PRESENTATION

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In his presentation, Dr. Zaffanella focused almost exclusively on reporting the methodology and results of RAPID Project #6, the two-phase Survey of Personal Magnetic Field Exposure study (the "1000-person study"). Material summarizing his presentation has been prepared from the transcripts and his slides. This material has been reviewed by the presenter for accuracy. A summary of the project is found in Appendix B.

Study Design

Zaffanella addressed the subject of designing the optimal study: to capture the greatest number of parameters of interest (in this case, TWA, intermittence, harmonics and so on), with minimum error. The nature of the optimum study was found to be a function of cost and hence of the available budget. To perform a cost-effectiveness analysis for different approaches, the research team defined an effectiveness index based on the sum of subjective worth for the measurable quantities divided by the variance. The variance has two components: the standard error (the more people, the less error) and bias in the conduct of the study, as determined by refusal rate. Refusal rate is the lowest when people are contacted in person; however, it is much less expensive to contact potential participants by phone (highest refusal rate and therefore highest possible bias).

The ideal method would have been a two-stage class of design, with recruitment through personal visits followed by extensive measurements. However, the RAPID budget did not allow for personal contact. The most cost-effective method, given the budget, was found to be recruiting by telephone, using a list-assisted random dialing method. The research team selected households as the frame of the sample. The household was called, and the member selected whose birthday was closest to the day of the phone call (to randomize the choice of individual). This stage incurred a significant level of refusal. A follow-up consent letter to those accepting explained the research in more detail. Zaffanella noted that this stage also experienced a significant level of refusal: only 70% of those who originally consented returned the signed form.

However, the research team experienced a relatively good response in the measurements stage: they sent a package containing the meter, instructions, a way to return the meter, a small diary and pen, a questionnaire, and $50. Out of 1,040 people, only 20 have failed thus far to return the meter.

The meter itself is small enough (pager-size) to put in a pocket or clip on a belt; it has no display (so people do not experiment with it). All the participants had to do was put the meter on, turn it on, and mark in the diary when they started and when they changed activities. Location/activity categories in the diary included: at home not in bed, in bed, at work, travel, at school, and other.

The meter has a sampling rate of 0.5 seconds and can collect data for 29 hours. It measures the rms field value in the frequency range between 40 and 1000 Hz. It does not store the entire data time sequence in memory, but summarizes and stores data every ten minutes. The stored quantities for each 10-minute period include: minimum, maximum, average, standard deviation, and the number of measurements in nine incremental magnitude bins (less than 0.5, 1, 2, 4, 8, 16, 32, and 64 mG, and > 64 mG). The meter also tracks the following: the number of sudden field changes, which the research team took as a surrogate for load changes that may correspond to transients (also counted in bins); an index of intermittence (average difference between consecutive readings); and the time for which the field was above 2 mG and constant for at least ten seconds. In addition, the interview and questionnaire collected demographic and residential information including: age, sex, geographic location, information about the residence, and occupation. Data collection produced exposure data for 1,012 people throughout the US.

Results

Zaffanella then presented and discussed a series of graphs and tables showing the distribution of PE data. The distribution of 24-hour average (TWA) magnetic field exposures for the entire U. S. population is shown in Figure 12-2. As shown in Figure 12-3, the estimated distribution of 24-h TWA exposures was approximately log-normal with a geometric mean of 0.89 mG and a geometric standard deviation of 2.18. However, the measurements deviated above the log-normal distribution at higher fields, and a second log-normal distribution was introduced for the extrapolation to high field exposure.

The measurements were weighted for subject characteristics, geographical location, and refusal rate, in order to produce the population distribution (Figure 12-2) and estimate the 95% confidence intervals around the distribution (Figure 12-4). As seen in Figure 12-4, the relative accuracy in determining what percentage of the U. S. population has a 24-h average exceeding certain values becomes lower as the smaller percentages with higher TWA are determined. For instance, the number of people with 24-h TWA exposure greater than 15 mG could be anywhere between 50,000 and 1.5 million, while for 24-h TWA greater than 1 mG, the estimated number of people is 109 to 124 million.

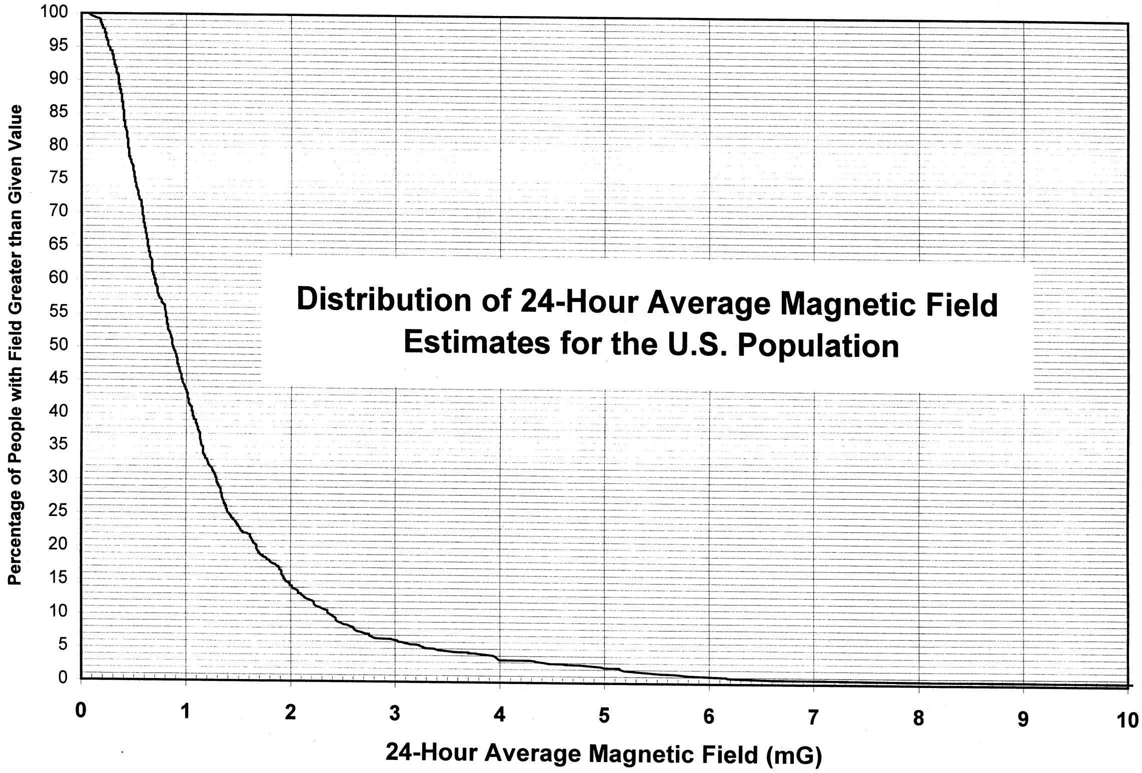

Figure 12-2. Distribution of 24-hour average magnetic-field estimates for the U.S. population.

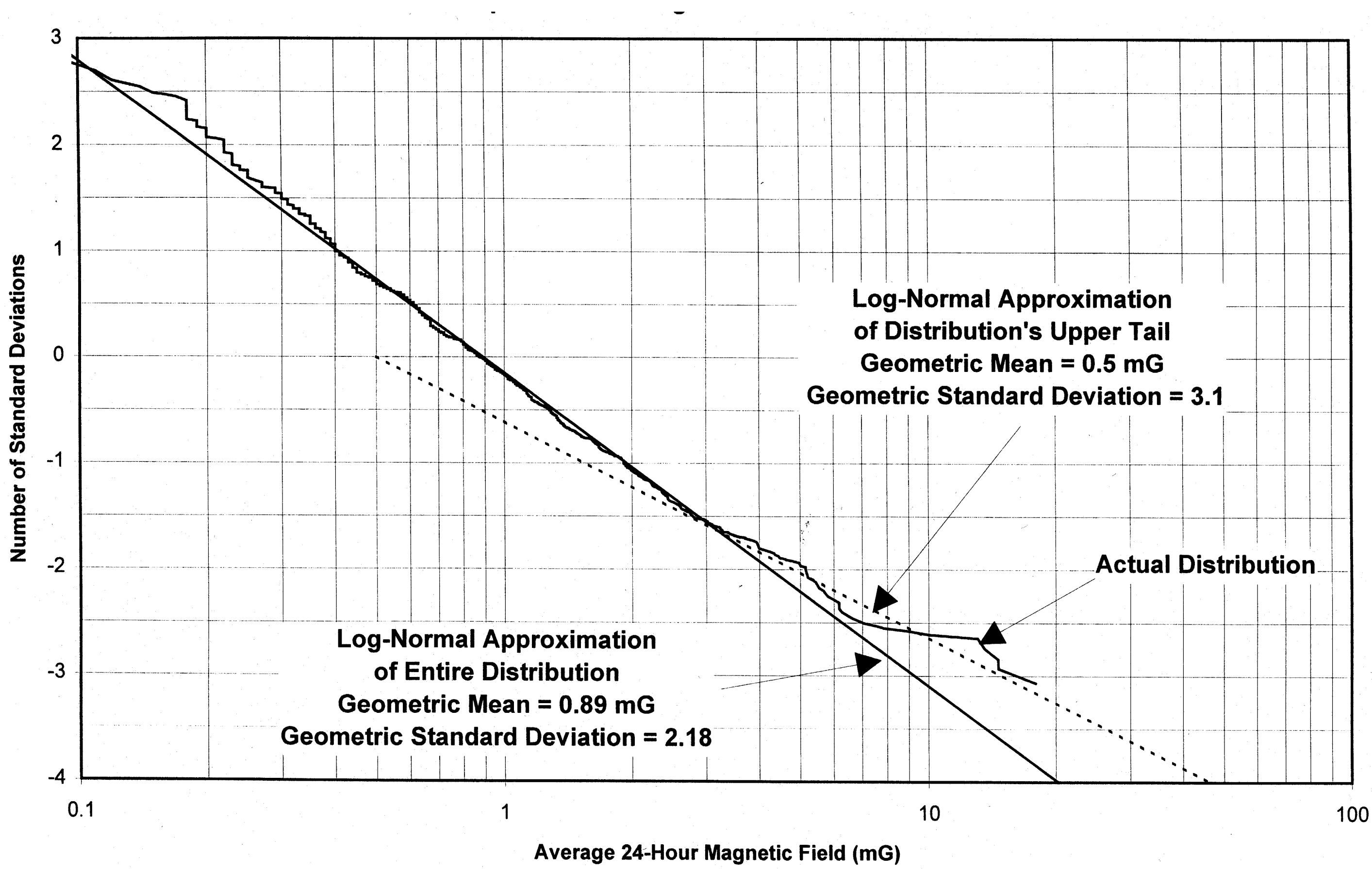

Figure 12-3. **Distribution of average 24-hour magnetic-field comparison with log-normal distributions.**

Average 24-Hour Field	Estimated Percentage	95% Confidence Interval	Value
> 0.5 mG	76.3	73.8% – 78.9%	197 – 211 million
> 1 mG	43.6	41.0% – 46.5%	109 – 124 million
> 2 mG	14.3	11.9% – 17.2%	31.8 – 45.9 million
> 3 mG	6.3	4.8% – 8.3%	12.8 – 22.2 million
> 4 mG	3.35	2.4% – 4.7%	6.4 – 12.5 million
> 5 mG	2.42	1.67% – 3.52%	4.5 – 9.4 million
> 10 mG	0.43	0.21% – 0.90%	0.56 – 2.4 million
> 15 mG	0.1	0.02% – 0.55%	50 thousand – 1.5 million

Figure 12-4. Percentage of the U.S. population with 24-hour average field exceeding given values.

In looking at maximum field, the research team discovered that about 1.6% of the people encountered at least 1 G in a given 24-h period. In examining this population, they discovered that many of them were students. The team attributed the exposure possibly to the use of electronic gates in libraries through which a person must pass to check out books. (A number of retired people had similar results, possible for similar reasons.)

Zaffanella also reported on other measures including: sudden field changes greater than 10 mG in one day (5% of the people had at least 100 of these), the distribution of the length of time of constant field above 2 mG (5 percent with about 7 hours of this exposure, mostly at nighttime), and the distribution of intermittence (travel highest, in-bed lowest).
Zaffanella examined linear regression correlation between different exposure parameters. The results are shown in Figure 12-5. He noted that intermittence could be a good surrogate for TWA and vice versa (r = 0.83). Time above 4 mG and time above 16 mG also correlated reasonably well with TWA (r = 0.71 and 0.73, respectively). However, TWA did not correlate as well with other measures, such as field changes >10 mG (r = 0.35).

	TWA	**St. Dev.**	**Geom. Mean**	**Geom. St. Dev.**	**Time above 4 mG**	**Time above 16 mG**	**# of Field Changes > 10 mG**	**Time w/ Constant Field > 2 mG**	**Intermit-tence (Av. Change)**
TWA	1.00	0.65	0.76	0.53	0.71	0.73	0.35	0.59	0.83
St.. Dev.		1.00	0.17	0.34	0.22	0.30	0.46	0.17	0.64
Geom. Mean			1.00	0.14	0.75	0.51	0.09	0.7	0.83
Geom. St. Dev.				1.00	0.51	0.50	0.27	0.28	0.71
Time above 4 mG					1.00	0.43	0.14	0.67	0.90
Time above 16 mG						1.00	0.26	0.23	0.91
Number of Field Changes > 10 mG							1.00	0.08	0.75
Time with Constant Field > 2 mG								1.00	0.68
Intermit-tence (Av. Change)									1.00

Figure 12-5. Correlation coefficients: Linear regression between exposure metrics. (24-hour Exposure of 1012 People Representative of the U.S. Population)

Zaffanella reported on an analysis of the sensitivity and specificity of the 90th percentile of TWA as a surrogate for the 90th percentile of other parameters. The sensitivity of TWA (90th percentile) for other measures was in the range of 20 to 79%, with the highest value occurring for time above 4 mG. The specificity of TWA for all other parameters was above 82%.

The distributions of exposures during different activity periods are shown in Figure 12-6. In general, work was the category with the highest exposure, and school and bed were the lowest. The team examined correlation of TWA for different activities with total TWA and between TWA for different activities. TWA for in-bed, home (not in bed), and work were all important contributors to total exposure, with none dominating. Correlation between TWA from different activities was not strong.

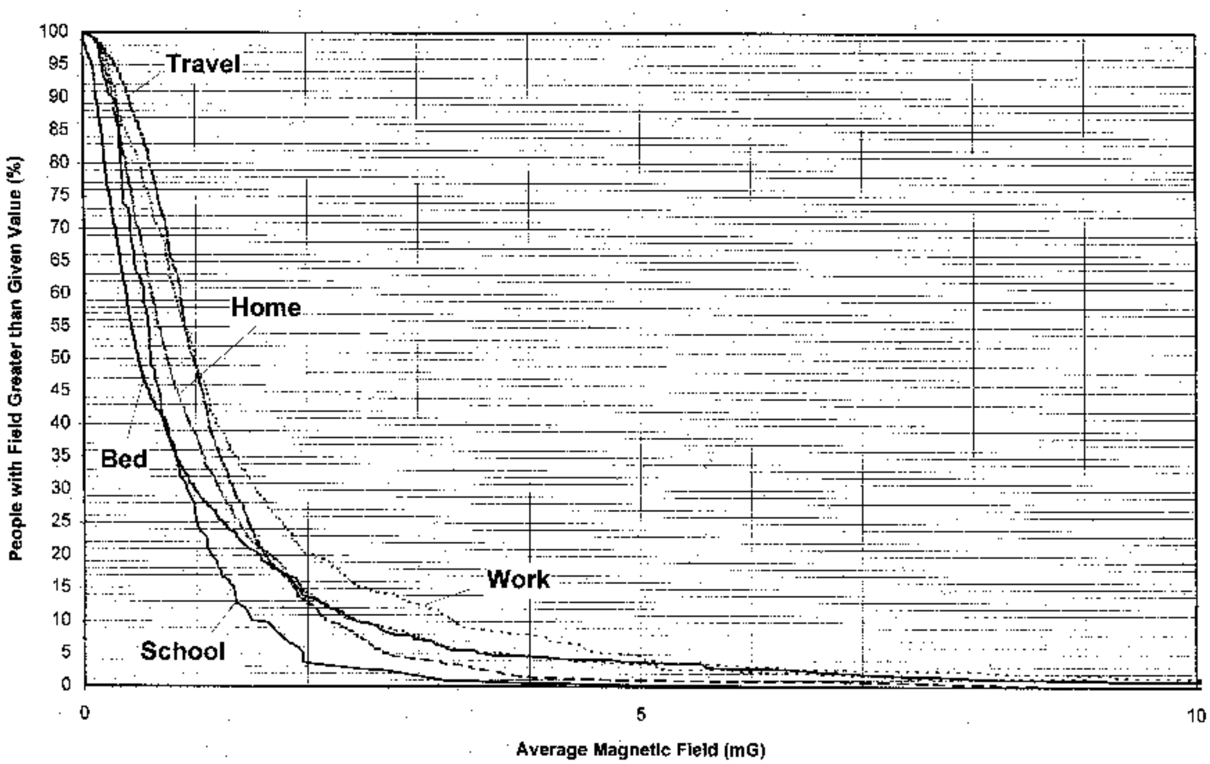

Figure 12-6. Distribution of average magnetic field during different activities estimates for the U.S. population.

Other findings from analysis of the data were as follows: no discernible difference in the exposures of males and females; the age group with the highest exposure (but not by much) was 18 - 64 years old; children under 17 seemed to have the lowest exposures, although there was considerable uncertainty because of small numbers; and no large differences in exposures by geographic region. These results are summarized in Figure 12-7, which shows how small the differences are between groups.

Analysis by occupation revealed some interesting findings: as might be expected from previous research, so-called "electrical occupations" tended to have a higher distribution curve, but service occupations paralleled and even surpassed the numbers found in exposures above 3 mG. Not surprisingly, farming ranked as the lowest exposure.

Analysis of the residential PE data in terms of house characteristics indicated that exposure level went down as house size increased. Zaffanella noted that this finding raises some questions about the social justice issues associated with EMF, especially when considering field-management possibilities. Apartments and duplexes, especially small ones, all had higher fields. There was no finding of effect by floor level of the bedroom, although, as Zaffanella noted, this could be due to insufficient data. The distance from a residence to a line was also associated with field level, although Zaffanella noted that the kind of line was identified by the respondents from pictures and that accuracy would be improved with technicians measuring directly. The team also found that exposures in houses with metal plumbing was higher than in those with plastic plumbing.

Zaffanella compared results from the 1000-person study with those from the EPRI 1000-home study (which studied sources, not PE) and the EPRI EMDEX Residential study, as shown in Figure 12-8. The distributions of PE measurements from the 1000-person and EMDEX studies coincide well for high fields but not for low fields (possibly because meter technology has improved since the earlier studies). Zaffanella also noted the differences between area measurements, typically taken in the center of a room away from sources, and PE measurements, which involve averages over the entire house, including near appliances. (This observation serves as the basis for the model of exposure described in the Discussion of Topic #9.) As a final comparison, Zaffanella overlaid distributions of residential-exposure data from two epidemiology studies on the upper 15% of PE measurements from RAPID Project #6. Cases from the NCI study had comparable exposures with those from the 1000-person study, but the controls were lower. The cases from the Los Angeles study exhibited higher exposures than those from the nationwide study, while the controls had comparable exposures.

		50^{th}	90^{th}	95^{th}	Average	Standard Deviation	Geometric Mean	Geometric Standard Deviation
Gender	Males	0.89	2.36	3.54	1.25	1.41	0.90	2.16
	Females	0.86	2.38	3.21	1.25	1.60	0.88	2.21
Age	Pre-schoolers	0.65	2.76	3.67	1.12	1.17	0.80	2.11
	School Age	0.68	2.00	2.32	1.03	0.90	0.76	2.19
	Working Age	0.94	2.45	3.70	1.37	1.76	0.97	2.17
	Retirement Age	0.79	2.32	2.66	1.07	0.84	0.80	2.16
Region	Midwest	0.65	2.22	3.19	1.19	1.18	0.87	2.20
	Northeast	1.00	2.77	3.95	1.36	1.26	1.00	2.20
	South	0.86	2.40	3.42	1.24	1.58	0.86	2.21
	West	0.85	2.20	2.71	1.22	1.83	0.87	2.10

Figure 12-7. Parameters of the distribution of 24-hour averages for different genders, age groups and regions.

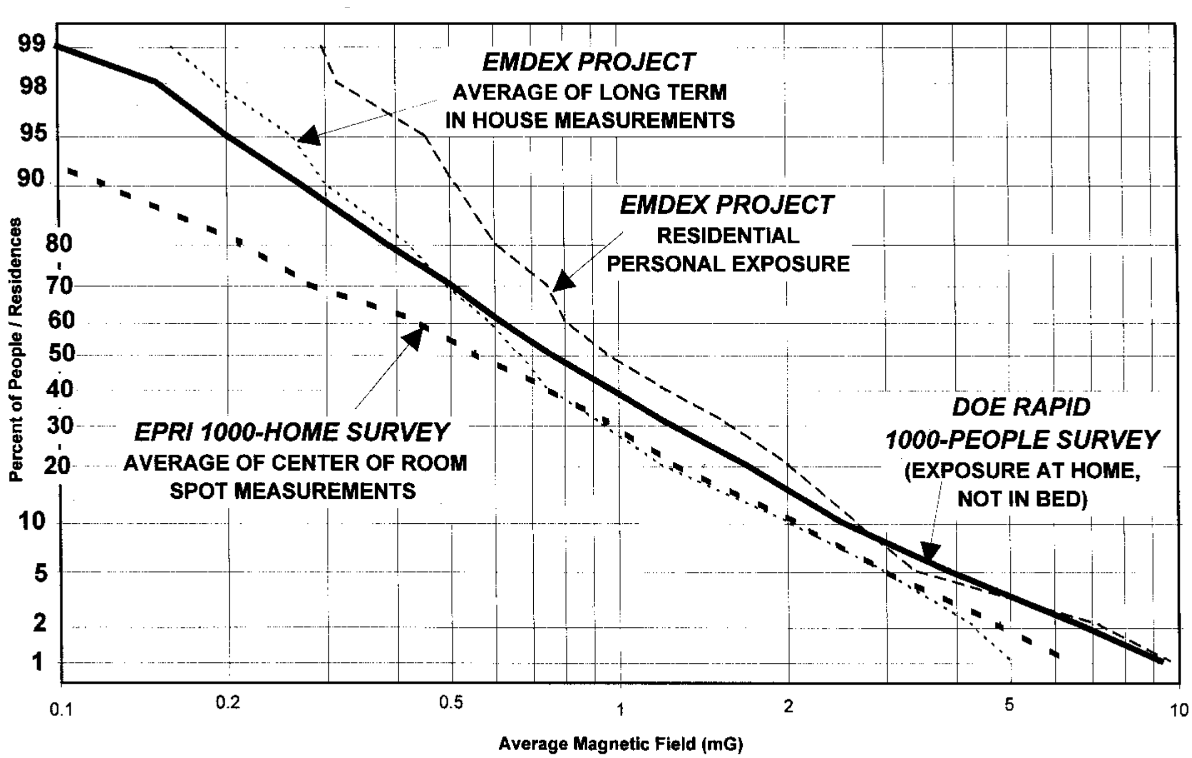

Figure 12-8. Comparison of data from different studies.

SUMMARY OF DISCUSSION

Several issues came under discussion following the presentation on general public exposures by Dr. Luciano Zaffanella. The summary below was prepared from the symposium transcript.

Several clarifications were sought on the status of analysis, data, and results for RAPID Project #6, as Dr. Zaffanella presented them. Zaffanella indicated the following: that they had not performed analysis of exposures within job category by gender; that they had not investigated correlations of any factors with distance from power lines except for personal exposure; that the exposure distributions had been adjusted for region, gender, and age groups; and that they had not been able to do repeat measurements for any subjects.

Zaffanella reported that they had checked the diary entries as much as they could, and believed that the diaries were a reasonable record of where people were while wearing the meter. There were some cases of elevated exposure measurements during sleep, possibly associated with the meter being placed near a clock or other local source. He indicated that data cleansing was required in approximately 15 of the 1012 exposure days. This cleansing may make a difference in the upper portion of the exposures.

In response to an observation that, in previous studies, subjects may have changed their behavior while wearing the PE meter, Zaffanella indicated that this was a major concern in the study design and that the researchers had taken great care to minimize this possibility. The meter that was used did not have a display, eliminating visual temptation for the subject to experiment with the meter. Since the meter recorded for 29 hours, it might be possible to compare the first five hours of data with the last five hours (same time on the following day) to examine day-to-day changes and possible protocol violations. Another discussant pointed out that the PE meters used in RAPID Project #6 were much smaller and less intrusive than those used in previous studies. Consequently, the researchers could have more confidence that subjects followed the protocols.

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