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Measuring light-switching behavior with the use of occupancy and light data logger

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Dear Editor,

We wish to submit an article entitled "Using HOBO Occupancy/Light Data Logger UX90-005 in field experiments: an example in studying light-switching behavior" for consideration by *JoVE.* We confirm that this work is original and has not been published, nor is currently under consideration for publication elsewhere.

In this paper, we show how the use of occupancy/light data loggers can serve as a valuable measurement in field experiments that concern energy conservative behaviors (as well as discussion about its possible uses in other domains). Below we let ourselves to explain the significance of our paper.

Until now, researchers heavily rely on declarative measures or direct observation in studies concerning pro-environmental behaviors (or other types of behaviors). Due to the disadvantages of these measurement methods, we believe in the significance of presenting the instrument that we've described in our manuscript, as it allows researchers to conduct precisely operationalized and broad studies without interrupting the participants' naturally occurring behaviors. To our knowledge, this is the first attempt to provide a detailed description of this instrument in the context of conducting experimental research.

We believe that this manuscript is appropriate for publication by *JoVE* because it describes an instrument (technical description of hardware and software as well as deployment tutorial) that can be used in experimental research..

We hope that our work will serve as a valuable addition to the *JoVE* , especially since this would be our first publication attempt in your journal. We would like to assure that we have no conflicts of interest to disclose.

Thank you for your consideration of this manuscript.

Sincerely,

Krzysztof Jan Leoniak and Wojciech Cwalina

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TITLE:

Measuring Light-Switching Behavior Using an Occupancy and Light Data Logger

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KEYWORDS:

Data logging, measuring behavior, field experiment, energy conservation, pro-environmental behavior, light-switching behavior, room occupancy logging, indoor light changes logging

SUMMARY:

This article describes a procedure for using and deploying an occupancy and light data logger which allows collecting data about light-switching behavior of participants in field settings.

ABSTRACT:

Due to discrepancies between self-reported and observed pro-environmental behavior, researchers suggest the use of more direct measures of behavior. Although direct behavioral observation may increase the external validity and generalizability of a study, it may be time-consuming and be subject to experimenter or observer bias. To address these issues, the use of data loggers as an alternative to natural observation can allow researchers to conduct broad studies without interrupting the participants' naturally occurring behaviors. This article describes one of such tools—the occupancy and light data logger—with its technical description, deployment protocol, and information about its possible applications in psychological experiments. The results of testing the reliability of the logger in comparison to human observation is provided alongside an example of the gathered data during a 15-day measurement in public restroom (N = 1,148) that includes: 1) room occupancy changes; 2) indoor light changes; and 3) room occupancy time.

INTRODUCTION:

One of the most commonly used measures of pro-environmental behavior in psychology are self-reports in the form of surveys, interviews, or questionnaires[1]. Among the reasons indicated for this trend is simply the difficulty in conducting field experiments, which usually require a fair amount of resources and precise operationalization[2,3]. However, the tradeoff is worth the effort since it is well established that relying on self-reporting measures can be misleading in the prediction of objective behavior[4-6].

While trying to avoid this problem, researchers that are focused on studying energy conservation behavior generally use observational (nominal categorization of observed events, e.g., turning on/off lights) or residual (quantifiable evidence of a past behavior, e.g., energy consumption in kWh) data as measurements of dependent variables[7]. Although both types of measurements are valuable, observational data is most commonly used in field experiments[2,3,8], particularly when their dependent variables concern light-switching behavior.

Before obtaining observational data, researchers should consider several methodological issues, which are: 1) sample representativeness; 2) the number of observers in order to exclude possible human errors; 3) inter-observer agreement in order to exclude experimenter bias; 4) observer location, which should be concealed in order to reduce the possibility of being spotted by participants; 5) clearly and specifically defined observation coding; 6) pretest of observational measures; 7) observer training; and 8) establishing systematic timing of observation[9]. Even though most of the mentioned issues were already addressed—for example those that concern reliability analysis[10] or coding observational data[11]—it seems that not all of them receive much attention in articles that describe experiments on light-switching behavior.

An analysis of four studies[12-15] that were chosen for their similarity in experimental context (all of them concerned light-switching behavior in public bathrooms/restrooms) showed that even though the location details in each of the studies were precise, the observation measurement details varied. Since each study employed naturalistic observation, gathering information about the behavior of participants that were the opposite sex of observers was not always possible[14] due to possible interference or violation of social norms (e.g., if a male experimenter were to enter a women's restroom or vice versa). In some instances, the precise data of the participants' genders were not provided[15]. This seems to be a limitation when taking into consideration that gender can be an important factor in predicting pro-environmental behavior[16].

The biggest differences, however, emerged in the description of observers and measurement times. Even though these descriptions will naturally differ on the basis of experimental location, the precise number of observers was not always provided[14]. Furthermore, the exact location of observers was not explicit[12,14,15] which makes it hard to conduct possible replications and ensure that participants are unaware of being observed. Across four analyzed articles, only one provided a detailed description of the observer's location[13].

Moreover, the exact times of observation intervals were provided only by one study[12] whereas other studies either described overall study times (with a general description of how many times on each study day the observation took place)[13,15] or did not describe it at all[14]. This can again impede replicating and establishing whether the observation timing was systematic and sufficient for the purposes of the study aims.

The limitations of these experiments are presented as guidelines and important points that should be taken into consideration in future research. In no case it was intended to undermine the importance of these studies. The indicated areas should be considered for maximizing study operationalization in order to facilitate replications, which play an important role in psychology[17,18], and simplify the conduction of field experiments. However, it is questionable whether all of the mentioned issues can be dealt with by improving observation methods that ultimately rely on human observers.

For these reasons, the occupancy and light data logger (see **Table of Materials**) is a valuable tool that can be effectively used to gather information about a particular type of energy conservation behaviors, light-switching, without the limitations of using observers or ethical restrictions (the logger does not gather the audio-visual data). Overall, the aim of this article is to present the technical description and possibilities of one model of the occupancy and light data logger. To the authors' knowledge, this is the first attempt to present this tool thoroughly in the context of its use in field experiments in psychology.

Loggers' technical description

The model of occupancy/light data logger (see **Table of Materials**) that was used for this article was equipped with standard memory capacity of 128 kB. The logger weights 30 g and its size is 3.66 cm × 8.48 cm × 2.36 cm. Additional details and the product manual can be found on the manufacturer's website[19].

Control buttons, the light sensor and the battery tray are located on the top panel. The front panel consists of the occupancy sensor and an LCD screen, whereas the back panel is equipped with mounting magnets and loops (**Figure 1**). The USB 2.0 port is located on the bottom panel, to allow the connection of the logger to the computer with a USB cable in order to enable set-up before deployment and to later obtain readouts using analysis software package dedicated to this data logger.

The integrated light sensor (photocell) threshold is greater than 65 lx, which works with different light types (LED, CFL, fluorescent, HID, incandescent, natural) that can be found in most public spaces. Overall, the logger interprets light status changes (ON/OFF) depending on the strength of the light signal, more precisely, whether it drops below or rises above levels of the calibration threshold. It should also be noted that the sensor is secured from false detection of ON and OFF states by a built-in hysteresis level of approximately ±12.5%[19].

A motion sensor determines whether the room is occupied or unoccupied. With the use of a pyroelectric infrared (PIR) sensor, it detects the motion of people by their body temperature (which differs from the temperature of the surroundings). The detection range of the discussed logger has a maximum of 5 m and the extended version of the logger has a range of 12 m. Horizontal detection performance works up to 94° (±47°), and vertical up to 82° (±41°).

The described model of occupancy/light data logger has been validated alongside Open Source Building Science Sensors and appears to provide a reliable measurement of light intensity and occupancy frequency[21]. Furthermore, these models of loggers have been shown useful in built-environment research, precisely in lighting applications[22-24].

PROTOCOL:

The study was approved by the ethics committee of the SWPS University of Social Science and Humanities in Warsaw (number 46/2016).

1. Choosing an experimental site for logger deployment

1.1. Choose an indoor experimental site that will allow mounting the logger in close proximity to the light source (for adequate light changes detection) as well as to gather the data on the behavior regarding the room occupancy status (for adequate movement detection) of individual participants (i.e., one at a time).

1.2. Establish the intended use of the room and its designated users (males, females or co-ed).

NOTE: An example of an experimental site could be a public single-stall restroom due to the fact that this type of room is frequently and individually visited by its users. Furthermore, in most instances, it is possible to specify if the room is visited by males or females, based on its designation.

1.3. Visit a chosen site and note the type / number of functioning light sources along with their light switches. Check whether multiple light sources are controlled by one or multiple light switches.

1.4. Check the possibilities of mounting the logger next to the light source. Ensure that the place of logger mounting is not in proximity to any kind of heating sources (e.g., heaters, windows or mirrors) to ensure that only the body heat of the room users will be recorded.

1.5. Acquire any necessary written permissions from the site owner for installation of the logger and conducting the experiment. Provide the site owner with the details of the experiment, loggers' type and its application in written form.

2. Logger configuration before deployment

2.1. Download and install the dedicated software (see **Table of Materials**) available for Windows/Mac platforms for launching, reading out, and plotting data from data loggers.

NOTE: Additionally a detailed description with basic system requirements and the software manual can be found on the manufacturer's website (see **Table of Materials**).

2.2. Connect the logger via USB cable to the computer (plug the larger end of the USB interface cable into a USB port on the computer and the smaller end of the USB interface cable into the port on the device).

2.3. Launch the software.

2.4. Click the **Launch** icon on the toolbar (or select **Launch** command from the device menu) which opens loggers' setup window.

NOTE: This option will be unavailable when the logger is not connected to the computer. The **Launch Logger** window is divided into the following three sections: 1) logger Information which presents model, serial number, deployment number, and current battery level of the selected logger; 2) list of the sensors available for the logger; and 3) deployment configuration. From this interface, one can set specific features that will configure the logger before deployment, such as those previously mentioned: sensor configuration, configuration of data display filters, start/stop logging, and display of the LCD screen.

2.5. Enter a name for the launch which will be used as the default file name during read out and saving the data recorded by the logger.

2.6. Select the **Light** sensor. Set the measurement to log **State** from the drop-down list, and choose the state description **off/on** from the drop-down list.

2.7. Select the **Occupancy** sensor. Set the measurement to log **State** from the drop-down list, and choose the state description **unoccupied/occupied** from the drop-down list.

NOTE: Occupancy and light sensor channels can be configured to log state changes or runtime. On the state change setting, the work of the logger is event-dependent. While checking every second for a state change, the logger will only record a time-stamped value (how long an event lasts, date and time) when the state change occurs. On the other hand, on the runtime configuration setting, the logger checks and records the state of the sensor status once every second.

2.8. Click the **Filters** button to enable automatic calculation of additional values (e.g., maximum, minimum, average, or total).

NOTE: Step 2.8 is optional and serves for filtering data for each series during loggers' readout.

2.8.1. Select the sensor type of choice. Select the type of filter and the interval to use.

2.8.2. Edit the **Name** and click **Create New Series**. Click **Done**.

2.9. Click the **Advanced** button to access the sensor properties.

2.9.1. Select the **Light** sensor. Select **Set to maximum sensitivity** for calibration and click the **Save** button.

NOTE: By default, the light sensor can be auto-calibrated at the location where the logger will be deployed using the control button located on the top panel. By simply pressing the calibration button, while on the site of deployment, the loggers' LCD screen will display the signal strength of the light being monitored (use this option when light levels in the experimental site are unknown prior to deployment). The sensors' sensitivity can also be adjusted via option "Set to Maximum/Minimum Sensitivity" - if the light levels in the place of deployment are known in advance. These forms of calibration ensure an accurate readout of light changes between ON and OFF states.

2.9.2. Select the **Occupancy** sensor. Select a preset timeout value (i.e., 10 s; 30 s; 1 min; 2 min; 5 min) or select **Custom** and enter a value in minutes and seconds if needed. Click the **Save** button.

NOTE: The timeout value specifies the period of inactivity required for the sensor to consider the area unoccupied. By default, this attribute is set to 1 min.

2.10. Select when to launch the logger, depending on the experimental plan: 1) immediately; 2) at intervals (available when logging runtime); 3) on a specified date/time; or 4) by manually using the start button.

2.11. Select when logger should stop logging: 1) when memory fills; 2) stop at a specified date/time; 3) stop manually or 4) never stop—resulting in the newest data overwriting the oldest.

2.12. Click the **Start** button upon finishing the configuration. Unplug the logger from the computer.

3. Deploying the logger in the field settings

3.1. Visit the experimental site before the time the logger will start recording the data.

3.2. Equip the logger with an additional fiber optic light pipe (see **Table of Materials**) by connecting it to the back of the logger, in order to filter out any ambient light (coming from windows or mirror reflections) and ensure the most accurate readings.

NOTE: The light pipe is 30.48 cm long and can be bent to gain access to hard-to-reach areas, which can be also useful in hiding the logger from the sight of any room user.

3.3. Mount the logger with the light pipe next to the designated light source with the use of: 1) four built-in magnets on the back of the logger that can attach it to a magnetic surface; 2) adhesive strip that can be attached to the back of the logger to mount it on walls or other flat surfaces; 3) any double-sided tape to stick the logger to a surface; or 4) the hook-and-loop strap which can be used through the mounting loops on both sides of the logger to mount it to a curved surface.

NOTE: The choice of the mounting method depends on the type of surface to which the logger will be mounted.

3.4. Leave the experimental site for the time of data logging set or planned.

3.5. After finishing recording, revisit the experimental site and remove the logger for the purpose of data readout.

4. Data readout

4.1. Connect the logger via USB cable to the computer and launch the analysis software package dedicated to the data logger (see **Table of Materials**).

4.2. Click the **Readout device** button from the control panel or select **Readout** from the device menu, which will enable the logger to unload the gathered data.

4.3. Choose a location and a filename or accept the default location and name to save the data. Click **Save** and select the sensors and/or events to display in a graph and click **Plot**.

4.4. Select the series to view on the table data and plot. Click the **All** or **None** button to select or deselect all series, or click the checkboxes to select or deselect individual series.

NOTE: The table data is presented numerically using added filters that were set before the deployment. Each column corresponds to the type of data gathered. For example, the column labeled "light" presents the occurrences of light-switching, whereas the column labeled "occupancy" presents the information about the presence of movement in the field where the logger was deployed. In each column, the state changes are presented dichotomously (the number "0" represents the light status of off in the "light" column and a lack of movement in the "occupancy" column).

4.6. Select **Export table data** from the control panel. Choose destination folder for the export.

NOTE: It is possible to perform a data readout and export it to text, comma-separated values, or spreadsheet files. Other options, such as data plotting, are also available; however, due to the fact that most researchers work on exported data and use statistical packages, we decided to present the most basic data readout. For more information refer to the loggers manual[19].

REPRESENTATIVE RESULTS:

Loggers' reliability test in comparison to human observation

In order to test the reliability of the logger in comparison to human observation, a 4 h field test was conducted in a single-stall male restroom located on the University campus. Two male observers waited outside the restroom (approximately 5 m away from the front door) and independently recorded the visitors' behavior in terms of occupancy rates/times and light switching (lights left ON or OFF upon exiting). Simultaneously, two data loggers were mounted in the same single-stall restroom and gathered the same information as human observers. In total, the behavior of 24 males was recorded.

Fleiss's kappa was run to determine if there was an agreement between loggers and human observers on whether visitors entered the single-stall restroom and exhibited switching off or on the lights upon leaving. Results showed almost perfect agreement[25] in terms of recording light status, $\kappa = 1.000$ (95% CI, 0.885 to 1.115), $p < 0.001$; as well as occupancy status $\kappa = 1.000$ (95% CI, 0.885 to 1.115), $p < 0.001$ (in both instances, the percentage of agreement between each pair of loggers/human observers was equal to 100%). Furthermore, the degree that loggers and human observers provided consistency in their ratings of occupancy time across subjects was assessed using a two-way mixed, consistency, average-measures intra-class correlation (ICC)[26]. The resulting ICC was in the excellent range, ICC = 0.99, indicating that coders had a high degree of agreement[27].

Therefore, it can be assumed that using data loggers could serve as a useful tool for conducting field experiments in psychology since the gathered data is reliable even when compared to human observers. More advantages of using data loggers will be presented through an example of the field experiment, that addressed the occurrence of energy conservation behavior.

Logger deployment in the field setting

The occurrence of energy saving behaviors (such as turning off the light when exiting a public space) may be influenced by descriptive norms, which specify what most people do in a particular situation, providing information on which behavior is generally seen as effective or adaptive[28]. Therefore, it can be assumed that people entering the room in which lights are switched off (descriptive norm) will behave according to this norm and will switch the light off when leaving the room. This assumption has already been positively verified by previous studies on light-switching behavior[13,14]. However, it should be noted that in these studies the descriptive norm of light-off status was, in most cases, manually manipulated by experimenters. The possibilities presented by the used occupancy/light data logger allow to verify the influence of naturally occurring changes in light status on the frequency of people switching off the light when exiting public restrooms.

Participants and procedure

During a 15-day deployment (weekdays from Monday to Friday) of the occupancy and light data logger, the light-switching behavior of 1,148 people (536 men and 612 women) was registered. Participants' gender identification was based on the visited restroom type (men's or women's). Demographic data was not obtained due to the nature of the study and the fact that the logger does not record audio-visual data.

The registration was conducted in two single-stall restrooms (one for women and one for men) in the building of a do-it-yourself (DIY) store located in Warsaw. Both restrooms had an identical architectural layout (i.e., two windowless rooms equipped with two separate light switches) consisting of: 1) first room with a sink, mirror, trash bin and an entrance door to a single stall; and 2) single stall with a toilet and one light source in the center of the ceiling.

Prior to registration, the logger was calibrated to log state changes for light and occupancy channels. The light sensor (with additional fiber optic light pipe) was set to maximum sensitivity and the occupancy sensors' timeout value was set at 10 s. After software setup, double-sided tape was used to stick the logger to the ceiling next to the light source, which was a fixture with an incandescent light bulb hanging from a suspended ceiling.

The first 5 measurement days were conducted in the men's restroom (after choosing it randomly). Next, measurements were taken in the women's restroom for 10 days (the longer period resulted from the fact that there were half the number of women than men visiting the DIY store per day). In summary, there were three 5-day logging shifts. On the first day of each shift, the logger was mounted at 7:00 AM (before logging started), and dismounted on the 5th day of each shift at 8:00 PM (after logging stopped). Proper logging in each restroom started at 8:00 AM on the first day of measurement and lasted till 7:00 PM on the last day. Acquired data allowed analyzing intervals ranging from 8:00 AM to 7:00 PM on each of the measurement days.

Results from field measurement

In the first step, the frequencies of light-switching behavior were compared between logging days (in both restrooms) in order to examine if the occurrence of studied behavior was stable across measurement days. For this purpose, we applied the chi-square test for one variable with Bonferroni correction. The results of analysis showed no statistical significance in the differences between measurement days in the men's restroom χ^2 (4, N = 536) = 5.56; p = 0.23 or in the women's restroom χ^2 (9, N = 612) = 3.27; p =0 .95.

For exploratory purposes, we conducted two additional ANOVA tests, one-way between subjects, on the measurement date of the occupancy time of the users in each restroom. In both instances, occupancy time did not differ to a level of statistical significance in the men's restroom F(4, 531) = 1.51, p = 0.19, η^2 = 0.01 or in the women's restroom F(9, 612) = 1.01, p = 0.43, η^2 = 0.01 across measurement dates. **Table 1** shows frequencies of light-switching behavior as well as occupancy time of users across measurement days in each of the restrooms.

To verify the influence of light status and restroom type on the occurrence of energy conservation behaviors, we conducted logistic regression analysis. Light status (ON vs. OFF before entering the restroom) and restroom type (men's vs. women's) were entered in a model. The dependent variable, energy conservation behavior, was equal to 1 if the participant turned off the light after leaving, and 0 if not. **Table 2** shows the coefficient of the built model.

The results from the built model indicated that restroom type and light status reliably distinguished between switching off/on the light: χ^2 (2) = 25.16; p < 0.001. The Wald criterion demonstrated as significant the restroom type: χ^2 (1) = 8.03; p < 0.01 and light status: χ^2 (1) = 16.08; p < 0.01. Statistics of Cox and Snell's (R^2 = 0.02) and Nagelkerke's (R^2 = 0.05) revealed a weak relationship between prediction and grouping, whereas overall prediction success was 85.9% (23.2% for turning off the light and 91.5% for leaving the light on). Analysis of the odds ratio (OR) revealed that turning off the light while exiting the restroom was 94% more likely to occur in the women's restroom (OR = 1.94) than in the men's restroom. Furthermore, entering a restroom with the light switched off generated an almost three times more likely occurrence of energy conservative behavior (*OR* = 2.96).

FIGURE AND TABLE LEGENDS:

Figure 1: Visual characteristics of the logger on each side.

Table 1: Light-switching behavior and occupancy time across measurement days.

Table 2: Coefficients of built model in logistic regression.

DISCUSSION:

When planning to use more than one site (for logger deployment) at the same time, it should be ensured that each site has an identical architectural layout in order to exclude the possibility of occurrence of different behavioral patterns from participants (i.e., resulting from occupancy times and light-switching possibilities). A suitable site should be equipped with one or more light sources with only one corresponding light switch, visible to the occupant. If otherwise, one should plann to use one logger fir each light source / light switch. Furthermore, prior to selecting a preset timeout value of occupancy sensor (second step in the protocol) it is advisable to run a pilot test of the loggers' deployment on the experimental site to choose to most optional value based on the actual occupancy frequencies of participants. In the third step of the protocol, it is advisable to check whether it is possible to hide the recorder from the eyes of possible room users (even though the data logger has relatively small size). Lastly, due to the fact that the loggers' deployment may take place in public spaces (e.g., restrooms) it is crucial to acquire any necessary written permissions from the site owners and ethics committees.

The presented type of occupancy/light data logger comes in two models (visit manufacturers website for more details – see the **Table of Materials**) that primarily differ in their levels of detection range, performance and zones. Other features such as standard memory capacity of 128 kB (which can be extended up to 512 KB) and design characteristics, are similar. Each model is equipped with a lithium coin battery which may last one year[19]. However, number of deployments as well as type of logging configuration may reduce battery life. Furthermore, there are two versions of loggers' dedicated software: free (that was used in the presented article) and a paid version for additional analysis options with different loggers. The logger can be additionally equipped with a data transporter which allows for convenient data offload in the field. Overall, researchers have the opportunity to choose a particular model, software type and compatible devices, based on their needs and characteristics of site on which the loggers' deployment takes place. An extensive troubleshooting guide is available on manufacturers' website.

The occupancy sensor can only provide the information about movement from one source. In other words, if the room is occupied by more than one person, the logger still would treat and record the occupancy as one. This limitation could be bypassed by employing multiple loggers at once (for example, in multiple-stall restrooms) with attention to the logger location in order to avoid possible false detection. Furthermore, the logger by itself does not provide data that would allow identification of the gender, age or other demographic information about potential participants. In the example presented, deploying the logger in restrooms dedicated to each of the genders allowed to overcome this obstacle. However, there is still a possibility that some men or women could visit a restroom not dedicated to their gender. In addition, it should be noted that the described model of the logger (as well as other models) is only available by purchase through the manufacturer or their distribution partners (see **Table of Materials**).

Despite the purchase costs, the capabilities of the loggers are worth their price. Deploying the occupancy/light data logger can provide a clear operationalization of a given experiment. Each logger setup, as well as logger mounting and deployment, can be presented explicitly. In comparison to reporting the location of human observers in experiments, there are no understatements in the context of the application of data loggers. This can provide well-established grounds for possible replications and a more frequent conduction of field experiments. An advantage of using occupancy/light data loggers is the type of data that can be gathered. In addition to nominal outcomes of light and occupancy status, it is possible to analyze quantitative information about the time of room occupancy status as well as time between occupancy events (which were not analyzed in previous studies concerning light-switching behavior). In this article this type of data was evaluated for exploratory purposes as well as to verify whether the occurrence of behavior was stable across measurement times. As a result, this type of information can be used for further methodological and theoretical refinements in conducting field experiments. During 15 days of measurement, it was possible to gather a substantial sample of 1,148 participants. Even though sample size is not always problematic in field experiments, the fact that the researcher only had to visit the experimental site six times (in contrast to a typical observation method requiring the constant presence of observers) shows tremendous promise for simplifying the conduction of field experiments. Moreover, while in some instances, researchers were not able to observe female light-switching behavior[14], the use of a logger allowed to easily gather this information without the risk of violating social norms regarding the use of restrooms by opposite genders (which would be problematic if a male researcher was to observe and enter a women's restroom). Overall, deploying a data logger reduced the need of hiring observers and thereby limited possible human errors.

Even though this article addresses the use of loggers in measuring light-switching behavior, it should be pointed out that the presented tool can be valuable in other domains as well. Whenever the indicator of dependent variable would require measuring the occurrence of movement and its time (in a closed space), data loggers would allow for precise and automated measurement. Starting with the domain of industrial-organizational psychology (e.g., measuring time spent in the workplace or rates of workspace occupancy), on through to environmental science (e.g., measuring wayfinding in healthcare facilities), and ending with behavioral sciences (e.g., in studies that would not allow for direct observation or using video recording of participants due to legal constraints). Furthermore, presented loggers could be effectively used as a supplementary measurement tool to ambulatory assessment methods such as electronically activated recorder (EAR)[20]. In effect, the acoustic data gathered from EAR could be compared to the data from occupancy logger in order to enhance the precision of the recorded information about the behavior of participants.

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None.

DISCLOSURES:

The authors have nothing to disclose.

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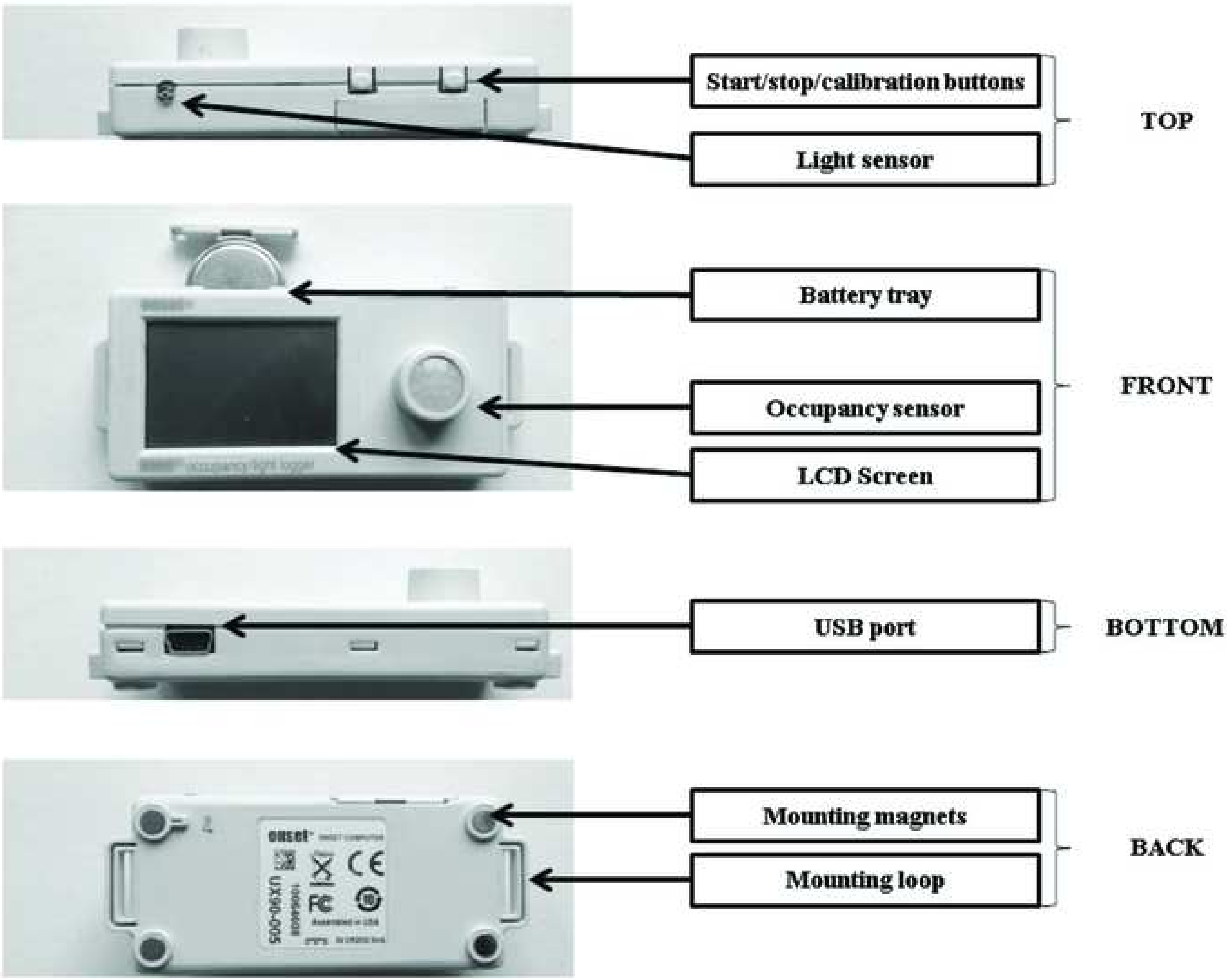
Figure 1


Start/stop/calibration buttons
Light sensor
TOP
Battery tray
Occupancy sensor
LCD Screen
FRONT
USB port
BOTTOM
Mounting magnets
Mounting loop
BACK

Restroom type	**Deployment day**	**N**	**Light-switching frequencies**	
			Light ON	**Light OFF**
Male	1	85	82	3
	2	99	92	7
	3	109	100	9
	4	132	129	3
	5	111	104	7
Female	1	62	54	8
	2	67	58	9
	3	56	51	5
	4	60	53	7
	5	58	52	6
	6	61	53	8
	7	62	56	6
	8	66	59	7
	9	63	56	7
	10	57	54	3

Occupancy time
M = 1 min 43 s SD = 1 min 11 s
M = 1 min 55 s SD = 1 min 21 s
M = 1 min 36 s SD = 0 min 54 s
M = 1 min 48 s SD = 1 min 06 s
M = 1 min 38 s SD = 0 min 50 s
M = 1 min 58 s SD = 1 min 02 s
M = 1 min 56 s SD = 0 min 50 s
M = 1 min 37 s SD = 0 min 44 s
M = 1 min 56 s SD = 0 min 53 s
M = 1 min 56 s SD = 1 min 06 s
M = 1 min 52 s SD = 0 min 53 s
M = 1 min 51 s SD = 0 min 52 s
M = 2 min 03 s SD = 1 min 13 s
M = 2 min 05 s SD = 1 min 15 s
M = 2 min 07 s SD = 1 min 43 s

	b	S.E.	Wald χ^2	*p*	Exp(b)	95% CI	
						LL	*UL*
Restroom type	0.66	0.23	8.03	< .01	1.94	1.22	3.07
Light status	1.08	0.27	16.08	< .001	2.96	1.74	5.02
Constant	-3.63	0.41	80.17	< .001	0.03		

Table of materials

Name of Material/ Equipment	Company	Catalog Number	Comments/Description
HOBO Occupancy/Light (5m Range) Data Logger	ONSET	UX90-005	As advertised by Onset - The HOBO UX90-005 Room Occupancy/Light Data Logger is available in a standard 128 KB memory model (UX90-005) capable of 84,650 measurements and an expanded 512KB memory version (UX90-005M) capable of over 346,795 measurements. For details and other products visit: https://www.onsetcomp.com/products/data-loggers/ux90-005
HOBO Light Pipe	ONSET	UX90-LIGHT-PIPE-1	An optional fiber optic attachment or light pipe that eliminates effects of ambient light to ensure the most accurate readings. For details visit: https://www.onsetcomp.com/support/manuals/17522-using-ux90-light-pipe-1
HOBOware	ONSET	-	Setup, graphing and analysis software for Windows and Mac. There are two versions of HOBOware: HOBOware (available for free) and HOBOware Pro (paid version which allows for additional analysis with different loggers). Each of them are dedicated to HOBO loggers. For details visit: https://www.onsetcomp.com/products/software/hoboware

Maria Curie-Sklodowska University, Lublin, Poland
Department of Social Psychology

Krzysztof Jan Leoniak and Wojciech Cwalina

Dear Dr. Alisha DSouza,

We would like to thank you and the Reviewers for the constructive feedback on our manuscript titled "Using HOBO Occupancy/Light Data Logger UX90-005 in field experiments: an example in studying light-switching behavior" (JoVE60771). Also we would like to thank you for the possibility of resubmission. We have made modifications to take into account all of the received feedback. Below you'll find pointed changes with reference to our resubmitted manuscript as well as to reviewers' comments. For the purpose of clarity, we let ourselves to respond to each issue in sub-points.

Response to editorial comments

1. As requested, we have simplified the title of our manuscript which now is "Measuring light-switching behavior with the use of occupancy and light data logger"

2. We have re-written lines 121-130, 370-394. Changes are visible in lines 115-121 and 350-368

3. We have changed our discussion based on the existing requirements. We have added following sections: "Critical steps within the protocol" (lines 405-417); "Modifications and troubleshooting" (lines 419-430); "Limitations of the method" (lines 432-442) – this section appeared in originally submitted manuscript; "Significance with respect to existing methods" (lines 444-467) – this section appeared in originally submitted manuscript; "Future applications" (lines 469-481) – this section appeared in originally submitted manuscript

4. We have replaced all commercial sounding language in our manuscript with generic names (appearing in title, summary, title of Figure 1, as well as in lines: 33; 95; 99; 103; 111; 122; 125; 128; 163; 168; 254; 279; 306; 341; 346; 441; 445; 450; 472. Overall, there is no more commercial sounding language in the revised manuscript.

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5. We have checked our manuscript for grammatical errors as well as we have defined all abbreviations at first use.

6. We would like to point out that all figures and tables are original. Moreover, we have submitted each figure as a vector image file and uploaded tables as .xlsx files.

Response to the commentary made by Reviewer 1

In the original manuscript we have already provided the information about approval of ethics committee (prior to the description of protocol). We agree with the reviewer that conducting research in the toilet area is associated with "ethical fragility". Therefore we have additionally addressed this issue in lines 415-417 (Discussion, subsection „Critical steps within the protocol).

Response to the commentary made by Reviewer 2

We aggree with the reviewer that the proposed procedure can can primarly help collecting data about occupant light switching behaviors and occupancy. Therefore we've edited our claims of contributions to collecting data about the energy conservation behavior (lines: 23; 96-97; 469-470).

Overall, we would like to thank both Reviewers for the feedback, since we believe it helped us greatly in improving our manuscript. We have tried to revise our manuscript accordingly to points made by all reviewers.

Thank you again for the possibility of resubmission.

We are looking to hearing from you with further comments on our manuscript.

Sincerely,

Krzysztof Jan Leoniak and Wojciech Cwalina

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Author(s):	Krzysztof J. Leoniak and Wojciech Cwalina

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