There's Nothing Like Being There: Perceptions of User Control and Information Quality in a Distributed Measurement Environment

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More and more customers are asking for and expecting remote access to measurement equipment. But, this new method of providing measurement information may have unintended consequences for the way users experience products and how they view the data provided. In this study, we examined the impact on users when they access information through a computer interface rather than directly from the instrument, the impact of physical distance from the measurement site, and the effect of using instruments that are stationary versus set up by the user. The results of an experiment suggest that users who are monitoring information from a remote location will feel less in control, but will feel equally confident in the measurement information gathered. The data also suggest that novices may feel more in control (but no more confident in the information) when using a stationary instrument as compared to having to set up the instrument themselves.

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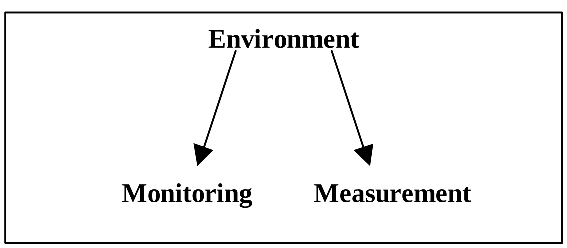
Acknowledgment

The research reported here was conceptualized and conducted by Janice Bradford, the project lead on the SIRCH project. After her departure from Hewlett Packard, the authors of this paper attempted to reconstruct the experiment, identified the hypotheses being tested, analyzed the data, and wrote up the results. Although Janice should not be held accountable for the content of this technical report, she deserves credit for the creativity involved in designing the study and the hard work of running it.

Introduction

The growing proliferation of technologies that allow remote access to information is causing people to gather more and more information from remote sources. Today, we rely not only on our own "first-hand" acquisition of knowledge, but also on secondary sources facilitated by technology. For example, many of us rely on the abundant resources of the Internet and other network systems to instantly gather information that would otherwise be more difficult and time-consuming to access. The Internet, however, is just one technology that facilitates distributed work. A monitoring system that takes readings in one or more locations and then reports back to a user in a different location also supports distributed work. For example, imagine a lab in which chemists set up analyses and later gather the results of these analyses from their desks or even from home or on the road. More and more customers are asking for and expecting this type of remote access to measurement information.

Remote monitoring systems offer new and efficient ways to collect information. However, there are important differences between the task of remote monitoring and the act of taking measurements at the instrument. In the example above, the chemist who is remotely monitoring the results of an analysis simply reads the information relayed to him or her by the system. On the other hand, a chemist who is physically present in the lab actively takes part in the measurement task. Thus, the distinction between monitoring and measuring may be quite significant from a psychological viewpoint. Monitoring requires the users' passive attendance to a system, while measurement generally involves active intervention on the part of the user. These two environments are represented in the diagram below:



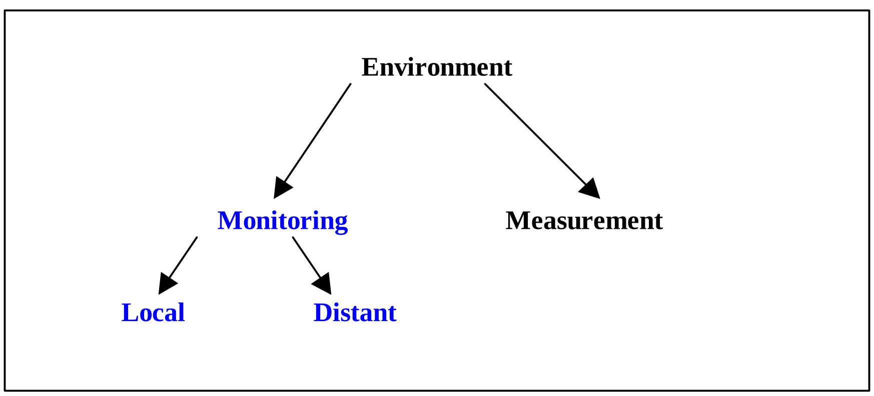
The differences in these two scenarios raises the question "How does the distance between a technology and its user effect the user's experience of the task and their perception of the measurement information?"

There are at least two major psychological differences between the monitoring and measurement environments. The first distinction is the extent to which the user is able to directly manipulate the instrument. In a traditional measurement scenario users actually see and touch the instruments they are working with. In a monitoring environment, users work with virtual tools and are unable to see directly the instrument taking the measurements. Similarly, in a measurement situation, users are able to view directly the instrument's output. In a monitoring scenario, users are viewing information that has been sent over a network. It is easy to imagine that users may be uncertain about how the data has been transferred and whether or not it is identical to the information they would have observed on the instrument. The second distinction is users' ability to subjectively verify information. Measurement users are physically co-located with the instrument. This co-location allows users to verify test information against information gathered through their own senses. For instance, they can see whether a probe is positioned properly or smell a chemical solution. In a monitoring environment, users are not able to use their own senses to verify measurement information because they aren't co-located with the instrument or the item being tested. Because users in a monitoring environment are not able to see and touch the instrument taking measurements and are not able to subjectively verify measurement information, we expect users in a monitoring environment to feel less in control than users in a measurement environment. We also expect users' trust in the information to be reduced when the information is sent over a network. Thus, we posit the following hypotheses:

> *H1: Users will feel more in control when taking measurements directly from an instrument than when monitoring measurement information taken remotely.*

> *H2: Users will trust the quality of the measurement information more when they are taking measurements directly from an instrument.*

Unlike the measurement scenario, in which the user and the technology are in direct physical contact, the monitoring scenario takes place with the user and the technology each situated in a different location. However, the physical distance between user and technology can differ radically. For example, one could be sitting in an office in a building, and access a monitoring device that is located on the opposite side of that same building (local). In another situation, a monitoring device could be located hundreds of miles away from the user (distant). These scenarios are represented in the diagram below, under the "monitoring" label:

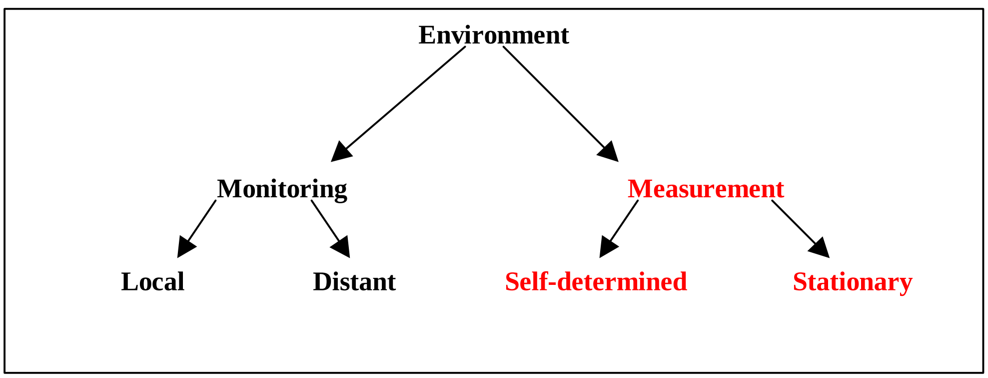


A user accessing a local monitoring system—that is, a system located in the same building that he or she is in—has, like measurement system users, a subjective knowledge of the environment the readings are being drawn from. This knowledge can be used to verify the monitoring equipment's readouts. Conversely, a user of a monitoring system located outside of the immediate environment had no additional knowledge to contribute to the output readings and must take it "on faith" that the information received is complete and correct. Similarly, users in the local situation have the option of walking over to the instrument and verifying that it is set up properly whereas those in distant situations are unable to check the instrument directly. Such distance from the instrument itself may reduce users' sense of control and users' confidence in the quality of the information. These observations lead us to formulate the following hypotheses:

H3: Perception of control will be higher when the user is monitoring an instrument from a local site.

H4: Perceptions of information quality will be higher when the user is monitoring an instrument from a local site.

Distinctions can also be made within a measurement environment. User orientation towards a technology can differ. Some instruments can be picked up and carried away, thus having its use and orientation determined by the user. Conversely, an instrument may need to remain stationary in a predetermined position while the user manipulates it. These scenarios are represented in the diagram below, under the "measurement" label:



When a user is able to determine his/her own measurement arrangement, he or she directs the course of the task at hand. In a task in which the instruments are stationary, the user works within a controlled measurement environment governed by predetermined protocols. This observation lead us to formulate the following hypothesis:

H5: Perception of control will be higher when the user is able to determine the position and orientation of the instruments being used.

The research reported here is designed to test the above hypotheses by examining users' experience in monitoring and measuring work environments.

Method

The study was a between-subjects design that compared perceived control and information quality when the user was conducting either a monitoring or measurement task. Participants were asked to record environmental measurements from four zones in a building. They were then asked to assess both the overall environmental quality of the building and the possibility that the building was suffering from "sick building syndrome" based on the data they had collected.

Participants

Participants were 61 undergraduate students enrolled in scientific disciplines (e.g., biology, chemistry) at Stanford University. They were recruited through postings on physical bulletin boards, and were paid for their participation. One subject was excluded from all analyses because he did the experiment twice.

Task

Participants were told that they would be working with measurement instruments made by HP competitors, and that they would be providing feedback on the instruments in order to help HP create their own versions of those instruments. Participants were told that the devices they'd be working with were designed to give readouts of different elements of environmental quality in a work environment, and that the readouts were essential in detecting the condition "sick building syndrome." Participants were also given information about "sick building syndrome," including its causes and consequences.

The first part of the task, outlined step-by-step in an instruction booklet given to each participant, consisted of taking a series of readings at four separate stations. Each of the four stations contained three instruments: a humidity/temperature meter, an anemometer for testing air velocity, and a light meter. At each station, participants took the maximum, minimum, and average readings for each instrument, which were recorded over time spans of 15 seconds to one minute.

In the second part of the task, participants completed the "Environmental Quality Assessment Task" worksheet (see appendix A). This task asked that participants use the worksheet to rate the overall environmental quality of the building on a scale ranging from "Dangerous" to "Optimal." They then wrote a brief description of how they came up with their assessment.

Manipulation

In this study, participants completed the task using either a set of measurement instruments or by monitoring measurement information through a computer interface. Participants either gathered the information by directly manipulating the instruments or by accessing the instruments through a computer interface. Each participant was assigned to one of four conditions: self-determined measurement, stationary measurement, local monitoring, or distant monitoring. The conditions were manipulated as follows.

Measurement Environment

Participants in the measurement environment conditions were assigned to either the "self-determined" or "stationary" condition. In both of these conditions, before beginning the task, the experimenter walked the participant around the building to see the four measurement stations. The participant was then taken back to the first station, where the experimenter showed him or her how to operate the instruments.

Participants in the self-determined instrument condition were shown that there were three measurement devices in a bag. After the devices were removed, the participant held each instrument, one at a time, while the experimenter demonstrated how to operate them. The participant was instructed to carry the instruments (in the bag) around to each station during the task. At each station, the participant was asked to remove the instruments from the bag and set them up to take measurements.

Participants in the stationary condition were shown that each station consisted of three devices, already set up and attached to a board. The experimenter demonstrated how to operate the instruments, and participants were instructed to walk up to each station to take measurements.

Monitoring Environment

Participants in the monitoring environment conditions were assigned to either the "local" or "distant" condition.

Participants in the local condition were told that they would access the instruments through a computer in the lab, but prior to starting the task they were walked around the building to see the four measurement stations. They were then taken back to the lab and seated in front of the computer. Participants in the distant condition were taken over to the computer, and told that they would access the instruments through a computer terminal in the room, although the actual source of the measurements was located in a HP laboratory in Colorado.

The measurement interface (see fig. 1) consisted of a visual representation of the three instruments in the bottom half of the screen. The upper portion on the monitor displayed a map of the building marked with the locations of the stations. The experimenter showed the participants how to operate the instruments by using the mouse to point and click at buttons such as "on," "units," "record," "average," and "off."

Table 1 shows the activities that participants in each condition performed.

Procedure

Upon arriving at the laboratory, each participant was asked to sign a consent form. The experimenter then gave oral instructions about the measurement component of the task, and presented the participant with information about "sick building syndrome."

The self-determined, stationary, and local condition participants were shown the physical location of the stations, while the distant condition participants were taken directly over to the computer. The experimenter demonstrated the procedure for operating each instrument (self-determined and stationary conditions at the actual instruments, local and distant at the computer) and told the participant what each instrument was designed to measure. The experimenter also told the participant why the measures were important, and explained how substandard measures could be indicators of a building's poor environmental conditions and possible precursors of occupational health hazards.

The participant was then instructed to record measurements from each of the four measurement stations, and was handed an instruction booklet containing step-by-step instructions. He/she was then left alone to complete the task.

After completing the measurement task, the participant was asked to complete a worksheet, entitled the "Environmental Quality Assessment Task," using the data they had collected. The worksheet required him or her to make an assessment about the building's health and to write up a brief description of how they arrived at their decision about the health of the building. Once the participant had finished, he or she was given a survey asking about their experience with the task. After completing the post-task survey, the participant was debriefed and paid.

Analysis

The primary dependent variables of interest in this study were participants' feelings of control and participants' perception of the quality of the information. Both dependent variables were measured using indices. Users' perceptions of control were measured with the following two questions:

> *How much did you feel like you were in control of the equipment?*
> *How much did you feel like the equipment was controlling you?*

These two items were rated on a 10-point scale where 1="not at all" and 10="very much". Responses to the two items were averaged to create a single index of perceived control, hereafter referred to as "control." The index had a reliability score of .6.

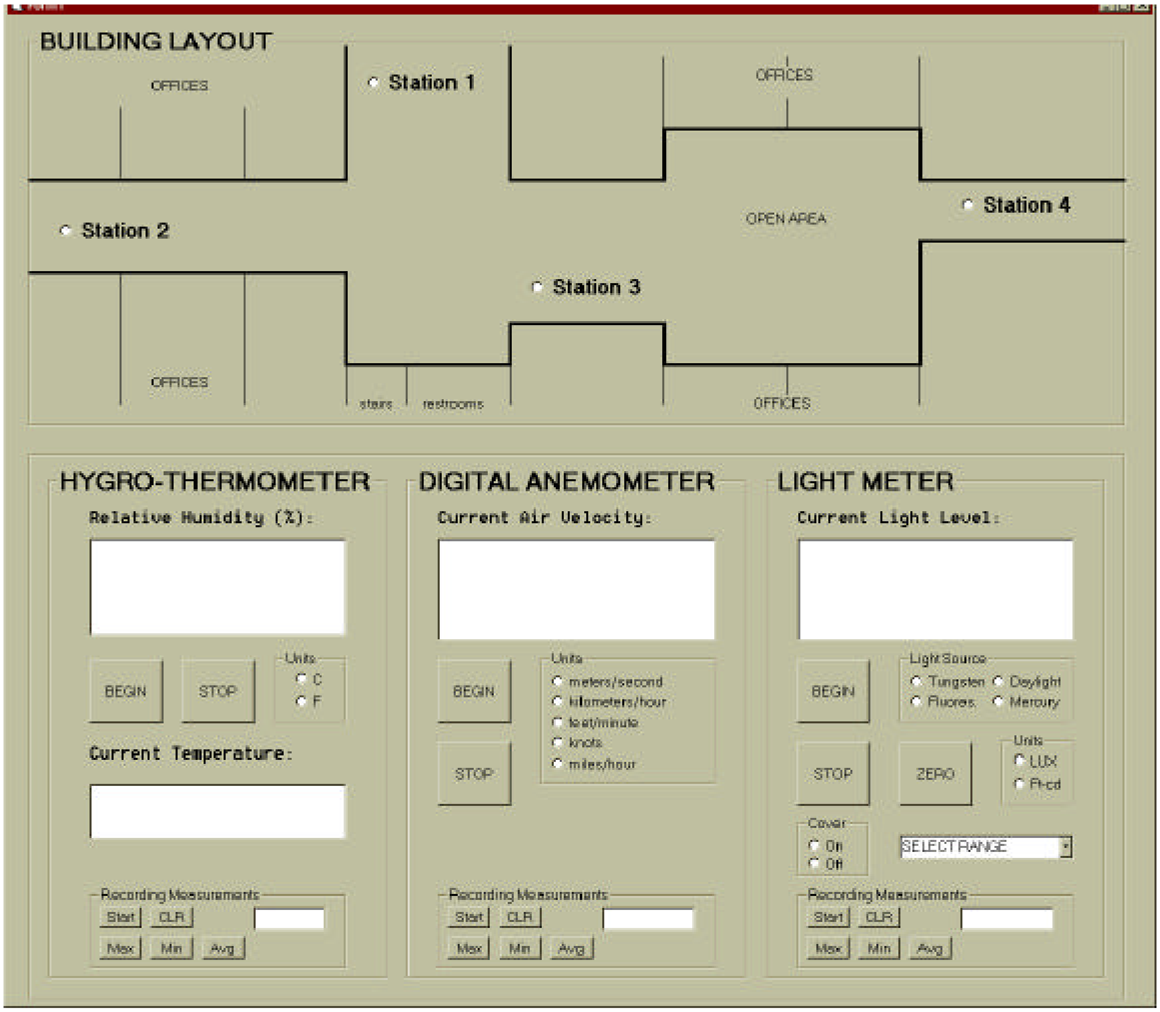


Fig. 1: Interface for Computer Conditions

Table 1: Activities performed by condition

Technology	Shown location of stations in building	Receiving Instructions			Taking Measurements		
		Given bag	Instructed at each station	Instructed on computer	Carries & sets up instruments	Walks up to instruments	Accessed through interface
Handheld instrument	**X**	**X**			**X**		
Anchored instrument	**X**		**X**			**X**	
Local computer	**X**			**X**			**X**
Remote computer				**X**			**X**

Participants were also asked to indicate their level of agreement with six statements about their perceptions of the quality of the information generated by the instruments. Ratings were made on a 10- point scale. Although the anchors were different, 1 always indicated a low level of the item (i.e. "not at all" and 10 indicated a high level of the item (i.e. "a lot"). The six questions were:

> *How much did you trust the measurement information from the equipment?*
> *How helpful was the equipment's information?*
> *How relevant was the equipment's information?*
> *How satisfied are you with the measurement information the equipment provided during this experiment?*
> *How confident are you that the Environmental Quality Assessment was accurate?*
> *How insightful was the equipment's information?*

Responses to these six items were averaged to create a single index of perceived information quality, hereafter referred to as "quality of information." The index had a reliability score of .8.

ANOVA was used to determine participants' responses to the differences between measuring and monitoring, distant and local, and established and self-determined.

Results

Measurement vs. Monitoring Environment Condition
Hypothesis 1 posited that users will feel more in control when taking measurements directly from an instrument than when monitoring measurement information remotely. As expected measurement condition users (N=30) rated their feelings of control on the task as 7.45 (SD=2.19) on a 10-point scale, while monitoring condition users (N=30) rated their perception of control as only 6.28 (SD=2.25) on average. To test the strength of this difference, a one-way ANOVA was performed with the measurement and monitoring conditions predicting control. The ANOVA results confirm a significant difference in users' preference of the measurement environment, $F[1,58]=4.15$, $p<.05$.

Hypothesis 2 argued that users will trust the quality of the information more when they are able to take the measurements directly from the instrument. The results show that those in the measurement condition rated their perception of information quality as 6.71 (SD=1.79), while those in the monitoring conditions rated perception of information quality as 7.19 (SD=1.42) on average. When tested with an ANOVA, the difference was not significant, $F[1,58]=1.34$,ns, thus showing no support for hypothesis 2.

Local vs. Distant
Hypothesis 3 argued that monitoring an instrument from a local site versus a distant site would increase users' perceptions of control. In this study, those in the local condition

rated their perception of control in the task as 6.33 (SD=2.35), while those in the distant condition rated their perception of control as 6.23 (SD=2.23) on average. Although those in the local condition reported higher levels of control, this difference was not significant, $F[1,28]=.01$, n.s.

Hypothesis 4 posited that perceptions of information quality would be higher when the user is monitoring an instrument from a local site. Those in the distant condition rated their perception of the quality of information as 7.8111 (SD=1.11), while those in the local condition rated their perception of the quality of information as 6.5667 (SD=1.46) on average. The difference in the perception of information quality in the verses local conditions was significant, $F[1,28)=.014$, $p<.05$, but in the opposite direction predicted by hypothesis 4. That is, people felt that information quality was better at a distance. This effect may have been an artifact of the experimental set-up. In the monitoring conditions, the computer program reported the same instrument readings for every session and were, therefore, often inaccurate. Participants at the local site may have been able to detect the inaccuracies in the measurements while those at a distance could not. This may have caused more skepticism on the part of the local users.

Stationary vs. Self-Determined Condition

Hypothesis 5 posited that feelings of control would be higher when the user is able to determine the position and orientation of the instruments being used. Those in the established condition rated their feelings of control in the task as 8.07 (SD=1.66), while those in the self-determined condition rated their perception of control in the task as 6.83 (SD=2.52) on average. To test hypothesis 5, a one-way ANOVA was performed with the established and self-determined conditions predicting control. The results suggest that participants who use stationary (established) instruments feel more in control than those who have to set up the instruments themselves, $F[1,28]=2.51$, $p<.13$. This result contradicts hypothesis 5. This effect may reflect the uncertainty felt by novice users when they are required to set up new instruments. Although they objectively had more control, they may have felt less in control because they were not confident in their ability to set up the instruments properly.

Discussion

This study was designed to develop an understanding of how different configurations of a distributed measurement environment effect users' feelings of control and perceptions of information quality. The data suggest that users who are monitoring instruments from a remote location will feel less in control than users who are able to gather measurement data in the more traditional way – that is, directly from the instrument. But, there is little evidence that being remote effects users' perceptions of information quality.

When examining the effect of distance in a monitoring environment, neither of our hypotheses was supported. Users' sense of control was not effected by their proximity to the actual measurement environment. Contrary to hypothesis 4, the data suggest that users are more confident in the quality of the information when it is gathered from a distant location. We believe that this result is an artifact of the experimental setting and suggest that more research be conducted to determine the relationship between distance and information quality.

Finally, the results of this study suggest that perception of control will be higher when the user works with stationary instruments. Although this was in contradiction to hypothesis 5, we believe that the finding is an accurate one for novices. Other research conducted on the SIRCH project at HP suggests that control is heavily impacted by peoples' feelings of self-efficacy – their confidence that they can act to accomplish their goals. If the novice users in this study were not confident that they could set up the equipment and take accurate readings, it may have reduced their feelings of self-efficacy and therefore their perceptions of control. It would be beneficial to conduct future research examining the effect of self-determined vs. stationary equipment on expert users' sense of control.

There are several limitations to this study that effect the interpretation and generalizability of the results. First, participants were not randomly assigned to condition. Randomization to condition is a standard experimental practice that provides some assurance that the differences detected in the study can be attributed to the manipulations and not to some other, unidentified attribute of participants or artifacts of the environment. Second, the participants in this study were novice users of the instruments. Expert users can not be expected to behave in exactly the same way. Third, the computer monitoring interface gave the same measurements every time, but the instruments took accurate environmental measurements. This could have contributed to a lack of confidence for those participants in the monitoring conditions who had some sensory knowledge of the actual environmental conditions (e.g. temperature, humidity, air velocity, light). For future work, it will be important to ensure that the accuracy of the measurements are the same between conditions.

Still, the results suggest that there may be differences in peoples' feelings of control and perceptions of information quality when they become more distant from their instruments. In terms of product design, the results point toward identifying ways to increase users' sense of control when monitoring instruments remotely. Although reliable design recommendations depend on future research that looks at the causes for reduced feelings of control, there are a few options that can be inferred from previous research. One method for increasing control may be to provide users with information on how the information is being gathered and transmitted. Another method is to provide a visual image of the measurement environment so that people can use their own senses to establish the credibility of the measurements provided. By increasing the user's awareness of what is actually happening in the measurement environment, he/she should feel more in control of the situation.

Appendix A – Assessment Task

The Environmental Quality Assessment Task

Complete all of the columns in the table below, using the measurements you recorded during this experiment.

For example, write the measurement you recorded in your workbook (value x) in the column titled "Level" right here

Now, using the Temperature Range diagram, put the rating of that temperature in this column here

Complete all of the blanks in the table in this manner.

Dangerous	Poor	Fair	Good	Optimal	Good	Fair	Poor	Dangerous
60 °F	60-63 °F	64-65 °F	66-67 °F	68 °F	69-70 °F	71-74 °F	75-95 °F	95 °F

	STATION 1	
	LEVEL	RATING
TEMPERATURE		
1st Measuremt (°F) – value 1 in workbook:		
2nd Measurement (°F) – value 7 in workbook:		
	STATION 2	
	LEVEL	RATING
TEMPERATURE		
1st Measuremt (°F) – value 18 in workbook:		
2nd Measurement (°F) – value 24 in workbook:		
	STATION 3	
	LEVEL	RATING
TEMPERATURE		
1st Measuremt (°F) – value 35 in workbook:		
2nd Measurement (°F) – value 41 in workbook:		
	STATION 4	
	LEVEL	RATING
TEMPERATURE		
1st Measuremt (°F) – value 52 in workbook:		
2nd Measurement (°F) – value 58 in workbook:		

How would you rate the **overall temperature level** of the building?
(circle one of the following):

Dangerous Poor Fair Good Optimal

Complete all of the columns in the table below, using the measurements you recorded in your workbook.

Refer to the Relative Humidity Range diagram below to complete the "Rating" column.

Dangerous	Poor	Fair	Good	Optimal	Good	Fair	Poor	Dangerous
0 %	**1-5%**	**6-15%**	**16-20%**	**21-25%**	**26-35%**	**36-50%**	**51-75%**	*Over 75%*

	STATION 1	
	LEVEL	RATING
HUMIDITY		
Maximum recorded RH – value 4 in workbook:		
Minimum recorded RH – value 5 in workbook:		
Average recorded RH – value 6 in workbook:		
	STATION 2	
	LEVEL	RATING
HUMIDITY		
Maximum recorded RH – value 21 in workbook:		
Minimum recorded RH – value 22 in workbook:		
Average recorded RH – value 23 in workbook:		
	STATION 3	
	LEVEL	RATING
HUMIDITY		
Maximum recorded RH – value 38 in workbook:		
Minimum recorded RH – value 39 in workbook:		
Average recorded RH – value 40 in workbook:		
	STATION 4	
	LEVEL	RATING
HUMIDITY		
Maximum recorded RH – value 55 in workbook:		
Minimum recorded RH – value 56 in workbook:		
Average recorded RH – value 57 in workbook:		

How would you rate the **overall relative humidity level** of the building?
(circle one of the following):

Dangerous Poor Fair Good Optimal

Complete all of the columns in the table below, using the measurements you recorded in your workbook.
Refer to the Air Velocity Range chart below to complete the "Rating" column.

Dangerous	Poor	Fair	Good	Optimal	Good	Fair	Poor	Dangerous
0 ft/min	**1**	**2**	**3-4**	**5**	**6-7**	**8**	**9-15**	**Over 15 ft/min**

	STATION 1	
	LEVEL	RATING
AIR VELOCITY		
Maximum recorded Velocity – value 10 in workbook:		
Minimum recorded Velocity – value 11 in workbook:		
Average recorded Velocity – value 12 in workbook:		
	STATION 2	
	LEVEL	RATING
AIR VELOCITY		
Maximum recorded Velocity – value 27 in workbook:		
Minimum recorded Velocity – value 28 in workbook:		
Average recorded Velocity – value 29 in workbook:		
	STATION 3	
	LEVEL	RATING
AIR VELOCITY		
Maximum recorded Velocity – value 44 in workbook:		
Minimum recorded Velocity – value 45 in workbook:		
Average recorded Velocity – value 46 in workbook:		
	STATION 4	
	LEVEL	RATING
AIR VELOCITY		
Maximum recorded Velocity – value 61 in workbook:		
Minimum recorded Velocity – value 62 in workbook:		
Average recorded Velocity – value 63 in workbook:		

How would you rate the **overall air velocity level** of the building?
(circle one of the following):

Dangerous Poor Fair Good Optimal

Complete all of the columns in the table below, using the measurements you recorded in your workbook.

Refer to the Light Level Range chart below to complete the "Rating" column.

Dangerous	Poor	Fair	Good	Optimal	Good	Fair	Poor	Dangerous
Below 25 LUX	**25-49**	**50-130**	**131-150**	**151-200**	**201-750**	**751-1000**	**1000-1300**	**Over 1300 LUX**

	STATION 1	
	LEVEL	RATING
LIGHT LEVEL		
Maximum recorded light level – value 15 in workbook:		
Minimum recorded light level – value 16 in workbook:		
Average recorded light level – value 17 in workbook:		
	STATION 2	
	LEVEL	RATING
LIGHT LEVEL		
Maximum recorded light level – value 32 in workbook:		
Minimum recorded light level – value 33 in workbook:		
Average recorded light level – value 34 in workbook:		
	STATION 3	
	LEVEL	RATING
LIGHT LEVEL		
Maximum recorded light level – value 49 in workbook:		
Minimum recorded light level – value 50 in workbook:		
Average recorded light level – value 51 in workbook:		
	STATION 4	
	LEVEL	RATING
LIGHT LEVEL		
Maximum recorded light level – value 66 in workbook:		
Minimum recorded light level – value 67 in workbook:		
Average recorded light level – value 68 in workbook:		

How would you rate the **overall light level** of the building?
(circle one of the following):

Dangerous Poor Fair Good Optimal

Now we would like you to give us your overall assessment of the environmental quality of the building.

We realize that this is a somewhat subjective assessment because you have incomplete information about other key factors that impact environmental quality (e.g., the level of biological contaminants, the level of carbon dioxide in the air, etc.). We also realize that not all factors should be weighted equally in determining overall environmental quality – for example, lighting levels may be more or less important than humidity levels, depending on the nature of the work being conducted in the building.

However, using the limited information that you have, and using your best judgement regarding how to weight the different factors, please give us your overall assessment of the environmental quality of the building.

How would you rate the **overall environmental quality** of the building?
(circle one of the following):

Dangerous	Poor	Fair	Good	Optimal

Briefly describe how you came up with your overall assessment: