29	0.25	-0.25	0.62	2.01	0.77	1.00	0.68	0.27	2.04
	8		0.55	1.72	1.86	1.81	0.91	1.66	0.74	1.00	1.26	1.43	1.17
TAC	9		1.91	0.30	0.27	0.27	-0.33	0.22	1.95	-1.00	0.19	0.22	-3.22
	10												
	11		0.35	0.33	1.98	0.74	1.98	-0.53	0.30	-1.00	1.17	0.45	-3.13
	12		-0.03	1.92	1.92	1.75	0.48	2.21	2.32	1.00	0.97	1.86	1.72
	13		0.03	2.09	2.70	1.17	3.22	2.61	2.09	-1.00	1.78	2.70	-0.27
	14		0.70	0.22	-0.48	-0.19	-1.95	2.93	-0.16	1.00	0.16	-1.05	-0.51
	15		0.49	-0.19	-0.39	-0.22	-0.22	-0.27	-1.23	-1.00	-1.23	-0.33	-2.38
	16		0.09	2.79	2.12	2.24	0.65	2.44	3.36	0.00	3.74	3.48	2.18
	17		1.01	0.94	1.03	1.20	-0.22	1.55	2.01	1.00	3.34	1.29	2.93
	18		0.12	1.75	1.11	2.09	1.66	0.42	3.62	-1.00	0.79	1.98	3.28

	subject #	median	trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
			0.33	**1.98**	**1.95**	**2.01**	**1.75**	**2.02**	**2.05**	**0.00**	**2.06**	**2.19**	**0.48**
	1		0.49	1.98	1.86	2.04	2.01	2.06	2.09	0.00	2.32	2.50	0.27
	2		0.00	2.06	1.92	2.09	1.86	1.98	-0.25	1.00	-0.19	0.36	-2.04
	3		0.90	1.63	1.86	1.86	1.63	1.49	3.42	0.00	3.77	1.60	3.80
	4		0.00	2.06	1.66	1.43	0.27	2.90	2.67	0.00	3.48	2.50	3.65
	5												
	6		-0.14	2.24	2.09	2.12	2.18	1.95	1.72	1.00	0.74	2.27	-0.36
	7		0.00	1.69	1.95	0.77	0.65	2.06	1.95	0.00	2.09	1.40	2.01
	8		-0.14	3.34	3.48	3.34	3.34	3.02	2.44	-1.00	1.49	2.58	2.61
control	9		1.94	1.14	1.26	0.68	0.48	1.46	2.01	0.00	1.92	0.39	-1.20
	10												
	11		1.83	1.40	2.04	2.09	2.12	1.11	1.52	-1.00	1.86	1.46	0.51
	12		-0.26	2.12	1.95	2.09	0.91	1.89	2.09	0.00	2.04	2.12	0.65
	13		0.32	1.98	2.41	1.98	3.02	2.35	1.83	0.00	2.84	2.61	0.45
	14		0.64	-0.16	-0.10	0.74	-1.05	3.05	0.22	1.00	0.36	0.36	-0.27
	15		0.35	0.16	0.19	-0.25	-1.26	1.11	-1.00	-1.00	-2.87	1.37	-3.31
	16		-0.12	3.88	3.77	4.00	2.06	3.77	3.39	-1.00	3.68	3.88	0.36
	17		0.49	1.29	2.09	2.04	-0.10	1.98	2.47	0.00	3.74	2.99	3.16
	18		0.38	3.34	3.13	1.83	3.39	3.25	3.19	0.00	3.22	3.34	3.48

	30°C	whole-body thermal sensation	whole-body thermal sensation preferred	left-hand thermal sensation	left-hand thermal sensation preferred	right-hand thermal sensation	right-hand thermal sensation preferred	feet thermal sensation	feet thermal sensation preferred	head thermal sensation	head thermal sensation preferred	leg thermal sensation	arm thermal sensation
subject #	median	**2.25**	**-0.19**	**1.32**	**-0.04**	**1.48**	**-0.10**	**1.91**	**-0.09**	**1.80**	**-0.04**	**1.75**	**1.54**
	1	2.81	-0.70	2.38	-1.10	2.17	-1.33	2.14	-0.41	2.17	-0.87	2.14	2.17
	2	0.55	-0.87	0.26	-0.67	0.20	-0.52	0.93	-0.17	0.23	-0.49	0.32	0.06
	3	2.12	-0.26	1.22	0.00	1.45	-0.09	1.91	-0.26	2.00	-0.06	1.59	1.13
	4	1.33	-0.81	1.30	-0.46	1.19	-0.49	1.94	-0.03	1.22	0.06	1.71	1.36
	5	1.36	0.17	1.33	0.14	1.28	0.23	1.16	0.12	1.10	0.17	1.13	1.16
	6	2.96	-0.26	2.93	-0.03	2.96	-0.09	2.90	-0.12	2.96	0.03	2.78	2.23
	7	2.84	0.03	2.46	-0.06	2.87	0.00	1.94	0.03	2.29	0.00	1.97	2.23
	8	4.00	-1.59	3.13	-0.84	3.77	-0.99	3.91	-0.90	2.93	-2.03	3.83	3.77
no	9	2.38	0.00	2.06	0.03	1.94	0.09	2.38	-0.03	2.38	-1.01	2.12	2.29
	10	0.99	0.06	1.07	0.12	-0.03	-0.03	1.04	0.14	1.01	-0.03	1.01	0.90
	11	2.58	0.64	1.48	1.45	1.74	0.52	1.22	-0.12	1.33	-0.35	1.62	1.91
	12	1.48	-0.12	0.55	-0.03	1.71	-0.12	1.74	0.00	1.68	0.00	1.80	1.83
	13	2.52	0.46	1.07	0.43	1.01	0.20	1.54	0.20	1.91	0.29	1.22	1.59
	14	1.25	-0.06	1.45	-0.12	1.51	-0.12	2.43	-0.06	0.87	0.03	1.97	1.48
	15	2.81	-1.91	1.68	-1.88	2.09	-1.25	2.70	-0.87	2.58	-0.99	2.43	2.20
	16	-0.49	-0.64	-0.55	-0.52	-0.49	-0.61	1.19	-0.55	0.00	-0.46	-0.29	-0.29
	17	2.41	-0.90	0.90	-0.96	0.90	-1.04	1.91	-0.96	2.84	-0.99	2.41	0.99
	18	1.16	0.29	0.17	0.09	0.84	0.32	-0.03	0.17	0.52	0.49	0.75	0.93
subject #	median	**0.46**	**-0.06**	**0.30**	**0.00**	**0.32**	**-0.01**	**0.93**	**-0.03**	**0.04**	**-0.04**	**0.55**	**0.45**
	1	0.06	-0.06	-0.06	0.00	-0.03	0.00	0.00	-0.03	0.06	0.00	0.03	-0.03
	2	-0.72	-0.84	-0.32	-0.55	-0.38	-0.67	-0.06	-0.29	-0.32	-0.70	-0.09	-0.35
	3	2.55	-0.55	1.71	0.06	1.68	-0.12	2.09	-0.23	2.61	-0.06	1.97	2.43
	4	0.29	0.03	0.52	0.06	0.70	0.03	0.96	-0.03	-0.67	0.03	0.29	0.46
	5	0.55	0.20	0.72	0.14	0.58	0.26	0.70	0.29	0.61	0.12	0.55	0.55
	6	0.03	0.03	-0.06	0.06	0.38	0.06	0.26	0.09	-0.06	0.00	-0.14	-0.06
	7	1.10	0.00	1.36	0.06	1.94	0.03	1.30	-0.03	0.06	-0.03	0.64	0.32
	8	2.78	-1.86	2.93	-0.90	2.03	-1.88	3.97	-0.29	0.84	-2.06	2.99	2.06
TAC	9	2.12	-0.06	1.51	-0.09	1.88	-0.03	2.35	0.00	1.91	-1.01	2.26	1.91
	10	0.06	0.03	0.06	0.06	0.06	0.03	0.09	0.03	0.00	0.17	0.03	0.00
	11	2.06	0.38	0.09	0.00	0.00	0.06	0.93	0.72	-0.49	-0.06	1.25	0.43
	12	0.38	0.26	-0.14	0.09	0.03	0.00	0.72	-0.06	-0.14	0.14	0.00	0.03
	13	0.70	0.17	0.14	0.06	0.72	0.14	0.93	0.35	0.46	0.49	0.78	0.64
	14	0.75	-0.06	0.67	-0.03	0.26	-0.17	1.19	-0.12	0.23	-0.03	1.22	0.78
	15	0.17	-0.84	0.52	-1.01	0.75	-1.07	0.90	-1.13	1.25	-0.96	0.55	1.10
	16	-0.55	-1.04	0.46	-0.06	-0.20	-0.14	1.28	0.06	-0.20	-0.26	0.23	0.35
	17	1.83	-1.04	-0.38	-1.04	-0.06	-0.93	2.87	-0.99	0.03	-0.99	2.46	0.78
	18	-0.23	-0.09	-1.01	-0.84	-0.12	-0.03	0.72	-0.06	-1.10	-0.17	-0.06	0.00
subject #	median	**0.71**	**-0.03**	**0.58**	**-0.04**	**0.52**	**-0.04**	**0.87**	**-0.09**	**0.09**	**-0.10**	**0.93**	**0.41**
	1	1.36	0.61	1.42	0.52	1.25	0.58	1.01	0.72	0.96	1.01	1.19	1.10
	2	-0.70	-0.78	-0.72	-0.58	-0.96	-0.99	-0.43	-0.61	-0.93	-1.07	0.09	-0.43
	3	1.86	-0.32	0.99	-0.09	1.07	-0.06	1.30	0.00	1.91	-0.12	1.54	1.16
	4	0.46	0.00	0.23	0.00	0.20	0.00	0.03	0.00	-0.67	0.03	0.87	0.81
	5	0.00	-0.03	0.00	-0.06	0.00	-0.03	-0.03	-0.12	0.00	-0.06	0.03	0.00
	6	0.67	-0.09	0.58	-0.12	0.43	-0.09	0.29	-0.03	0.06	0.09	0.23	1.04
	7	0.75	0.00	0.99	-0.03	1.13	0.00	0.93	-0.03	-0.03	0.03	0.67	0.06
control	8	1.25	-1.80	1.13	-0.96	0.96	-1.19	3.97	-0.17	0.09	-1.07	1.30	0.93
	9	1.94	-0.03	1.30	-0.09	1.86	0.06	2.32	0.09	1.51	-1.04	2.23	1.54
	10	1.04	0.12	1.04	0.06	-0.09	-0.03	1.04	0.03	1.01	0.12	0.96	0.84
	11	1.65	0.46	0.06	0.00	0.00	0.00	0.46	-0.09	-0.61	-1.01	0.90	1.28
	12	-0.20	-0.03	-0.03	0.03	0.09	-0.09	-0.29	-0.12	0.09	-0.17	0.00	-0.20
	13	0.84	0.23	0.58	0.06	0.81	0.29	0.81	0.49	0.55	0.46	0.96	0.58
	14	0.64	-0.06	0.64	0.03	0.61	-0.17	1.36	-0.09	-0.09	-0.09	1.07	0.23
	15	1.01	-0.93	1.22	-1.28	1.68	-0.58	1.71	-0.12	1.57	-1.16	0.99	-0.12
	16	-0.61	-0.64	-0.32	-0.29	-0.43	-0.58	0.61	-0.70	-1.25	-1.30	-0.12	-0.32
	17	0.67	-1.01	0.06	-0.93	0.75	-0.81	1.94	-1.01	0.17	-0.87	1.42	-0.06
	18	0.43	0.00	0.06	0.12	0.38	0.09	0.70	-0.09	0.26	0.17	0.06	0.17

30°C	subject #	median / value	trunk thermal sensation	whole-body thermal comfort	left-hand thermal comfort	right-hand thermal comfort	foot thermal comfort	head thermal comfort	air quality	Currently would you prefer	air movement acceptability	thermal environment	dry eye discomfort
no	subject #	median	**1.93**	**-2.06**	**-0.74**	**-0.58**	**-1.40**	**-0.36**	**-0.45**	**1.00**	**-1.52**	**-1.89**	**0.27**
	1		2.38	-2.93	-2.56	-2.50	-2.53	-2.99	-2.64	1.00	-3.25	-2.70	-1.78
	2		0.32	0.33	0.33	0.36	1.17	0.30	-0.53	1.00	-1.00	-0.16	-1.26
	3		2.17	-2.04	-0.62	-0.48	-1.46	-1.86	2.01	0.00	2.21	-1.78	2.53
	4		1.88	-2.12	-1.57	-1.14	-2.01	0.53	1.46	1.00	-0.51	-2.32	3.57
	5		1.16	0.74	0.82	0.91	0.79	0.91	0.97	1.00	0.82	1.08	2.76
	6		2.29	-3.62	-3.08	-2.82	-2.67	-3.08	-2.56	1.00	-3.22	-1.89	-3.02
	7		2.32	-2.90	-2.04	-2.04	-2.64	-2.09	-1.66	1.00	-2.24	-2.27	-0.33
	8		3.59	-4.00	-3.94	-4.00	-3.97	-3.31	-3.80	1.00	-3.97	-3.97	-4.00
	9		3.04	-2.50	-0.88	-0.68	-1.34	-2.09	-0.36	1.00	-2.47	-2.35	2.44
	10		1.01	0.25	-0.30	1.92	-0.22	0.22	0.19	1.00	0.25	0.30	0.19
	11		2.72	-2.09	0.45	0.51	1.40	0.79	0.33	1.00	-0.65	-1.89	-0.48
	12		1.86	-0.51	0.27	0.45	-1.05	-0.94	-1.55	1.00	-2.04	-0.97	0.56
	13		1.97	-0.30	0.30	0.30	0.25	0.25	0.22	1.00	0.42	-0.25	0.36
	14		1.48	-1.81	-1.81	-1.95	-3.08	0.22	-2.01	1.00	-2.35	-2.30	-0.36
	15		2.49	-2.58	-2.56	-2.47	-3.48	-2.99	-3.28	1.00	-2.58	-3.19	-2.09
	16		0.64	3.10	3.13	3.34	0.79	1.86	0.62	1.00	-0.65	0.42	3.39
	17		1.88	-3.68	-0.85	-0.68	-3.34	-4.00	-0.77	1.00	-4.00	-3.77	1.14
	18		1.01	1.52	2.90	1.83	2.70	2.79	1.52	1.00	0.30	2.30	3.13
TAC	subject #	median	**0.51**	**1.75**	**1.73**	**1.72**	**1.07**	**1.44**	**1.92**	**0.00**	**1.50**	**1.07**	**0.65**
	1		-0.03	2.21	1.95	1.98	1.95	1.86	0.77	-1.00	0.39	1.43	-0.97
	2		-0.41	1.92	2.32	2.38	2.09	2.12	2.61	0.00	2.53	2.50	-0.36
	3		2.84	-2.82	-2.09	-2.12	-2.44	-2.93	1.98	1.00	-3.34	-2.67	3.83
	4		0.09	1.89	1.78	1.92	1.29	0.53	2.87	-1.00	-0.51	0.71	3.05
	5		0.43	3.71	3.77	3.74	3.71	3.77	3.83	1.00	3.80	3.91	3.97
	6		-0.06	1.81	1.69	1.40	2.24	2.15	0.45	-1.00	1.72	1.52	0.68
	7		0.23	0.39	-0.33	-0.65	-0.62	1.37	1.95	0.00	2.32	-0.22	1.29
	8		1.59	-2.53	-1.95	-2.01	-4.00	0.68	-1.14	1.00	-1.43	-3.02	-3.86
	9		2.84	-2.09	-0.36	-0.88	-2.06	-1.05	-0.30	1.00	0.30	-1.49	0.36
	10		0.00	2.04	2.12	1.86	1.98	2.04	3.86	0.00	3.80	3.83	3.88
	11		1.80	0.13	2.06	1.98	1.78	0.65	1.78	-1.00	1.43	0.16	-0.36
	12		0.99	1.69	1.46	1.75	0.85	1.92	1.17	1.00	1.17	1.46	1.89
	13		1.01	1.89	1.92	2.04	0.59	1.52	1.89	0.00	1.69	1.52	0.62
	14		0.58	0.48	0.27	0.27	-0.68	2.21	-0.62	-1.00	-0.45	-1.46	-0.19
	15		0.84	-0.25	-0.27	-0.10	-0.42	-0.45	-0.42	-1.00	-2.61	-2.84	-4.00
	16		0.03	3.94	3.94	3.94	2.70	3.54	3.91	0.00	3.97	3.34	1.66
	17		2.09	-1.14	0.10	0.10	-2.04	0.10	2.53	0.00	1.89	-0.77	0.42
	18		-0.03	2.76	1.95	1.69	1.49	0.85	3.36	-1.00	1.57	2.90	3.16
control	subject #	median	**0.68**	**1.11**	**1.24**	**1.42**	**-0.29**	**1.14**	**1.98**	**0.00**	**1.37**	**1.01**	**0.23**
	1		1.19	-0.65	-0.71	-0.42	-0.36	-0.39	-0.36	0.00	0.59	-0.97	-1.66
	2		-0.23	2.61	2.18	2.12	0.25	2.04	3.60	0.00	3.36	2.96	-1.23
	3		2.23	-0.91	0.39	0.53	-0.62	-0.77	2.04	0.00	3.71	-1.14	3.65
	4		0.03	1.92	2.44	1.57	1.75	2.79	2.44	-1.00	1.31	2.30	3.62
	5		-0.06	3.94	4.00	4.00	3.97	3.97	3.97	0.00	4.00	3.97	3.94
	6		0.75	-1.83	-1.20	-1.75	-1.57	-2.06	-2.09	1.00	-1.72	-1.92	-2.50
	7		-0.06	1.26	0.82	-0.33	-0.42	1.23	2.12	0.00	1.81	0.62	1.92
	8		0.99	0.97	0.39	0.45	-4.00	0.65	0.33	1.00	0.68	0.45	-2.70
	9		2.41	-0.33	-0.19	-0.77	-1.72	-0.30	1.03	0.00	1.11	-0.33	-1.52
	10		0.90	0.25	-0.19	2.01	-0.22	-0.19	0.33	1.00	0.39	0.22	0.19
	11		1.62	0.19	2.09	2.01	2.87	1.63	1.37	0.00	1.43	0.88	0.27
	12		0.06	2.18	2.12	2.21	2.04	2.04	2.09	0.00	2.24	2.44	0.91
	13		0.70	1.40	1.34	1.26	0.25	1.05	2.06	0.00	2.50	1.52	0.39
	14		0.26	1.46	1.14	1.11	-1.75	2.76	1.29	0.00	1.08	1.29	-0.36
	15		0.29	-1.31	-1.63	-1.20	-1.69	-2.01	-4.00	-1.00	-2.90	1.14	-4.00
	16		-0.52	3.62	3.83	3.42	1.98	3.25	3.77	0.00	4.00	3.88	-0.25
	17		1.01	0.36	2.06	2.01	-1.52	0.68	2.12	0.00	3.45	0.74	2.21
	18		0.67	2.56	2.56	1.81	1.69	3.45	1.92	1.00	1.03	2.64	3.45

APPENDIX *B*: PRODUCTIVITY TEST DATA

math 18°C

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	75	66	15	58	63	32	62	56	60	12	62	32	70		56	22	81	60
TAC	107	87	15	67	57	32	59	65	67	28	87	38	61		77	24	78	78
control	100	66	18	78	51	41	50	66	66	25	87	44	65		73	19	53	58

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%
TAC	42.67%	31.82%	0.00%	15.52%	-9.52%	0.00%	-4.84%	16.07%	11.67%	133.33%	40.32%	18.75%	-12.86%		37.50%	9.09%	-3.70%	30.00%
control	33.33%	0.00%	20.00%	34.48%	-19.05%	28.13%	-19.35%	17.86%	10.00%	108.33%	40.32%	37.50%	-7.14%		30.36%	-13.64%	-34.57%	-3.33%

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first hour	75	66	15	58	51	41	62	56	60	12	62	38	61		56	22	81	60
second hour	100	66	18	78	63	32	50	66	66	25	87	32	70		73	19	53	58
third hour	107	87	15	67	57	32	59	65	67	28	87	44	65		77	24	78	78

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first hour	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%
second hour	33.33%	0.00%	20.00%	34.48%	23.53%	-21.95%	-19.35%	17.86%	10.00%	108.33%	40.32%	-15.79%	14.75%		30.36%	-13.64%	-34.57%	-3.33%
third hour	42.67%	31.82%	0.00%	15.52%	11.76%	-21.95%	-4.84%	16.07%	11.67%	133.33%	40.32%	15.79%	6.56%		37.50%	9.09%	-3.70%	30.00%

math 20°C

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	116	103	21	62	50	31	42	48	47		84	33	79	27	26	17	49	83
TAC	114	99	20	57	50	43	53	51	41		77	26	78	23	40	18	57	102
control	111	83	18	45	51	23	59	50	50		65	38	77	23	35	25	51	75

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TAC	-1.72%	-3.88%	-4.76%	-8.06%	0.00%	38.71%	26.19%	6.25%	-12.77%		-8.33%	-21.21%	-1.27%	-14.81%	53.85%	5.88%	16.33%	22.89%
control	-4.31%	-19.42%	-14.29%	-27.42%	2.00%	-25.81%	40.48%	4.17%	6.38%		-22.62%	15.15%	-2.53%	-14.81%	34.62%	47.06%	4.08%	-9.64%

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first hour	111	83	18	45	50	31	53	51	41		65	38	79	23	26	17	49	83
second hour	114	99	20	57	51	23	42	48	47		84	33	77	27	35	25	51	75
third hour	116	103	21	62	50	43	59	50	50		77	26	78	23	40	18	57	102

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first hour	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
second hour	2.70%	19.28%	11.11%	26.67%	2.00%	-25.81%	-20.75%	-5.88%	14.63%		29.23%	-13.16%	-2.53%	17.39%	34.62%	47.06%	4.08%	-9.64%
third hour	4.50%	24.10%	16.67%	37.78%	0.00%	38.71%	11.32%	-1.96%	21.95%		18.46%	-31.58%	-1.27%	0.00%	53.85%	5.88%	16.33%	22.89%

math 28°C

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	104	91	9	52	52	32	76	78	54	17	71	23	61	22		18	52	77
TAC	102	77	17	49	54	30	78	64	59	15	84	44	72	18		23	47	78
control	105	101	21	52	59	34	66	53	54	7	85	41	72	22		32	57	74

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%
TAC	-1.92%	-15.38%	88.89%	-5.77%	3.85%	-6.25%	2.63%	-17.95%	9.26%	-11.76%	18.31%	91.30%	18.03%	-18.18%		27.78%	-9.62%	1.30%
control	0.96%	10.99%	133.33%	0.00%	13.46%	6.25%	-13.16%	-32.05%	0.00%	-58.82%	19.72%	78.26%	18.03%	0.00%		77.78%	9.62%	-3.90%

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	104	91	9	52	54	30	66	53	54	7	71	23	61	22		23	47	78
second	102	77	17	49	52	32	78	64	59	15	85	41	72	22		18	52	77
third	105	101	21	52	59	34	76	78	54	17	84	44	72	18		32	57	74

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%
second	-1.92%	-15.38%	88.89%	-5.77%	-3.70%	6.67%	18.18%	20.75%	9.26%	114.29%	19.72%	78.26%	18.03%	0.00%		-21.74%	10.64%	-1.28%
third	0.96%	10.99%	133.33%	0.00%	9.26%	13.33%	15.15%	47.17%	0.00%	142.86%	18.31%	91.30%	18.03%	-18.18%		39.13%	21.28%	-5.13%

math 30°C

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	91	78	26	45	56			46	55	17	52	28	85	15	33	7	40	57
TAC	98	82	16	49	53			76	60	26	48	21	77	14	37	19	49	62
control	118	111	23	63	56			49	59	29	59	20	68	10	32	17	56	61

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00%	0.00%	0.00%	0.00%	0.00%			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TAC	7.69%	5.13%	-38.46%	8.89%	-5.36%			65.22%	9.09%	52.94%	-7.69%	-25.00%	-9.41%	-6.67%	12.12%	171.43%	22.50%	8.77%
control	29.67%	42.31%	-11.54%	40.00%	0.00%			6.52%	7.27%	70.59%	13.46%	-28.57%	-20.00%	-33.33%	-3.03%	142.86%	40.00%	7.02%

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	98	82	16	49	56			46	55	17	48	21	85	14	33	28	86	62
second	91	78	23	45	53			49	60	29	52	28	68	15	32	20	77	57
third	118	111	26	63	56			76	59	26	59	20	77	10	37	24	84	61

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	0.00%	0.00%	0.00%	0.00%	0.00%			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
second	-7.14%	-4.88%	43.75%	-8.16%	-5.36%			6.52%	9.09%	70.59%	8.33%	33.33%	-20.00%	7.14%	-3.03%	-28.57%	-10.47%	-8.06%
third	20.41%	35.37%	62.50%	28.57%	0.00%			65.22%	7.27%	52.94%	22.92%	-4.76%	-9.41%	-28.57%	12.12%	-14.29%	-2.33%	-1.61%

sudoku 18°C

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	900.00	662.50	491.66	652.00	620.00	140.00	632.00	788.00	412.00	200.00	544.00	340.00	856.00	380.00	572.00	237.50	600.00	641.66
TAC	1000.00	741.66	483.33	628.00	700.00	148.00	772.00	852.00	472.00	204.00	428.00	448.00	812.00	348.00	424.00	300.00	591.66	733.33
control	862.50	741.66	487.50	680.00	520.00	224.00	716.00	872.00	484.00	208.00	532.00	264.00	736.00	340.00	300.00	250.00	541.66	491.66

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TAC	11.11%	11.95%	-1.69%	-3.68%	12.90%	5.71%	22.15%	8.12%	14.56%	2.00%	-21.32%	31.76%	-5.14%	-8.42%	-25.87%	26.32%	-1.39%	14.29%
control	-4.17%	11.95%	-0.85%	4.29%	-16.13%	60.00%	13.29%	10.66%	17.48%	4.00%	-2.21%	-22.35%	-14.02%	-10.53%	-47.55%	5.26%	-9.72%	-23.38%

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	900.00	662.50	491.66	628.00	520.00	224.00	716.00	872.00	484.00	208.00	428.00	448.00	812.00	348.00	424.00	237.50	600.00	641.66
second	862.50	741.66	487.50	652.00	620.00	140.00	772.00	852.00	472.00	204.00	544.00	340.00	856.00	380.00	572.00	250.00	541.66	491.66
third	1000.00	741.66	483.33	680.00	700.00	148.00	632.00	788.00	412.00	200.00	532.00	264.00	736.00	340.00	300.00	300.00	591.66	733.33

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
second	-4.17%	11.95%	-0.85%	3.82%	19.23%	-37.50%	7.82%	-2.29%	-2.48%	-1.92%	27.10%	-24.11%	5.42%	9.20%	34.91%	5.26%	-9.72%	-23.38%
third	11.11%	11.95%	-1.69%	8.28%	34.62%	-33.93%	-11.73%	-9.63%	-14.88%	-3.85%	24.30%	-41.07%	-9.36%	-2.30%	-29.25%	26.32%	-1.39%	14.29%

sudoku 20°C

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no		712.5	445.83	591.66	570.83		779.16		395.83	144	492	344	744	340	252	164	460	768
TAC		737.5	437.5	654.16	720.83		579.16		337.5	284	552	308	864	324	380	272	424	768
control		762.5	375	654.16	683.32		700		358.33	264	500	340	884	308	304	300	368	788

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no		0.00%	0.00%	0.00%	0.00%		0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TAC		3.51%	-1.87%	10.56%	26.28%		-25.67%		-14.74%	97.22%	12.20%	-10.47%	16.13%	-4.71%	50.79%	65.85%	-7.83%	0.00%
control		7.02%	-15.89%	10.56%	19.71%		-10.16%		-9.47%	83.33%	1.63%	-1.16%	18.82%	-9.41%	20.63%	82.93%	-20.00%	2.60%

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first		762.5	375	654.16	570.83		579.16		337.5	144	500	340	744	308	380	164	460	768
second		737.5	437.5	654.16	683.32		779.16		395.83	264	492	344	884	340	252	300	368	768
third		712.5	445.83	591.66	720.83		700		358.33	284	552	308	864	324	304	272	424	788

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first		0.00%	0.00%	0.00%	0.00%		0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
second		-3.28%	16.67%	0.00%	19.71%		34.53%		17.28%	83.33%	-1.60%	1.18%	18.82%	10.39%	-33.68%	82.93%	-20.00%	0.00%
third		-6.56%	18.89%	-9.55%	26.28%		20.86%		6.17%	97.22%	10.40%	-9.41%	16.13%	5.19%	-20.00%	65.85%	-7.83%	2.60%

sudoku 28°C

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	956	576	392	592	692	152	679.16	854.16	854.16	854.16	533.33	350	691.66	320.83	400	204.16	379.16	725
TAC	976	632	432	700	636	200	745.83	904.16	904.16	904.16	541.66	337.5	758.32	316.66	425	229.16	416.66	745.83
control	1020	668	420	616	680	252	662.50	750.00	750.00	750.00	575	362.5	829.16	366.66	500	216.16	500	800

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TAC	2.09%	9.72%	10.20%	18.24%	-8.09%	31.58%	9.82%	5.85%	5.85%	5.85%	1.56%	-3.57%	9.64%	-1.30%	6.25%	12.25%	9.89%	2.87%
control	6.69%	15.97%	7.14%	4.05%	-1.73%	65.79%	-2.45%	-12.19%	-12.19%	-12.19%	7.81%	3.57%	19.88%	14.28%	25.00%	5.88%	31.87%	10.34%

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	956	576	392	592	636	200	662.5	750	750	750	533.33	350	691.66	320.83	425	229.16	416.66	745.83
second	1020	668	420	616	692	152	745.83	904.16	904.16	904.16	575	362.5	829.16	366.66	400	204.16	379.16	725
third	976	632	432	700	680	252	679.16	854.16	854.16	854.16	541.66	337.5	758.32	316.66	500	216.16	500	800

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
second	6.69%	15.97%	7.14%	4.05%	8.81%	-24.00%	12.58%	20.55%	20.55%	20.55%	7.81%	3.57%	19.88%	14.28%	-5.88%	-10.91%	-9.00%	-2.79%
third	2.09%	9.72%	10.20%	18.24%	6.92%	26.00%	2.51%	13.89%	13.89%	13.89%	1.56%	-3.57%	9.64%	-1.30%	17.65%	-5.67%	20.00%	7.26%

sudoku 30°C

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	936.00	684.00	500	540.00	636	220	675.00	687.50	412	162.50	487.50	362.50	872	316.66	348	300.00	637.50	575.00
TAC	880.00	564.00	420	604.00	652	124	704.16	866.66	496	116.66	408.33	304.16	692	233.33	328	224.99	500.79	600.00
control	832.00	540.00	480	672.00	700	208	658.33	841.66	448	187.50	437.50	266.66	840	291.66	300	304.16	641.66	679.16

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TAC	-5.98%	-17.54%	-16.00%	11.85%	2.52%	-43.64%	4.32%	26.06%	20.39%	-28.21%	-16.24%	-16.09%	-20.64%	-26.32%	-5.75%	-25.00%	-21.44%	4.35%
control	-11.11%	-21.05%	-4.00%	24.44%	10.06%	-5.45%	-2.47%	22.42%	8.74%	15.38%	-10.26%	-26.44%	-3.67%	-7.89%	-13.79%	1.39%	0.65%	18.11%

subject #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	880	564	480	604	636	220	675	687.5	412	162.5	408.33	304.16	872	233.33	348	224.99	500.7916	600
second	936	684	500	540	700	208	658.33	841.66	448	187.5	487.5	362.5	840	316.66	300	300	637.5	575
third	832	540	420	672	652	124	704.16	866.66	496	116.66	437.5	266.66	692	291.66	328	304.16	641.66	679.16

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
first	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
second	6.36%	21.28%	4.17%	-10.60%	10.06%	-5.45%	-2.47%	22.42%	8.74%	15.38%	19.39%	19.18%	-3.67%	35.71%	-13.79%	33.34%	27.30%	-4.17%
third	-5.45%	-4.26%	-12.50%	11.26%	2.52%	-43.64%	4.32%	26.06%	20.39%	-28.21%	7.14%	-12.33%	-20.64%	25.00%	-5.75%	35.19%	28.13%	13.19%

18°C

GROSS SPEED

wpm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	38	79	32	72	51	21	44	64	50	50	49	56	74	42	42	61	65	72
TAC	41	82	36	72	51	19	42	65	50	47	54	57	69	44	51	67	68	63
control	40	79	33	70	50	22	42	62	48	45	52	59	76	43	55	70	70	72

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	0.08	0.04	0.13	0.00	0.00	-0.10	-0.05	0.02	0.00	-0.06	0.10	0.02	-0.07	0.05	0.21	0.10	0.05	-0.13
control	0.05	0.00	0.03	-0.03	-0.02	0.05	-0.05	-0.03	-0.04	-0.10	0.06	0.05	0.03	0.02	0.31	0.15	0.08	0.00

ACCURACY

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	96	96	96	96	98	83	97	96	97	90	97	95	98	94	80	97	98	93
TAC	97	96	94	97	97	86	89	97	97	91	97	94	97	97	93	96	97	92
control	98	96	96	95	97	80	98	98	97	93	98	94	97	96	90	97	96	94

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	0.01	0.00	-0.02	0.01	-0.01	0.04	-0.08	0.01	0.00	0.01	0.00	-0.01	-0.01	0.03	0.16	-0.01	-0.01	-0.01
control	0.02	0.00	0.00	-0.01	-0.01	-0.04	0.01	0.02	0.00	0.03	0.01	-0.01	-0.01	0.02	0.13	0.00	-0.02	0.01

20°C

GROSS SPEED

wpm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	45	85	33	70	46	19	42	69	49	44	51	63	77	43	53	70	62	85
TAC	45	85	34	70	48	19	41	63	50	42	51	57	79	43	37	72	63	83
control	40	81	35	71	45	18	43	69	51	43	51	59	75	44	43	69	64	83

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	0.00	0.00	0.03	0.00	0.04	0.00	-0.02	-0.09	0.02	-0.05	0.00	-0.10	0.03	0.00	-0.30	0.03	0.02	-0.02
control	-0.11	-0.05	0.06	0.01	-0.02	-0.05	0.02	0.00	0.04	-0.02	0.00	-0.06	-0.03	0.02	-0.19	-0.01	0.03	-0.02

ACCURACY

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	97	95	95	97	98	83	96	96	96	95	97	97	96	97	91	96	98	97
TAC	98	95	93	96	95	88	96	96	95	89	96	94	96	95	93	94	95	98
control	95	98	96	95	97	82	96	97	95	91	98	96	98	96	92	95	97	97

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	0.01	0.00	-0.02	-0.01	-0.03	0.06	0.00	0.00	-0.01	-0.06	-0.01	-0.03	0.00	-0.02	0.02	-0.02	-0.03	0.01
control	-0.02	0.03	0.01	-0.02	-0.01	-0.01	0.00	0.01	-0.01	-0.04	0.01	-0.01	0.02	-0.01	0.01	-0.01	-0.01	0.00

28°C

GROSS SPEED

wpm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	43	83	34	67	48	18		66	49	37	48	55	73	43	52	63	64	87
TAC	43	81	34	68	49	15		68	51	41	56	59	74	43	57	63	62	87
control	42	82	34	70	49	18		62	46	38	50	59	76	44	45	70	68	88

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	0.00	-0.02	0.00	0.01	0.02	-0.17		0.03	0.04	0.11	0.17	0.07	0.01	0.00	0.10	0.00	-0.03	0.00
control	-0.02	-0.01	0.00	0.04	0.02	0.00		-0.06	-0.06	0.03	0.04	0.07	0.04	0.02	-0.13	0.11	0.06	0.01

ACCURACY

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	96	96	95	95	98	85		96	95	87	97	96	98	96	89	98	97	96
TAC	97	96	93	93	98	89		95	96	96	95	94	97	96	91	97	98	98
control	96	95	97	97	98	83		96	96	95	98	96	97	97	85	96	97	97

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	0.01	0.00	-0.02	-0.02	0.00	0.05		-0.01	0.01	0.10	-0.02	-0.02	-0.01	0.00	0.02	-0.01	0.01	0.02
control	0.00	-0.01	0.02	0.02	0.00	-0.02		0.00	0.01	0.09	0.01	0.00	-0.01	0.01	-0.04	-0.02	0.00	0.01

30°C

GROSS SPEED

wpm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	48	88	36	75	51		44	66	54	38	44	61	73	39	44	68	65	88
TAC	44	83	37	71	53		46	65	49	42	47	57	80	47	35	62	62	84
control	44	88	36	72	50		38	65	50	39	45	65	79	41	38	65	68	89

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	-0.08	-0.06	0.03	-0.05	0.04		0.05	-0.02	-0.09	0.11	0.07	-0.07	0.10	0.21	-0.20	-0.09	-0.05	-0.05
control	-0.08	0.00	0.00	-0.04	-0.02		-0.14	-0.02	-0.07	0.03	0.02	0.07	0.08	0.05	-0.14	-0.04	0.05	0.01

ACCURACY

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	95	97	95	98	99		96	96	95	95	97	95	97	97	68	95	96	97
TAC	96	95	95	97	98		97	96	95	94	98	94	97	96	86	95	94	96
control	95	96	91	97	99		95	96	94	94	99	94	96	96	89	96	97	96

%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
no	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TAC	0.01	-0.02	0.00	-0.01	-0.01		0.01	0.00	0.00	-0.01	0.01	-0.01	0.00	-0.01	0.26	0.00	-0.02	-0.01
control	0.00	-0.01	-0.04	-0.01	0.00		-0.01	0.00	-0.01	-0.01	0.02	-0.01	-0.01	-0.01	0.31	0.01	0.01	-0.01

REFERENCES

Arens E., Zhang H., (2006). T*he skin's role in human thermoregulation and comfort, from Thermal and Moisture Transport in Fibrous Materials*, edited by N. Pan and P. Gibson

Arens, E., Zhang H., Huizenga C., (2006). *Partial- and whole body thermal sensation and comfort Part II: non-uniform environmental conditions*. Journal of Thermal Biology, Vol. 31, 60-66.

ASHRAE (2004). ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy. Atlanta, ASHRAE, Inc.

Attia, M. and P. Engel (1981). *Thermal Alliesthesial Response in Man Is Independent of Skin Location Stimulated* Physiology & Behavior 27(3): 439 - 444.

Bauman F., Carter T., Baughman A., (1998). *Field Study of the Impact of a Desktop Task/Ambient Conditioning System in Office Buildings*, eScholarship Repository, University of California

Brager G., de Dear R., (2000). *A Standard for Natural Ventilation*, ASHRAE Journal.

Cabanac, M. (1971). *The Physiological Role of Pleasure*. Science 173: 1103 - 1107.

Chen Q., Moser A., & Suter P. (1992). *A numerical study of indoor air quality and thermal comfort under six kinds of air diffusion.* ASHRAE Transactions, 98(1), 203-217.

Fang L., Wyon D.P., Clausen G., Fanger P.O. (2004). *Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance*, Indoor Air 2004; 14 (Suppl 7): 74–81

Fanger, P.O., Melikov A. K., et al. (1988). *Air Turbulence and Sensation of Draught*. Energy and Buildings 12: 21 - 39.

Fisk W.J., Faulkner D., Pih' D., McNeel, Bauman F., Arens E., (1991) *Indoor Air Flow and Pollutant Removal in a Room with Task Ventilation,* Indoor Air, 3, 247-262

Givoni B., (1969). *Man, climate, and architecture,* Amsterdam, New York, Elsevier.

Goto, T., J. Toftum, et al. (2002). *Thermal Sensation and Comfort with Transient Metabolic Rates*. Proceedings of Indoor Air Conference, Monterye, USA.

Hagino, M. and J. Hara (1992). *Development of a Method for Predicting Comfortable Airflow in the Passenger Compartment.* SAE Technical Paper Series 922131: 1 - 10.

Hedge A. (2004). *Chilly Offices Up Errors*. ASHRAE e-News Oct. 21.

Heschong L., (1979). *Thermal Delight in Architecture*, The MIT press.

Holmberg, I. and D.P. Wyon (1969). *The Dependence of Performance in School on Classroom Temperature.* Educational and Psychological Interaction 31.

Humphreys M.A., Nicol J.F., McCartney K.J., (2002). *An analysis of some subjective assessments of indoor air-quality in five European countries*. Indoor Air 2002 Vol. 5, 86-91

Huizenga C., Abbaszadeh S., Zagreus L., Arens E., (2006). *Air Quality and Thermal Comfort in Office Buildings: Results of a Large Indoor Environmental Quality Surve.* Proceedings of Healthy Buildings, Lisbon, Vol. III, 393-397

Lechner R., (2001). *Heating, Cooling and Lighting*, John Wiley & sons, inc

Marston Fitch J., (1972). *American Building: The Environmental Forces That Shapes It*, Boston MA: Huoghton Miffin Co.

Melikov A.K., (2004). *Personalized Ventilation* Indoor Air 2004; 14 (suppl.7): 157-167

Melikov A.K., Knudsen G.L., (2007). *Human Response to an Individually Controlled Microenvironment*, vol.13, n.4 HVAC&R RESEARCH.

Niemela, R., M. Hinnula, K. Reijula, and J. Railio, (2002). *The effect of air temperature on labour productivity in call centers – A case study*. Energy and Buildings, Vol. 34 (8): 759 – 764.

Parsons, K. (1983) *Human Thermal Environment*, London, UK: Taylor & Francis, 199-217.

Pepler, R.D., R.E. Warner (1968). *Temperature and Learning: An Experimental Study*. ASHRAE Transactions 74, 211 - 219

Persily A., (2005). *What we think we know about ventilation* Preceedings of Indoor Air 2005. Bejiin

Seppänen O., Fisk W., (2006). *Some Quantitative Relations between Indoor Environmental Quality and Work Performance or Health*. Vol. 12, n.4 HVAC&R RESEARCH. October 2006

Tanabe, S. and N. Nishihara, (2004). *Productivity and fatigue*. Indoor Air, Vol. 14 (suppl 7): 126–133.

Tham KW and HC Willem, (2004). *Temperature and ventilation effects on performance and neurobehavioral-related symptoms of tropically acclimatized call center operators near thermal neutrality*. ASHRAE Transactions.

Toftum J. (2004). Air movement-good or bad? Indoor Air 2004; 14 (Suppl 7): 40–45

Tse W.L., So A.T.P., (2007). The Importance of Human Productivity to Air-Conditioning Control in Office Environments vol.13, n.4 HVAC&R RESEARCH

Yi-Fu Tuan, (1974). *Topophilia: A Study of Environmental Perception, Attitudes, and Values*, Englewood Cliff NJ: Prentice-Hall

Wang D., Zhang H., Arens E., Huizenga C., (2005). *Time Series Observations of Upper-Extremity Skin Temperature and Corresponding Thermal Sensation*. Proceedings: Indoor Air 2005

Zagreus L., Huizenga C., Arens E. and Lehrer D., (2004) *Listening to the occupants: a Web-based indoor environmental quality survey*, Indoor Air, 14, Issue s8, Page 65-74

Zhang, H., (2003) *Human Thermal Sensation and Comfort in Transient and Non-Uniform Thermal Environments*. Ph.D. Thesis, CEDR, University of California at Berkeley, pp 415

Zhang H., Arens E., Abbaszadeh Fard S., Huizenga C., Paliaga G., Brager G., Zagreus L., (2007) *Air Movement Preferences Observed in Office Buildings* International Journal of Biometeorology 51: 349-360

Wargocki P., Seppänen O., Andersson J., Boerstra A., Clements–Croome D., Fitzner K., Hanssen S., (2006) *Indoor climate and productivity in office. How to integrate productivity in life–cycle cost analysis of building service*, Rehva, Federation of European Heating and Air–conditioning Associations.

Witterseh, T., Wyon D.P., Clausen G., (2004). *The Effects of Moderate Heat Stress and Openplan Office Noise Distraction on SBS Symptoms and the Performance of Office Work.* Indoor Air 14 (Suppl 8): 30 – 40.

Zhang H., Kim D., Arens E., Buchberger E., Bauman E., Huizenga C., (2008) *Study of comfort, perceived air quality and productivity with a highly-efficient task-ambient conditioning (TAC) system. Internal report,* Center for the built environment