PERSONAL FANS FOR IMPROVING COMFORT

by

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PERSONAL FANS FOR IMPROVING COMFORT

INTRODUCTION

ASHRAE Standard 55-1981, Thermal Environmental Conditions for Human Occupancy, deals with six factors influencing the thermal environment. The environmental parameters are air temperature, mean radiant temperature, water vapor pressure, and air movement. The other parameters, clothing and activity, are personal in nature. The 1981 standard specifies conditions in which at least 80% of the occupants will find the environment thermally acceptable, that is, they will be slightly warm, neutral, or slightly cool. ASHRAE Standard 55 also incorporates winter and summer comfort ranges as well as a means of extending the summer comfort envelope by correspondingly increasing air movement.

The use of fans for cooling is not a new idea. Egyptian kings and Roman emperors were cooled by the air movement produced by fans in the hands of their slaves. However, research on the effect of air movement on the thermal environment has been limited. Many of the early studies that were conducted neglected to report on many of the factors affecting thermal comfort and the thermal environment. Rohles (1967) addressed the problems associated with research in environmental psychology. The number of variables that must be considered is large and includes physical variables (temperature, relative humidity, air movement, radiant temperature, atmospheric pressure, inspired gas, light, sound), organismic variables (basal metabolism rate, rhythmicity, age, sex, diet), and reciprocative variables (activity, clothing, exposure time, group size). The large number of factors to be considered (keeping in mind that each may vary along a continuum), added to the subjectivity of responses to the thermal environment, compounds the difficulty of research in this area.

One of the first studies dealing with air velocity as a primary variable was published by Houghten and Yaglou (1924). The experiment was conducted with three subjects, each stripped to the waist and wearing lightweight trousers. The subjects moved from one chamber with still air to another chamber with a uniform velocity and voted on the relative coolness between the two. Temperatures ranged from 4.4 C to "body temperature"; air velocities ranged from 0 to 3.6 m/s; and relative humidities were 20, 40, 60, 80 and 100 percent. Approximately 1000 tests were made. The conclusions reached by Houghten and Yaglou were that: a) the higher the relative humidity for a given dry bulb temperature, the greater the cooling produced by any air velocity, b) no cooling is produced by moving air for dry bulb temperatures equal to body temperature at 100% relative humidity or for slightly lower temperatures at 0% relative humidity, and c) for any condition, there is greater cooling per unit increase in air velocity for lower velocities than for higher velocities.

In 1965, Rohles published two articles dealing with the effect of wind (air movement) on monkeys. He also published a third article in 1970 on the same subject. The monkeys were placed one at a time into a test chamber. The chamber was equiped with a device to stop the air velocity when the monkey pressed a lever inside the chamber. These studies were conducted at velocities ranging from 0.6 to 9.0 m/s and temperatures ranging from 10 to 32.2 C. The conclusions were that: a) winds greater than 4.5 m/s were regarded as aversive and were avoided most of the time regardless of temperature, b) as velocity decreased or as temperature increased, percent avoidance decreased, and c) winds less than 2.2 m/s each have a normal curve of pleasantness. That is, at low temperatures the wind is unpleasant, at comfortable temperatures the wind is pleasant, and at high temperatures the wind is again unpleasant.

Another type of cooling using air movement is the use of "air showers". With air showers, the air temperature, humidity, and velocity output all can be controlled. Air showers are generally used in "hot" environments with the air directed at the subject's face. Berdan et al. (1970) as well as Azer et al. (1971) studied the effect of various speeds (up to 4 m/s) and temperatures (15 to 35 C) of air directed at the face of a worker in a hot environment. Azer et al. found that the most important factor for improving thermal comfort was the temperature of the air output. The conditions most favored in both of these studies were 29 C air temperature with 58 to 60% relative humidity. Berdan et al. found favorable results with air velocities up to 3 m/s while Azer et al. found a velocity of 1 m/s to be most comfortable.

Most research in thermal comfort has been done by allowing two parameters to vary and keeping the other factors constant. Fanger (1967) felt this method of research was very limited, time consuming, and expensive. Based upon mean skin temperature and sweat secretion, Fanger developed a comfort equation with the following principal variables: air temperature, humidity (partial vapor pressure), mean radiant temperature, relative air velocity, activity level (internal heat production), and insulation value of the clothing.

Fanger's comfort equation makes it possible to predict the cooling effect of air movement on thermal comfort. It shows that, for a lightly clothed sedentary person, an increase in ambient temperature of 2.5 C is compensated by an air speed of 1 m/s (McIntyre, 1978). However, the comfort equation does not indicate whether such a condition is found acceptable or whether a maximum temperature exists above which an increase in air speed does not compensate for the increased air temperature. It also fails to account for other aspects of the air velocity such as the air pressure.

Research in thermal comfort and conditions affecting the thermal environment has been conducted in one of two ways. The first is to establish the parameters to be evaluated, expose subjects to these conditions, and then obtain results based upon physical measurements (skin temperature, sweat secretion, etc) and/or ballots completed by the subjects. The second method is to establish the parameters to be evaluated, then allow control of those parameters by the subject.

Fanger et al. (1974) conducted a study in which four subjects were exposed to a *uniform* air flow (0.8 m/s) from five directions: horizontal from the front, from the side, and from behind, and vertical from below and from above. The temperature initially was set where, according to Fanger's comfort equation (1967), optimum comfort would occur (25.5 C in still air and 27.7 C in 0.8 m/s velocity). (This is equivalent to a 2.75 C increase in temperature with a 1 m/s increase in velocity.) The temperature then was adjusted according to the subject's desires. The result of this study indicated that the preference of an ambient air temperature is independent of the direction of the air flow. During the same test, Fanger added turbulence to the air flow from the front. Although insufficient information was available to draw any firm conclusions, a higher temperature was preferred when the turbulence was added. This again points out the need to look at the characteristics of the air movement studied.

Rohles et al. (1974) exposed 90 subjects to a uniform air flow at three velocities (0.2, 0.4, and 0.8 m/s) at each of three temperatures (22.2, 25.8, and 29.6 C). The four responses measured were skin temperature, thermal sensation, air plume quality, and sound level. The results indicated that: a) thermal sensation, weighted mean skin temperatures, air motion, and sound level affectivities all demonstrated significant exposure period adaptations, b) no significant sex differences existed in thermal sensations at the higher velocities tested after three hours exposure, c) significant differences in temperatures and temperature by air motion interaction indicate the importance of convective heat transfer in predicting thermal sensations and air motion affectivity, d) weighted mean skin temperatures were significantly influenced by air temperatures and velocities, and e) thermal sensations may be linearly correlated with ET* and air movement.

Fanger (1975) published a report on two types of spot cooling--

radiant and convective. Fanger made these assesments on convective spot cooling. A significantly higher ambient temperature is acceptable when the velocity is increased up to around 1 m/s, but the effect of a further increment of the velocity is small. If the air temperature in the space is higher than 29 to 30 C, comfort "cannot" be achieved by increasing the velocity. However, an increase in velocity will reduce the degree of warm discomfort. At temperatures above 35 C, the air velocity should not be raised as it increases convective heat supply to the body. Fanger suggests that, when using spot cooling, the individual should be allowed to control the system.

Several studies have been conducted on the cooling effects of ceiling fans. Burton et al. (1975) observed six individuals (all males) who were seated directly beneath a ceiling fan. Each subject experienced four different temperatures (26.3, 27.3, 28.1, and 29.1 C) at 60% relative humidity for three hours. During the exposure period, the subject was allowed to control the speed of the fan. Burton found that the fan speed chosen was dependent upon the temperature but that the air velocities chosen were higher than those predicted by Fanger's equation. An age effect also was found that had not been reported elsewhere; that is, the younger the subject, the higher the velocity chosen for a given temperature. The subjects ranged in age from 44 to 62.

McIntyre (1978) experimented with eleven subjects to determine what air speed would be desired at temperatures ranging from 22 to 30 C at 50% relative humidity. The subjects varied the speed of the ceiling fan--allowing them to take two variables into account, the cooling effect of the air as well as the pressure it exerts on the skin. The fan speeds chosen were linked to the air temperature but the velocities were below those predicted by Fanger's comfort equation. Therefore the subjects did not use the fan to obtain thermal neutrality but set it at some intermediate level of cooling. This may be due to the perception that the pressure of the air movement varies with the square of the air speed and the cooling effect varies with the square root. Some subjects preferred air speeds at low temperatures which were higher than those needed for thermal comfort--possibly to benefit from "freshness". McIntyre also found that the upper limit of air temperature at which comfort can be maintained is about 28 C. Above this, the air speed required to decrease warmth discomfort produces too much disturbance.

Rohles et al. (1982) conducted research on the effect of ceiling fans at 24.4, 26.1, 27.8, and 29.4 C at 50% relative humidity. The air velocities produced by the fan at set locations in the room were 0.15, 0.25, 0.46, and 1.02 m/s; the velocity without the fan was 0.06 m/s. Rohles found that if the velocity was 1.0 m/s, the use of a ceiling fan was comparable to a 3.3 C decrease in air temperature, thus allowing the upper limit of the summer comfort envelope to be increased to 29.4 CET* by using a velocity of 1.0 m/s. This exceeds the upper limit of 27.8 C with a velocity of 0.8 m/s established by ASHRAE Standard 55-1981. However, the ASHRAE Standard was based upon a uniform air velocity. Since the air plume from the ceiling fan has a highly variable velocity, the ASHRAE Standard may need to be adjusted to account for this variability.

Another type of fan that has been introduced to the market is a personal fan. The purpose of this paper is to explore various positions and orientations for placement of this fan to determine which produce the best results.

METHOD

Location and subjects

All tests were conducted in the main KSU-ASHRAE chamber during the week of 14-18 June 1982. Sixteen college age students, all right-handed females, participated; each was paid $15.

Design

The fan used during this study was a Braun personal fan (Figure 1). This fan is relatively small (approximately 6 inches (16 cm) long and 2½ inches (6.3 cm) in diameter) with a very directional air flow--velocity of 1.5 m/s at .7 m (Figure 2). Eleven conditions were used--four no-fan conditions, six standard fan conditions, and one "choice" fan condition. The six standard fan conditions included air directed at the subject's torso and air directed at the subject's face from each of three directions: directly in front of the subject (0^o), 30^o to the right of the subject, and 60^o to the right of the subject. Each condition was experienced for 20 minutes in the following sequence: three no-fan conditions (60 minutes), six standard fan positions (random se-

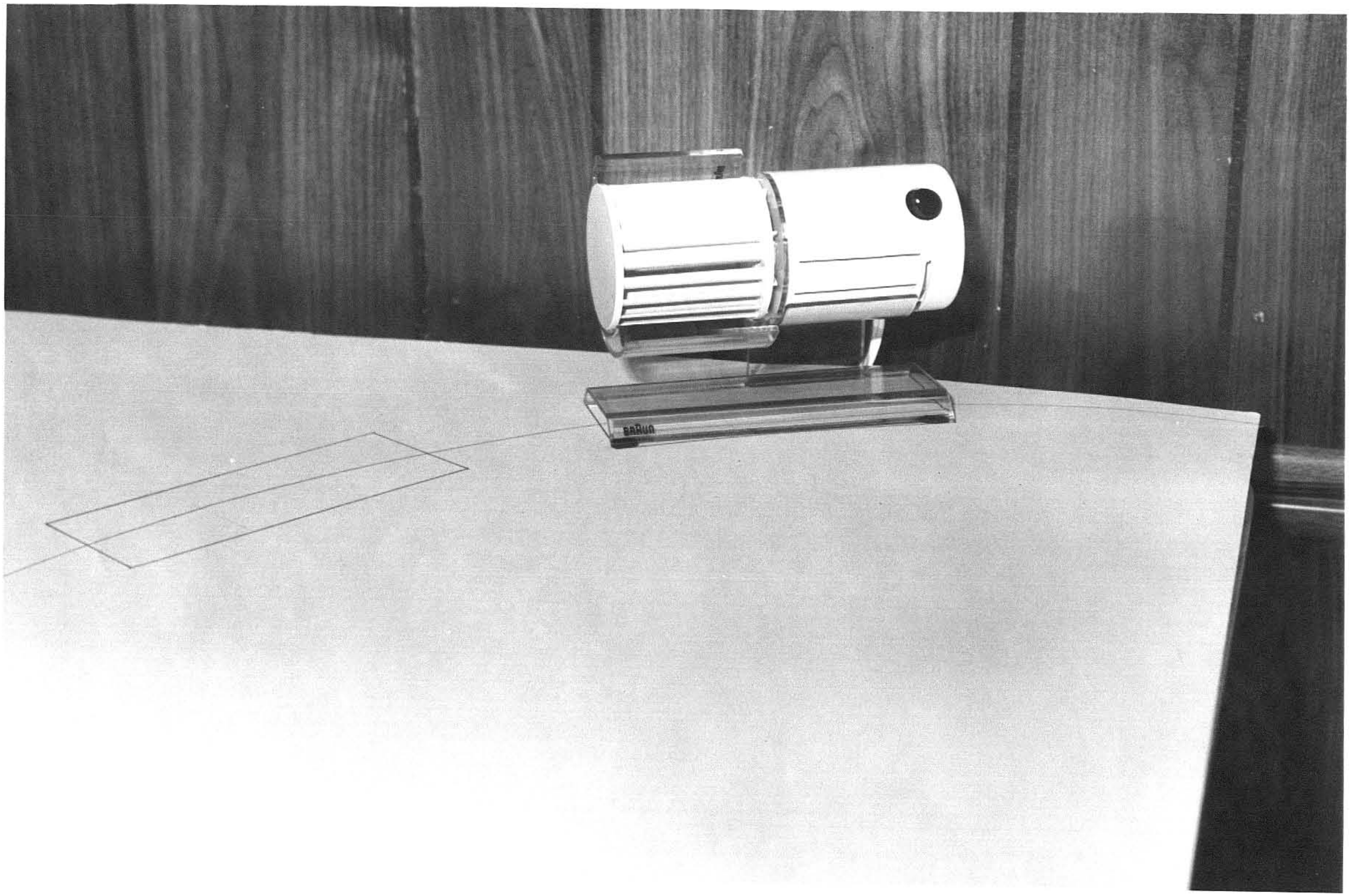

Figure 1. Braun personal fan used during the study.

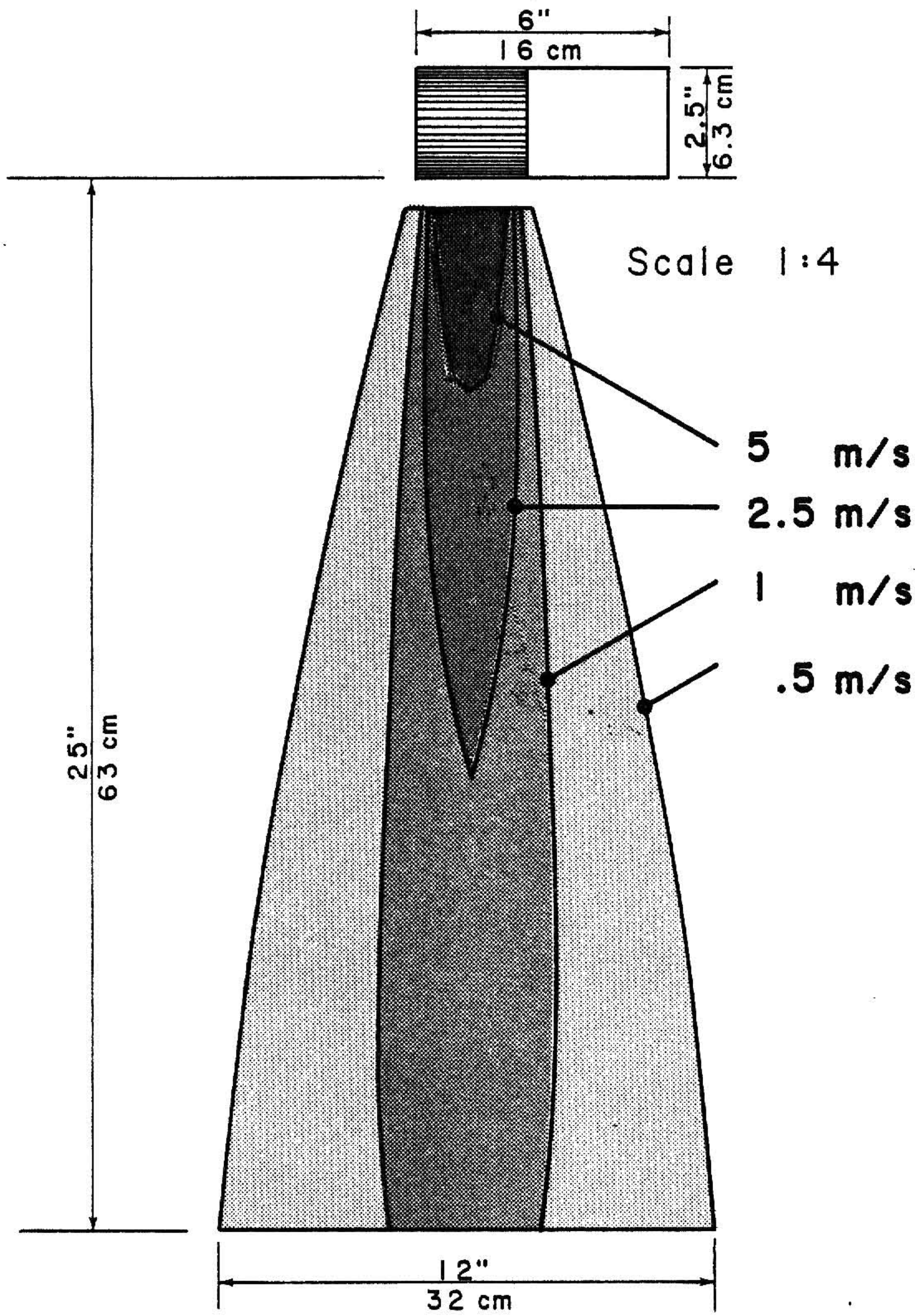

Figure 2. Velocity profile contours from Braun fan at various distances.

quence--120 minutes), the fourth no-fan condition (20 minutes), and the "choice" condition (20 minutes). The fan positions were located along a .46 m (18") radius arc (from the fan to the edge of the work station) where the velocity was approximately 1.5 m/s. For the choice fan condition, the subject was allowed to position the fan anywhere along the same arc. This kept the distance from the fan to the person constant.

Four criteria were measured by using votes taken during the tests. Thermal Sensation was evaluated through use of a nine category scale. Thermal Comfort was evaluated by using seven adjective pairs with nine possible values for each pair (Figure 3). Air Plume Quality was evaluated by means of a ballot with 34 adjective pairs with each pair having nine possible values (Figure 4). Temperature Preference was evaluated by having each subject indicate whether they desired the same temperature or how many degrees F warmer or cooler they preferred (Figure 5).

The air temperature was maintained at 26.1 C (79 F) throughout the experiment. The relative humidity was 50%. The activity level was seated sedentary. Each subject wore a short sleeved shirt, lightweight trousers, socks and sandals plus their own underwear; clo value was 0.5.

There were four subjects per test group. Each subject was assigned a work station consisting of a 36 by 27 inch (91.4 by 68.6 cm) work table with a chair, flourescent desk light, and a fan. Each work station was separated by a partition. Figure 6 shows the arrangement of the work stations in the chamber as well as the positions of the fan at each work station.

Subject Number _______
Ballot Number _______

THERMAL SENSATION

- ☐ VERY HOT
- ☐ HOT
- ☐ WARM
- ☐ SLIGHTLY WARM
- ☐ NEUTRAL
- ☐ SLIGHTLY COOL
- ☐ COOL
- ☐ COLD
- ☐ VERY COLD

THERMAL COMFORT

COMFORTABLE	___:___:___:___:___:___:___:___:___	UNCOMFORTABLE
BAD TEMPERATURE	___:___:___:___:___:___:___:___:___	GOOD TEMPERATURE
PLEASANT	___:___:___:___:___:___:___:___:___	UNPLEASANT
WARM	___:___:___:___:___:___:___:___:___	COOL
UNACCEPTABLE	___:___:___:___:___:___:___:___:___	ACCEPTABLE
SATISFIED	___:___:___:___:___:___:___:___:___	DISSATISFIED
UNCOMFORTABLE TEMPERATURE	___:___:___:___:___:___:___:___:___	COMFORTABLE TEMPERATURE

Figure 3. Thermal Sensation and Thermal Comfort Ballots.

Subject Number ______
Ballot Number ______

AIR PLUME QUALITY SCALE

RELAXING	___:___:___:___:___:___:___:___:___	TENSE
ACCEPTABLE	___:___:___:___:___:___:___:___:___	UNACCEPTABLE
TEAR INDUCING	___:___:___:___:___:___:___:___:___	NON-TEAR INDUCING
GUSTY	___:___:___:___:___:___:___:___:___	CONSTANT
REFRESHING	___:___:___:___:___:___:___:___:___	UNREFRESHING
FAVORABLE	___:___:___:___:___:___:___:___:___	UNFAVORABLE
EXCITING	___:___:___:___:___:___:___:___:___	SOOTHING
BAD CIRCULATION	___:___:___:___:___:___:___:___:___	GOOD CIRCULATION
DISLIKE	___:___:___:___:___:___:___:___:___	LIKE
DAMP	___:___:___:___:___:___:___:___:___	NON-DAMP
FRESH	___:___:___:___:___:___:___:___:___	STALE
BREEZY	___:___:___:___:___:___:___:___:___	CALM
CLEAN	___:___:___:___:___:___:___:___:___	DIRTY
GOOD ODOR	___:___:___:___:___:___:___:___:___	BAD ODOR
NOISY	___:___:___:___:___:___:___:___:___	QUIET
BAD DIRECTION	___:___:___:___:___:___:___:___:___	GOOD DIRECTION
APPEALING	___:___:___:___:___:___:___:___:___	UNAPPEALING
SATISFYING	___:___:___:___:___:___:___:___:___	ANNOYING
USELESS	___:___:___:___:___:___:___:___:___	USEFUL
IMPRESSIVE	___:___:___:___:___:___:___:___:___	UNIMPRESSIVE
DISTINCTIVE	___:___:___:___:___:___:___:___:___	ORDINARY
FUNCTIONAL	___:___:___:___:___:___:___:___:___	NON-FUNCTIONAL
GOOD VENTILATION	___:___:___:___:___:___:___:___:___	POOR VENTILATION
UNCOMFORTABLE	___:___:___:___:___:___:___:___:___	COMFORTABLE
HUMID	___:___:___:___:___:___:___:___:___	NON-HUMID
DRAFTY	___:___:___:___:___:___:___:___:___	NON-DRAFTY
UNPLEASANT	___:___:___:___:___:___:___:___:___	PLEASANT
DRY	___:___:___:___:___:___:___:___:___	NOT DRY
GENTLE	___:___:___:___:___:___:___:___:___	BRISK
SUBDUING	___:___:___:___:___:___:___:___:___	STIMULATING
REPELLING	___:___:___:___:___:___:___:___:___	INVITING
GOOD	___:___:___:___:___:___:___:___:___	BAD
INVIGORATING	___:___:___:___:___:___:___:___:___	NON-INVIGORATING
TURBULENT	___:___:___:___:___:___:___:___:___	SMOOTH

Figure 4. Air Plume Quality ballot.

Subject Number ______
Ballot Number ______

TEMPERATURE PREFERENCE

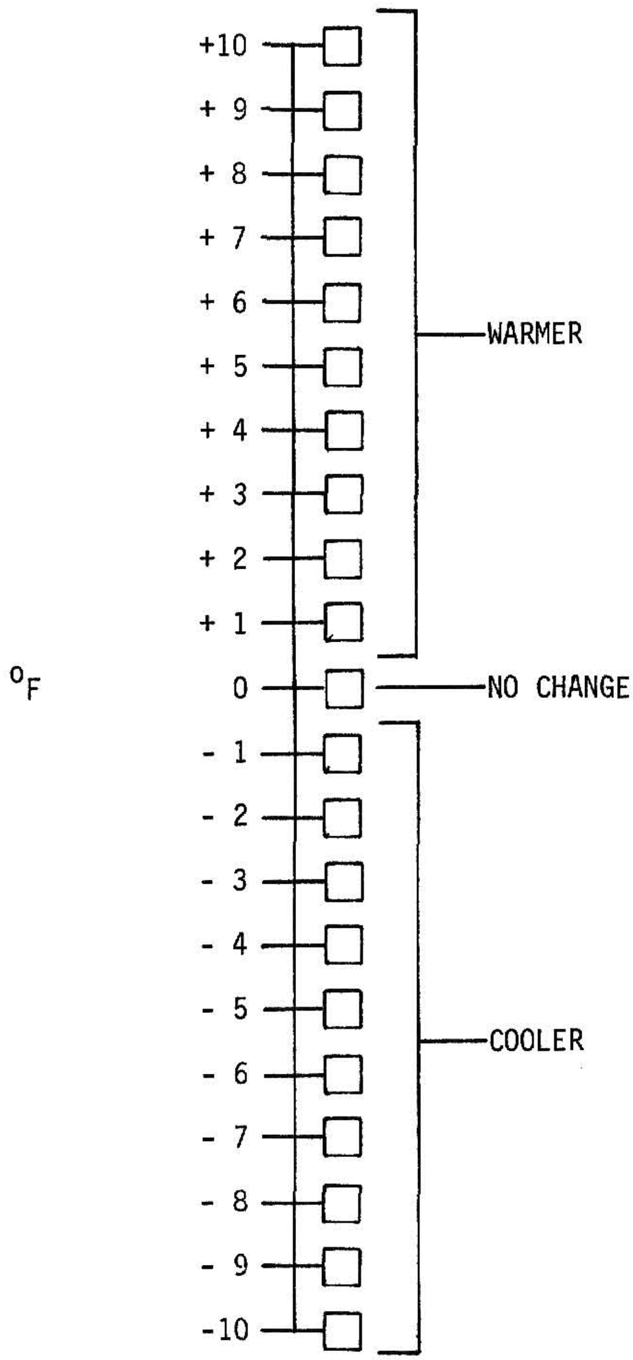

Figure 5. Temperature Preference ballot.

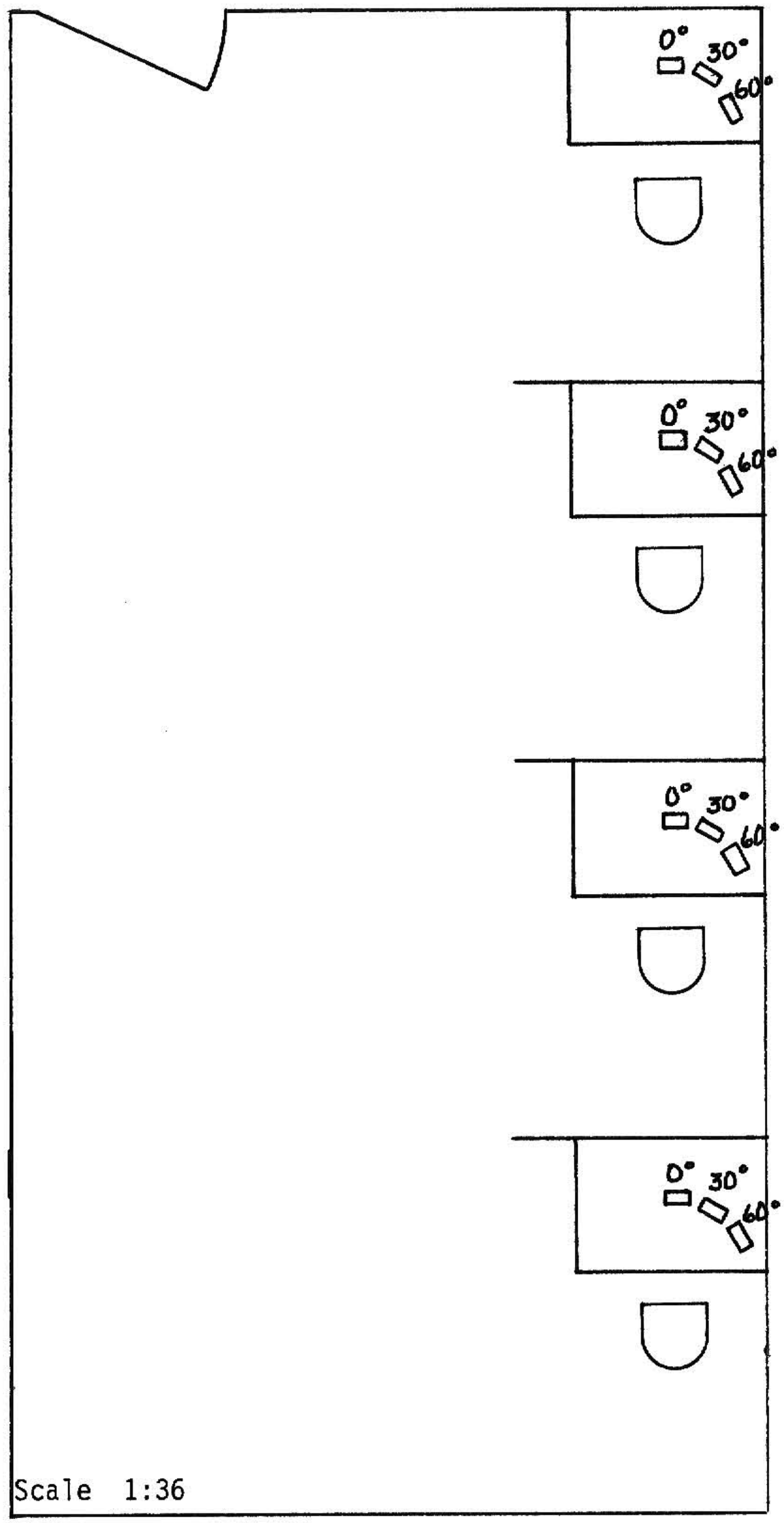

Figure 6. Arrangement of work stations within the chamber and position of fan at the work station.

Procedure

When the subjects reported for the experiment, they changed into the clothing provided and were seated in the pre-test room. They then were read an orientation statement (Appendix A) and completed the agreement and release form (Appendix B). They were assigned work stations in the chamber where they were allowed to read or study and the evaluation began.

The fan was off during the first hour of the test. Three "no-fan" ballots were taken during this period, one after each twenty minutes. All ballots were collected as soon as they were completed. During the next 120 minutes, each standard fan condition was experienced in a random sequence (Appendix C) for twenty minutes. Ballots were completed and collected at the end of each period. The fans then were turned off for another twenty minutes (4th no-fan condition) and another set of ballots completed and collected. During the final twenty minute period, the subjects were allowed to position the fan anywhere along the arc that they wanted (choice condition), completed another set of ballots, and were asked to define the most and least favored fan positions. At this time, the subjects were paid, changed clothes and were dismissed.

RESULTS

The eleven conditions analyzed were as follows: T0 - Torso at 0^o, T3 - Torso at 30^o, T6 - Torso at 60^o, F0 - Face at 0^o, F3 - Face at 30^o, F6 - Face at 60^{o}, C1 - Choice, and N1 through N4 - No-fan conditions. An analysis of variance was run on the six standard fan positions and angle was not found to be significant for any responses measured. Therefore, angle was deleted from further consideration. Another analysis of variance was performed which included the four no-fan conditions. This ANOVA indicated no significant differences existed among the no-fan conditions so they were combined in subsequent tests. The subjects also were divided into three groups based upon their eye characteristics: those wearing contact lenses, those wearing glasses, and those with no corrective lenses.

Thermal Sensation

The Thermal Sensation votes were rated as follows: very hot = 9, hot = 8, warm = 7, slightly warm = 6, neutral = 5, slightly cool = 4, cool = 3, cold = 2, very cold = 1. The data were subjected to an analysis of variance. Neither the angle from which the air was directed nor its position on the body (face vs torso) made a significant difference. There was, however, a significant difference between the no-fan conditions (mean = 5.3) and the fan conditions (mean = 4.1); $F_{3,164} = 24.8$, $\alpha < .05$. During the six fan conditions, corrective lenses were significant; $F_{2,103} = 3.4$, $\alpha < .05$. Table 1 shows a mean vote of 3.6 with glasses and 4.2 for contact lenses or no corrective lenses.

Temperature Preference

The same analysis was performed on the Temperature Preference votes

Table 1. Mean Thermal Sensation vote.

Corrective Lenses	Mean	Grouping*
Neither	4.2	A
Contacts	4.2	A
Glasses	3.6	B

*Means with the same letter are not significantly different at $p < .05$.

Table 2. Mean Temperature Preference vote.

Corrective Lenses	Mean (^{o}F)	Grouping*
Glasses	.7	A
Neither	.7	A
Contacts	-.4	B

*Means with the same letter are not significantly different at $p < .05$.

as was done on the Thermal Sensation votes. Temperature Preference also was independent of the angle from which the air was directed as well as the part of the body it was directed at (face vs torso). Again, the no-fan condition (want .88 F cooler) was significantly different ($F_{3,164}$ = 10.6, $\alpha < .05$) from the fan conditions (want .26 F warmer)--a difference of 1.14 F. Temperature Preference also showed the eye effect. Table 2 shows those wearing contacts preferred to have a cooler temperature (-0.4 F) than those with glasses (+0.7 F) or those with neither contacts nor glasses (+0.5 F); $F_{2,103} = 6.4, \alpha < .05$.

Thermal Comfort

Using the same procedure as Rohles et al. (1982), the Thermal Comfort ballots were evaluated by assigning a value from 1 for the least favorable adjective of the pair to 9 for the most favorable adjective. The assigned values then were multiplied by weighting factors and a percent comfort vote obtained (Figure 7). These votes were subjected to an analysis of variance and Duncan's Multiple Range Test. Table 3 shows means of all the conditions and their groupings. The choice condition was significantly better than the other conditions with a mean of 84; $F_{3,164} = 2.5$, $\alpha < .05$. There was no corrective lens effect on Thermal Comfort.

Air Plume Quality

The air plume quality votes were evaluated by assigning a value

Scoring of the Thermal Comfort Ballot

COMFORTABLE	9	8	7	6	5	4	3	2	1	UNCOMFORTABLE
BAD TEMPERATURE	1	2	3	4	5	6	7	8	9	GOOD TEMPERATURE
PLEASANT	9	8	7	6	5	4	3	2	1	UNPLEASANT
WARM	9	8	7	6	5	4	3	2	1	COOL
UNACCEPTABLE	1	2	3	4	5	6	7	8	9	ACCEPTABLE
SATISFIED	9	8	7	6	5	4	3	2	1	DISSATISFIED
UNCOMFORTABLE TEMPERATURE	1	2	3	4	5	6	7	8	9	COMFORTABLE TEMPERATURE

Numbers in the cells are the values assigned to each adjective pair. These values were multiplied by the following loadings: comfortable-uncomfortable, 0.555; bad temperature-good temperature, 0.693; pleasant-unpleasant, 0.628; warm-cool, 0.579; unacceptable-acceptable, 0.521; satisfied-dissatisfied, 0.568; uncomfortable temperature-comfortable temperature, 0.762. Percent Comfort is determined by the following formula: Thermal Comfort (%) = (Σ(Rating x loading) - 4.270) 2.92.

Figure 6. Scoring of the Thermal Comfort ballot.

Table 3. Mean Thermal Comfort votes.

Condition	Mean (%)	Grouping*
Choice	84	A
No-fan	71	B
Face	71	B
Torso	70	B

*Means with the same letter are not significantly different at $p < .05$.

from 1 for the least favorable of the adjective pair to a value of 9 for the most favorable. A factor analysis was performed which resulted in 27 of the adjective pairs being divided into five factors. The adjective pairs associated with each factor and the loading of each pair are listed in Table 4 with the most favorable adjective of the pair listed first. Each adjective's value then was multiplied by its loading factor summed and converted to a 100 point scale. These values then were subjected to the same analysis as the rest of the data. The analysis of variance on each of the factors established that the angle from which the air was directed was not significant. In four of the five factors, the vote was significantly higher for the choice fan condition than for the other conditions.

Factor 1 (Pleasantness) (Table 5 and Figure 8) had a mean of 88 for the choice condition which was significantly higher than the means of 67 for the no-fan and torso conditions. The face condition was least preferred with a mean of 55; $F_{3,164} = 9.3$, $\alpha < .05$. These means are plotted by eye characteristics in Figure 8. Those individuals wearing contacts found air directed on the torso to be more pleasant than the face while those wearing glasses liked the air on the face.

Factor 2 (Stimulation) (Table 6) showed that the choice position (mean 58) was significantly better than the other positions (mean 50); $F_{3,164} = 3.0$, $\alpha < .05$. There was no difference for Factor 2 for those wearing corrective lenses.

Factors 3 (Freshness) (Table 7); $F_{3,164} = 6.0$, $\alpha < .05$, and 4 (Distinction) (Table 8); $F_{3,164} = 14.0$, $\alpha < .05$, showed that all fan

Table 4. Factors and loadings derived from the Air Plume Quality vote.

FACTOR 1 - Pleasantness		FACTOR 2 - Stimulation	
good/bad	.938	stimulating/subduing	-.869
like/dislike	.934	exciting/soothing	-.829
comfortable/uncomfortable	.934	gentle/brisk	.671
appealing/unappealing	.971	smooth/turbulent	.644
pleasant/unpleasant	.916	invigorating/non-invigorating	.634
favorable/unfavorable	.914		
satisfying/annoying	.906	FACTOR 3 - Freshness	
acceptable/unacceptable	.887	clean/dirty	.896
good direction/bad direction	.856	good odor/bad odor	.890
inviting/repelling	.725	fresh/stale	.738
relaxing/tense	.635	non-humid/humid	.665
useful/useless	.632	non-damp/damp	.661
good circulation/bad circulation	.613		
FACTOR 5 - Variability/gustiness		FACTOR 4 - Distinction	
non-tear inducing/tear inducing	.834	distinctive/ordinary	.770
constant/gusty	.777	dry/not-dry	-.713

Table 5. Mean values for Factor 1 (Pleasantness).

Condition	Mean (%)	Grouping*
Choice	88	A
No-fan	67	B
Torso	67	B
Face	55	C

*Means with the same letter are not significantly different at $p < .05$.

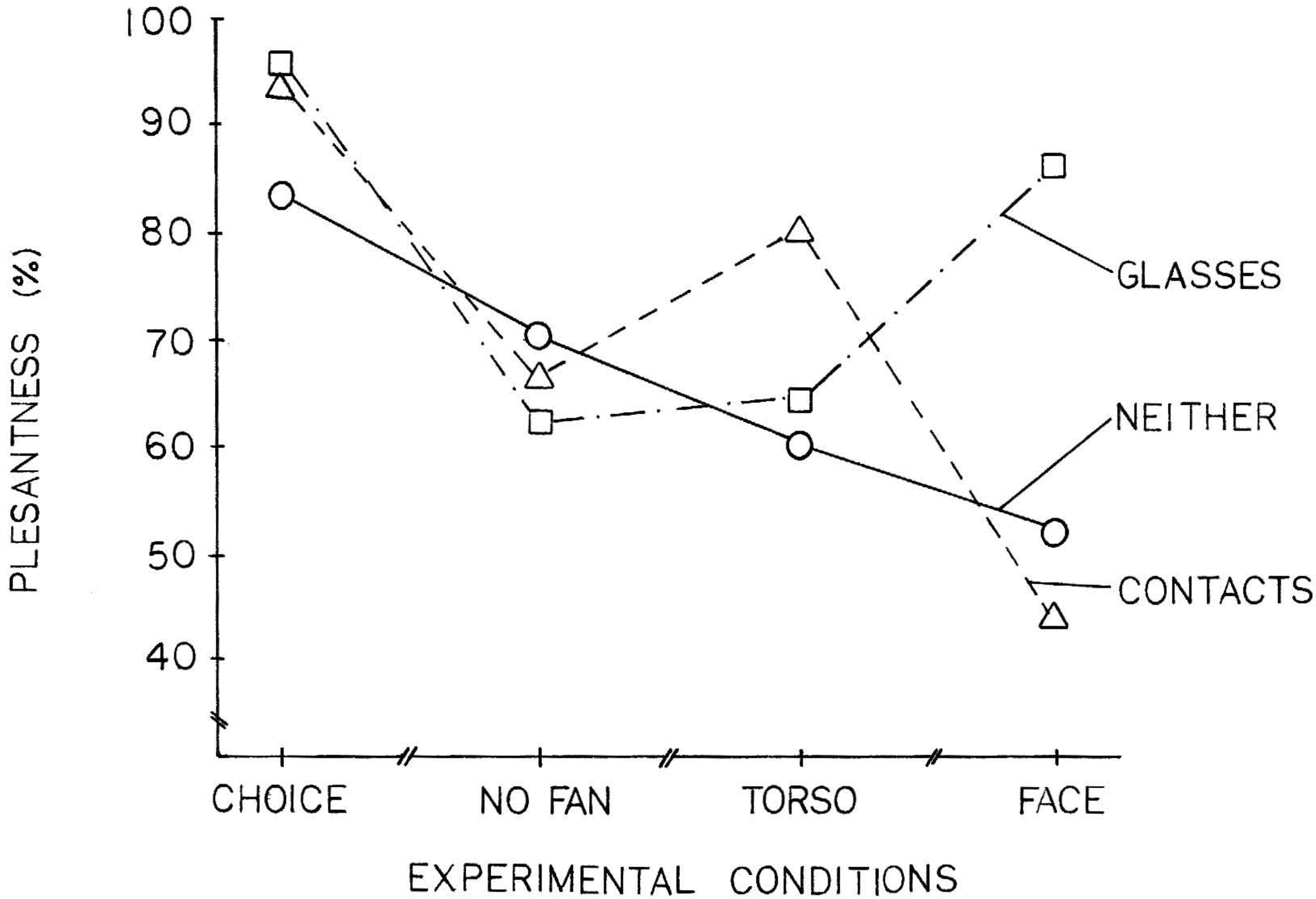

Figure 8. Mean values for Factor 1 (Pleasantness) for persons wearing glasses, contacts, and neither.

Table 6. Mean values for Factor 2 (Stimulation).

Condition	Mean (%)	Grouping*
Choice	58	A
Face	50	B
No-fan	50	B
Torso	50	B

*Means with the same letter are not significantly different at $p < .05$.

Table 7. Mean values for Factor 3 (Freshness).

Condition	Mean (%)	Grouping*
Choice	80	A
Face	77	A
Torso	76	A
No-fan	67	B

*Means with the same letter are not significantly different at $p < .05$.

conditions were better than the no-fan condition.

Factor 5 (Variability/Gustiness) (Table 9) showed a significant difference between conditions (90 for no-fan, 79 for choice, 58 for torso, and 47 for face); $F_{3,164} = 42.1$, $\alpha < .05$. The means for the eye characteristics are shown graphically in Figure 9.

Most and Least Favored Fan Positions

Table 10 gives most and least favored fan position votes. All five subjects with contact lenses preferred the torso and disliked the face. Of the three subjects with glasses, two preferred the face and one preferred the torso while one disliked the face and two disliked the torso. The remaining 8 subjects with no corrective lenses were fairly evenly divided. The face was preferred by five subjects and disliked by five subjects and the torso was preferred by three subjects and disliked by three subjects.

If most favored is +1 and least favored is -1, people with glasses rank the face +1 and the torso -1. People with no corrective lenses rank the face and torso as 0. People with contacts rank the face -5 and the torso +5.

DISCUSSION

One of the primary reasons for using a fan is to make the temperature "feel" cooler. There doesn't seem to be agreement on how much cooler a given velocity makes us feel. ASHRAE Standard 55 equates an

Table 8. Mean values for Factor 4 (Distinction).

Condition	Mean (%)	Grouping*
Choice	56	A
Face	56	A
Torso	54	A
No-fan	41	B

*Means with the same letter are not significantly different at $p < .05$.

Table 9. Mean values for Factor 5 (Variability/Gustiness).

Condition	Mean (%)	Grouping*
No-fan	90	A
Choice	79	A
Torso	58	B
Face	47	C

*Means with the same letter are not significantly different at $p < .05$.

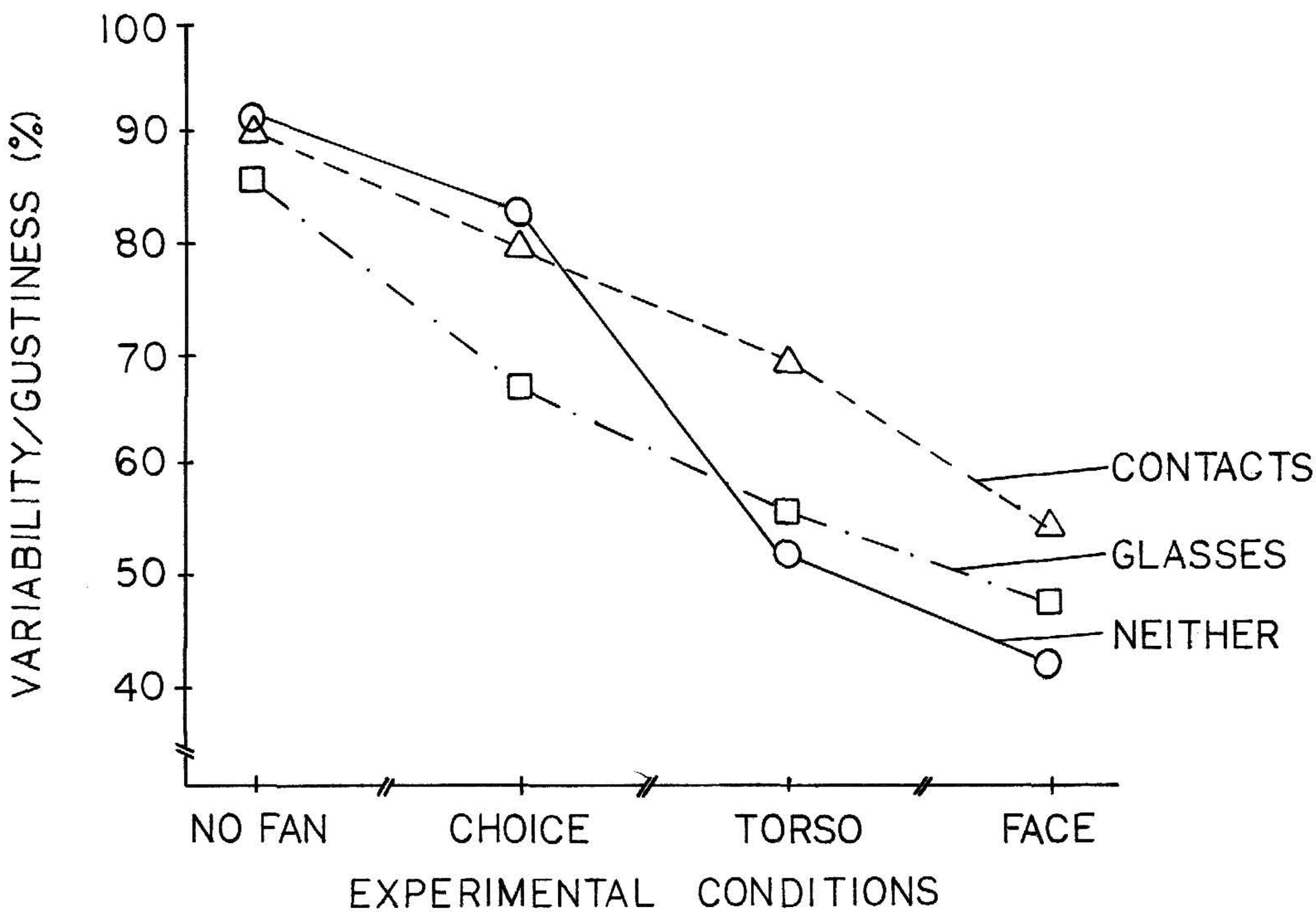

Figure 9. Mean values for Factor 5 (Variability/Gustiness) for persons wearing glasses, contacts, and neither.

Table 10. Most and least favored fan positions (divided into eye characteristics) for the 16 subjects.

Contacts

MOST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	0	0	0	0
Torso	0	4	1	5
	0	4	1	5

LEAST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	3	1	1	5
Torso	0	0	0	0
	3	1	1	5

Glasses

MOST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	0	1	1	2
Torso	1	0	0	1
	1	1	1	3

LEAST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	0	0	1	1
Torso	2	0	0	2
	2	0	1	3

Neither

MOST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	4	0	1	5
Torso	0	1	2	3
	4	1	3	8

LEAST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	4	1	0	5
Torso	0	0	3	3
	4	1	3	8

Consolidated (All)

MOST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	4	1	2	7
Torso	1	3	5	9
	5	6	5	16

LEAST FAVORED POSITIONS

	0^o	30^o	60^o	
Face	7	2	2	11
Torso	2	0	3	5
	9	2	5	16

increase of 1 C to a velocity of 2.75 m/s. Fanger's comfort equation uses a .8 m/s velocity to compensate for a 2.2 C increase in temperature (2.75 C = 1.0 m/s). Rohles (1974) recommended an increase of 52.4 ft/min for each degree FET* (2.09 C = 1.0 m/s). In the study on ceiling fans, Rohles (1982) suggested an increase in the upper limit of the summer comfort envelope to 29.4 CET* with a velocity of 1.0 m/s (3.30 C = 1.0 m/s).

This study found the velocity from the personal fan equivalent to a 1.14 F (.63 C) decrease in temperature (.42 C = 1.0 m/s). Thus, the cooling effect of this fan is not as large as that found in studies involving other types of fans, possibly due to the smaller area of the body that is exposed to the air movement. This finding suggests that the personal fan should not be expected to make large differences in thermal sensation but rather to allow an individual to make a "fine tuning" to conditions at or near the comfort envelope currently defined in ASHRAE Standard 55. Unlike other types of cooling devices, including conventional fans, that are used to cool several people or an entire room, the personal fan is very individualized. This feature of the personal fan allows the individual the freedom to turn the fan on or off and direct it where it is most suitable for his needs at the time. This flexibility can compensate for individual differences in temperature preference, metabolic rate, activity level, and even radiant temperature increases such as when the sun shines through the window.

The control of the personal fan should be left to the individual. The need for individual control of spot cooling has been stressed by others and was confirmed by the results of this study. The votes obtained from Thermal Comfort and Factors 1 (Pleasantness), 2 (Stimulation), and 5 (Variability/Gustiness) all were significantly higher for the "choice" condition than for other conditions. The differences among those wearing contacts, glasses, and no corrective lenses also point to the need for individual freedom in fan placement and direction. Those wearing contact lenses disliked air directed at the face; those with glasses liked air directed at the face (possibly because their glasses act as a shield for the eyes); and those with no corrective lenses showed no obvious preferrences for the face or the torso. The angle from which the air was directed made no difference in any of the conditions.

In conclusion, the personal fan may be used to "fine tune" an already "acceptable" environment, it is individual in nature, and control of the fan must be left to the individual.

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APPENDIX A

ORIENTATION STATEMENT

The purpose of this study is to determine what effect, if any, the use of a personal fan has on your comfort. You should be fully aware that the conditions to which you will be exposed entail no physical risk or mental stress. You have volunteered to act as a subject and are participating on your own volition. You may leave the experiment any time you wish. Your identity as a subject will not be disclosed and anonymity will be maintained. You should be aware that Kansas State University as an agency of the State of Kansas, does not provide financial compensation (and/or long-term care) to human subjects for injuries resulting from participation in research. When the testing begins, you will go into the chamber and sit at assigned work stations. You may read or study. No eating, drinking or smoking will be allowed during the experiment. Each twenty minutes, you will be asked to complete these ballots. (Explain each ballot and how to mark.) During the experiment, the fan will be placed in various locations and orientations. At the end of the test, you will be allowed to position the fan anywhere you like along the arc marked at each work station. You will then complete another set of ballots and the last form which asks for the most and least favored fan positions and any comments that you have on the fan. At that time you may change into your clothes and be paid $15.00. Do you have any questions?

APPENDIX B

AGREEMENT AND RELEASE

1. I, ____ volunteer to participate in a project in connection with research studies to be conducted by Kansas State University.

2. I fully understand the purpose of the study as outlined in the orientation statement.

3. I understand that I may be observed during my participation and that my conduct and/or voice may be recorded by photographic and/or recording devices. I also realize that public reports and articles may be made of the experiments and all of the observations, and I consent to publication of such including the use of photographs if my face is "blanked" out.

4. I also understand that my performance as an individual will be treated as research data and will in no way be associated with me for other than identification purposes, thereby assuring anonymity of my performance and response.

5. I understand that I will be permitted to leave the test at any time and I may discontinue participation without penalty or loss of benefits to which I am otherwise entitled.

6. As compensation for my voluntary services as a participant in the aforesaid studies, Kansas State University may pay me. It is clearly understood and agreed, however, that in no event am I to be considered an employee of Kansas State University during such participation. Therefore, no Social Security, income tax, retirement or other benefits of employment will be deducted or accrued.

7. I hereby agree, under penalty of forfeiture of all compensation due me, not to give information regarding these studies to any public news media nor to publicize any articles or other accounts thereof without prior written approval of Kansas State University.

8. If I have any questions concerning my rights as a test subject, injuries or emergencies resulting from my participation or any questions concerning the study, I understand that I can contact ______________________________ at ___________________________.

   I have read the Subject Orientation and Test Procedure statement (reverse side) and signed the herein Agreement and Release, this _______ day of ________________, 19____.

____
Signature

Sign and return one copy. The second copy is for your records.

APPENDIX C

SEQUENCE OF SUBJECT'S EXPOSURE TO FAN CONDITIONS

CONDITION / SUBJECT	FACE			TORSO		
	0^o	30^o	60^o	0^o	30^o	60^o
1	3	6	4	2	5	1
2	2	3	4	5	6	1
3	6	3	4	5	1	2
4	3	2	6	4	5	1
5	5	2	1	4	3	6
6	2	3	6	1	4	5
7	4	6	2	1	3	5
8	5	4	3	6	2	1
9	5	6	1	3	4	2
10	4	1	6	3	2	5
11	5	6	1	2	3	4
12	2	3	6	4	5	1
13	4	6	5	2	1	3
14	3	6	2	1	5	4
15	4	3	5	1	2	6
16	4	2	5	1	2	6

PERSONAL FANS FOR IMPROVING COMFORT

by

HELEN M GOUGH

B.S., Kansas State University, 1972

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

This study tested different orientations and locations of a Braun personal fan to determine its effect on comfort.

Eleven conditions were used--four no-fan conditions, six standard fan conditions, and one "choice" fan condition. The six standard fan conditions included air directed at the subject's torso and air directed at the subject's face from each of three directions: directly in front of the subject (0^o), 30^o to the right of the subject, and 60^o to the right of the subject. All tests were conducted at 26.1 C (79 F) and a velocity on the person of about 1.5 m/s. The subject responded on four ballots: Thermal Sensation, Thermal Comfort, Air Plume Quality Scale, and Temperature Preference.

The use of the personal fan was equivalent to a 1.14 F (.63 C) decrease in air temperature (ie, .42 C = 1.0 m/s). This implies that the personal fan may be used as a "fine tuner" in an acceptable environment rather than a means of significantly improving thermal comfort in an unacceptable environment.

Placement of the fan should be left to the individual. Acceptability was considerably higher for the "choice" conditions than the other fan conditions. Those wearing contacts disliked air directed at the face, those with glasses liked air directed at the face, and those with neither contacts nor glasses were evenly divided between face and torso. The angle from which the air was directed was not significant for any of the conditions.