Estimating Consumer Willingness to Pay for Personal Chemical Device Monitors:

Technical Report to Accompany *Tracking Chemical Exposures: Insights on the market demand for personal chemical monitoring technologies*

Final Report

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1. Background and Overview

This technical report provides details on the choice experiment designed and conducted by Eastern Research Group Inc. (ERG) to estimate consumers' willingness to pay (WTP) for personal chemical exposure monitors (PCEM) with input from Environmental Defense Fund (EDF). The results from this work are summarized in the EDF's report entitled *Tracking Chemical Exposures: Insights on the market demand for personal chemical monitoring technologies* (hereafter, "main report"). The details in this technical report provide information on the methods used to develop the summary estimates presented in the main report and the detailed statistical results that support the estimates in the main report.

The primary purpose of the analysis was to derive estimates of the demand for PCEM devices among consumers. We did this using a choice experiment approach. Choice experiments are a "stated preference" method in which respondents to a survey are asked about their preferences for a specific good or service. Stated preference methods are used in situations in which a market for a good or service is absent; that is, we construct a hypothetical market and use respondents' decisions within that market to assess demand.

This technical report will provide details on the choice experiment method as applied to the market for PCEM devices (Section 2), the survey data that were collected (Section 3), the statistical results that we used to estimate WTP for devices and device features (Section 4), and the resulting estimated WTP values (also Section 4).

2. Choice Experiment Design

Overview

Choice experiments are a more general form of a contingent valuation survey. In a standard contingent valuation survey (e.g., for an environmental restoration project), respondents are provided with a description of the project and a description of the project's benefits. They are then asked whether or not they are willing to contribute or pay a certain amount (usually in the form of increased property or income taxes) for the project to be performed.[1] The dollar amounts are varied among respondents and respondents' answers to the yes/no WTP question along with other data collected through the survey are used to characterize demand for the project.

In a choice experiment, respondents are also provided with a description of a good or service and a description of the potential benefits of that good or service. The valuation question differs substantially, however. Instead of simply asking if the respondent is willing to pay a certain amount to have the project done, respondents are provided with two (or more) options to choose from, with the possibility of selecting neither one, and with each option characterized by a set of "attributes." In this survey, the attributes reflect features of the PCEM devices such as the number of chemicals included in the results or the timeliness of getting the results. Each attribute is also assigned a pre-determined set of "levels" reflecting specific values for the feature. For example, one attribute we used in characterizing the devices was the "number of chemicals" that the device could detect; for that attribute we defined three levels: "200 chemicals," "30 chemicals," and "just a few". In a choice experiment, each option (or device, in this case) respondents can choose from is comprised of the attributes set to specific levels; that is, each option corresponds to a hypothetical device in our case. Each device is also associated with a price.

Table 1 contains a list of the attributes and their associated levels that were used in our survey. We focused on five attributes:

- **Type of device**: Is the device worn by the person or is the device one that requires biomonitoring (e.g., blood or urine samples)?
- **Timeliness of results**: How long does it take to get the results? The survey asked about receiving results immediately, in a week, and in a month.
- **Number of scans**: How many scans (described as a frequency over time) will the device allow? Survey options included unlimited scans, one scan per week, one scan per month, and one scan per year.
- **Number of chemicals**: How many chemicals are included with the results? The survey asked about getting information on 200 chemicals, 30 chemicals, or "just a few."
- **Nature of the results**: What type of information does the device provide? The survey provided three options: 1) a simple yes/no indicator on whether exposure had occurred, 2) quantified exposure level information, or 3) quantified exposure level information coupled with additional interpretation (e.g., exposure is of low, medium, or high concern).

Except for type of device, the levels in Table 1 are listed in order of hypothesized preference (e.g., we assumed that "immediate" results would be preferred to "one week" for timeliness); in the analyses

[1] This description simplifies a standard contingent valuation survey.

that follow, we refer to the feature that we think is most-preferred as the "premium" feature for that aspect. For type of device, we simply used a qualitative distinction between devices someone could wear compared to ones that involve biomonitoring.

Table 1. Attributes and Levels Used in Choice Experiment

Attribute	Levels
Type of Device	■ Wearable device ■ Biomonitoring
Timeliness of Results	■ Immediate ■ One week ■ One month
Number of Scans	■ Unlimited ■ Once per week ■ Once per month ■ Once per year
Number of Chemicals	■ 200 ■ 30 ■ Just a few
Nature of Results	■ Exposure level with interpretation of what level means ■ Exposure level ■ Detect only

The final attribute included in the design was the device price. ERG used four values for device prices: $50, $150, $250, and $350.

Experimental Design

Several experimental design decisions were made as part of this research. These included:

- Determining the appropriate number of devices to use in the survey
- Combining the levels of each attribute to formulate "hypothetical devices"
- Combining the hypothetical devices into pairs that are presented to respondents
- Determining the number of times we ask respondents to select between pairs of devices

A key aspect of a choice experiment is selecting a manageable design for combining attributes into options for respondents to select from. Our design involved one attribute with two levels, three attributes with three levels, and one attribute with four levels. This implies there are 216 (=2x3×3x3×2) possible devices; this is referred to as the "full factorial design." Using 216 combinations is unwieldy to design and would require a large sample size to adequately analyze. ERG used "fractional factorial design" methods to select a set of combinations that would allow for efficient statistical estimation. This process resulted in 24 devices that were combined into 12 choice sets (device pairs). Each of the 12 sets contain specific values for a "Device A" and "Device B." One consideration in developing the set of 24 devices was to ensure that each level within an attribute appear an equal number of times as other levels within the attribute. For the most part, ERG was able to satisfy this requirement.

Together EDF and ERG selected an initial set of 24 devices and formulated them into 12 pairs, and then we reviewed the devices and pairings to assess:

- **Realism** – We reviewed the initial set of devices to ensure that each hypothetical device was realistic combination of features.
- **Dominance** – Some combinations will be "dominated" (unlikely to be chosen over another option) by other ones; for example, a combination with the lowest level for each attribute and the highest cost would be dominated by every other combination.
- **Relevant comparison** – EDF and ERG also reviewed the pairings to ensure that the two devices were sufficiently different to allow respondents to make a meaningful choice.

Table 2 summarizes the 24 devices and the 12 device pairings used in the choice experiment.

Finally, ERG decided to ask each respondent two WTP questions; that is, to make a choice between two devices (or choose neither) twice. This essentially doubled our sample size since we now have two responses from each person.

Table 2. Devices and Pairings

Block	Device A						Device B					
	Type of Device	Timeliness	Number of Scans	Number of Chemicals	Nature of Results	Price Point	Type of Device	Timeliness	Number of Scans	Number of Chemicals	Nature of Results	Price Point
1	Biomonitoring	Immediate	Unlimited	30	Detect only	$250	Biomonitoring	4 weeks	Once per year	200	Detect only	$150
2	Biomonitoring	4 weeks	Once per week	200	Detect only	$150	Biomonitoring	1 week	Once per month	200	Exposure Level with Interp.	$350
3	Wearable	1 week	Unlimited	Just a few	Exposure Level with Interp.	$350	Biomonitoring	Immediate	Once per month	30	Exposure level	$350
4	Wearable	Immediate	Once per month	200	Exposure Level with Interp.	$150	Wearable	4 weeks	Unlimited	30	Exposure Level with Interp.	$50
5	Wearable	4 weeks	Unlimited	30	Exposure level	$50	Wearable	1 week	Once per month	200	Exposure level	$150
6	Wearable	Immediate	Unlimited	Just a few	Exposure Level with Interp.	$350	Wearable	4 weeks	Once per month	200	Exposure level	$150
7	Biomonitoring	1 week	Once per year	Just a few	Detect only	$150	Biomonitoring	4 weeks	Once per week	Just a few	Exposure Level with Interp.	$250
8	Wearable	Immediate	Once per month	30	Exposure level	$50	Wearable	1 week	Once per week	Just a few	Exposure Level with Interp.	$150
9	Biomonitoring	1 week	Once per week	30	Exposure Level with Interp.	$250	Biomonitoring	4 weeks	Once per year	200	Detect only	$150
10	Wearable	4 weeks	Once per week	30	Exposure level	$250	Wearable	Immediate	Once per week	200	Detect only	$350
11	Wearable	Immediate	Unlimited	Just a few	Exposure level	$250	Biomonitoring	1 week	Once per year	Just a few	Exposure level	$50
12	Biomonitoring	1 week	Once per week	200	Exposure level	$350	Biomonitoring	Immediate	Once per month	30	Detect only	$250

Sample Size and Selection

The sample size for the survey was calculated using the "rule of thumb" for choice experiments developed by Johnson and Orme (1996) and summarized in Orme (2010). The rule of thumb value provides a minimum sample size needed for a choice experiment study that involves having respondents assess multiple alternatives in which the attributes of the alternatives have multiple levels. In our case, the alternatives are the options for which we asked the respondents to indicate their preference. The attributes and their levels are defined in Table 1. The rule of thumb is:

$$n \geq \frac{500c}{ta}$$

where

- *n* is the (minimum) sample size.
- *t* is the number of tasks that each respondent is being asked to perform. In our case, this is the number of WTP questions we asked each respondent, or *t* = 2.
- *a* is the number of alternatives being presented to respondents each time they are asked to choose (excluding the "neither" option). In our case, we are asking respondents to compare two devices each time (*a* = 2).
- *c* is the number of levels for each attribute. In cases where the number of levels varies across the attributes, *c* is set equal to the largest number of levels for any attribute. The largest number of levels for any attribute is 4 (*c* = 4).

Using these values specified above for *t*, *a*, and *c* in the rule of thumb results in an estimated sample size of 500 respondents. ERG budgeted for a sample size of 600 respondents in the data collection effort, more than satisfying the required size for our design, and in the implementation a total of 616 respondents provided data. ERG implemented the survey using our web-based Qualtrics, Inc. account, and worked with Qualtrics to select a random public sample for survey response.

Survey Instrument

ERG and EDF developed a survey instrument to collect these data, which appears in Appendix A to this technical report. The key questions in the instrument were the WTP questions. The instrument also collected data on respondent characteristics and attitudes that assisted us in developing a detailed analysis of the surveyed population. The instrument began with an introductory section that provided some background information on PCEM devices and the potential features that could be offered. We also asked respondents about their:

- Perceived risk from chemical exposure
- Experience with health issues
- Healthy habits (e.g., exercising)
- Work locations
- Current exposure to chemicals at home and at work

- Education level
- Gender
- Race and/or Hispanic origin
- Income
- Age
- Marital status
- Children
- Pregnancy status

The two WTP questions were asked as part of this sequence and included a few follow up questions as well. First, we asked how confident respondents were in their responses after each WTP question. In our analyses, we used only respondents who indicated they were "very confident" in their WTP responses. Second, for respondents who selected neither device, we asked the respondent to select a reason for their choice, for each WTP question. Finally, following the second WTP question, we asked respondents to identify which device attributes (e.g., timeliness of results, type of device) were most and least important in making their decision, what the respondent would do with the information, and whether they felt the survey would have an effect on the development of devices. ERG reviewed the responses to these questions to assess the validity of the responses and to provide context for the survey, if needed.

Statistical Analysis Techniques

To analyze the data collected from the survey, ERG used the alternative-specific conditional (ASC) logistic regression model (McFadden, 1974; Greene, 2012). Before describing our use of the ASC logit model, we provide some context on the analytical data set. First, respondents represent multiple records in the final analytical data set. For example, we asked each individual to make a choice from two separate choice sets, and each set had three choices (i.e., "Device A," "Device B," and "None"). Thus, each respondent is represented by six records in the data (2 choice sets × 3 options to choose from within each set). Each record in the data corresponds to a hypothetical device (including the "no device" option). Each record has a binary variable set equal to 1 (= yes) if the respondent selected that option, or 0 (= no) if the respondent did not select that option.[2] Second, we formulated binary variables to represent the levels for each attribute we included in the model (e.g., type of device). For example, we defined three binary variables for *timeliness of results*:

- The device provides immediate results (yes = 1; no = 0)
- The device provides results in one week (yes = 1; no = 0)
- The device provides results in four weeks (yes = 1; no = 0)

[2] Thus, each respondent had six records in the data; for both WTP questions each respondent will have a record reflecting the details of "Device A", a record reflecting the details of "Device B", and a record reflecting the "no device" option. Given that the respondent selects only one device ("A", "B", or "none") in each WTP question, each respondent will have two records with a "yes" in the "selected option" binary variable and four records with a "no."

In our statistical analysis, it was necessary to exclude one of the binary variables for each attribute to allow the statistical model to be solved. We excluded the "lowest" category among the attributes where we could rank the levels (timeliness, number of scans, number of chemicals, and level of details provided); for type of device, we excluded the biomonitoring yes/no variable. Thus, the estimates for each level can be interpreted as being relative to the excluded category within each attribute. For example, the estimated regression coefficient for device with "immediate results" in the timeliness of results attribute is relative to devices that provide results within four weeks (the excluded category). Thus, the WTP estimate can also be interpreted in that manner; in our example, it's the value people are willing to pay for a device that provides immediate results compared to one that provides results within four weeks. Finally, the value for cost to the respondent was used in its quantitative form; this is necessary to derive WTP values.

The ASC logit model uses the binary variable for selection of the option (1 = respondent selected the device, 0 = respondent did not select the device) as the dependent variable. The independent variables are the binary variables used to represent the levels (described above) and the cost of the device. To calculate WTP, we divide the estimated coefficient for each level by the negative[3] of the estimated coefficient for the cost variable. For levels that are excluded from the analysis (to ensure the model estimates properly), the WTP value is calculated as the negative sum of the estimated values for the other WTP values.

The ASC logistic regression model incorporates respondent-level characteristics (e.g., gender, income, etc.) by including them as shift parameters (referred to as "alterative-specific constants") for the options that can be selected – for example, how does being a woman affect selection of "Device A"? However, in each of the 12 pairings we use, the device defined as "Device A" and the one defined as "Device B" are different. Thus, understanding what factors lead to selection of "Device A" is meaningless since "Device A" changes from pairing to pairing. On the other hand, the "no device" option in each WTP question is always the same; the respondent has decided to select neither device presented. Thus, the values for the "no device" alternative tell us how respondents' characteristics influence whether they select a device at all; that is, what are the characteristics of those who are more (or less) likely to select a device? We used the following respondent characteristics in our analyses:

- Gender*
- Having a child at home*
- Pregnancy[4]*
- Has at least a college degree
- Income
- Identifying as part of a minority population
- Married
- Age*
- Being exposed at work[5]*
- Being exposed at home[6]

[3] The value must be multiplied by -1 for algebraic reasons.
[4] Respondent indicated they or their partner was pregnant or planning to get pregnant within the next year.
[5] Respondent answered affirmatively when asked whether they are exposed to chemicals at work.
[6] Respondent answered affirmatively when asked whether they are exposed to chemicals at home.

- A measure of concern about chemical exposure[7]
- A measure of experience with medical/chemical exposure incidents[8]
- Extent to which the respondent has healthy habits[9]
- Extent to which the respondent considers him- or herself as healthy[10]

In our analyses, we developed a base analysis that uses data from all respondents who were "very confident" in their response to the WTP question. We then also performed a set of analyses to derive WTP values for specific respondent groups by selecting data from those specific groups. For example, we developed an analysis to estimate WTP for device attributes among women by using only data from women respondents (and who further said they were "very confident" in their response to the WTP questions). The groups selected for inclusion in the main report (denoted with an asterisks) were included based on EDF interest in the population and having an adequate number of responses to allow for valid and reliable estimates.

[7] The survey asked respondents three questions on a five-point agreement scale: "I am at risk of chemical exposure daily," "I am worried about my exposure to harmful chemicals," and "I want to know what I am being exposed to." We converted the responses to a numeric value by assigning "Strongly disagree" to a "1", "Disagree" to "2", etc. We then created an index as the sum of those three questions for each respondent.

[8] The survey asked respondents to indicate whether or not they (1) had ever been diagnosed with cancer, (2) hospitalized for chemical exposure, (3) exposed to chemicals at a level that worried them, (4) have a compromised immune system, (5) have any serious chronic medical conditions (e.g., asthma, diabetes), or (6) have any medical conditions that limit their activities. For each respondent we calculated an index value as the number of "yes" responses across the six questions.

[9] The survey asked respondents about the frequency they took part in certain habits: (1) eating organic, (2) exercising, (3) measuring their vital signs (e.g., blood pressure, heart rate), (4) smoking, (5) eating healthy, (6) wearing a personal fitness monitor, and (7) tracking what they eat for dietary reasons. The responses could range from "never" (numerically coded as "1") to "Always" (coded as a "5") with the question on smoking being reverse-coded (i.e., "never" was coded as "5" etc.). We calculated an index value as the sum of the numerically coded values.

[10] Respondent were asked if they considered themselves "healthy" on a 5-point agreement scale. Responses were coded as 1 = "significantly disagree" to 5 = "significantly agree."

3. Description of Collected Survey Data

The survey was implemented on October 8 and 9, 2018 using a representative sample from the U.S. as a whole. ERG specified a required sample size of 600 from Qualtrics Public Sampling unit and received a total of 616 usable responses. To ensure the data were relevant to assessing the market for PCEM devices, we limited the sample to those who indicated they were "very confident" in their response to the WTP question. Table 3 provides a cross-tabulation of the responses to the confidence questions associated with each WTP question that was asked. As can be seen, 304 respondents were "very confident" in their responses to the first WTP question and 312 were "very confident" in their responses to the second WTP question. Combined, the "very confident" responses from both questions represented 355 total respondents.[11]

Table 3. Confidence Expressed by Respondents for Each Willingness to Pay Question, Cross-Tabulated

Level of Confidence for First WTP Question	Level of Confidence for Second WTP Question				
	Not at all confident	Somewhat unsure	Somewhat confident	Very confident	Totals
Not at all confident	7	4	6	3	**20**
Somewhat unsure	3	32	22	3	**60**
Somewhat confident	1	21	165	37	**224**
Very confident	1	6	44	261	**312**
Totals	**12**	**63**	**237**	**304**	**616**

A set of demographics for the respondents in the sample who were "very confident" in their responses appears in Figure 1. Additionally, 53 percent of the sample were men and the remaining 47 percent were women.

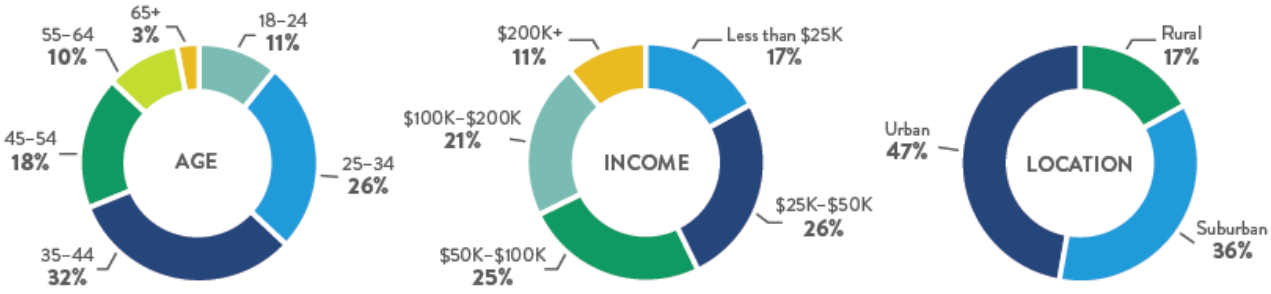

Figure 1. Demographics for the Sample of "Very Confident" Respondents

[11] This is calculated as the number of the "very confident" responses for each question (312 + 304) minus the number who were "very confident" for both (261).

4. Statistical Estimates and Willingness to Pay Values

This section begins by providing the ASC logit models and the associated WTP values for our base estimation that includes all respondents who were "very confident" in their WTP responses. Next, we use the base analysis to explore how average WTP values vary across different aspects of devices. Finally, we provide estimates and WTP values for six demographic-specific analyses we present in the main report.

Base Analysis

Table 4 provides the estimated statistical model for our base analysis along with the associated WTP estimates.[12] The WTP values can be either positive or negative. A positive value reflects the idea that, all else equal, respondents are willing to pay more for a device with that feature. A negative value indicates that, all else equal, respondents are willing to pay less for a device with that feature. For example, respondents are willing to pay $76.55 more for devices that provide unlimited scans, all else equal. On the other hand, respondents are willing to pay $21.27 less for devices offering data on only 30 chemicals. The WTP estimates can be summarized as follows:

- *Device type*. Respondents preferred wearable devices to biomonitoring, but the difference was not statistically significant.
- *Timeliness of getting results*. Respondents viewed immediate results as a positive benefit; they were willing to pay on average $154.37 more for devices with this feature. Getting results in either a week or a month reduced the value of devices by $8.44 and $145.93, respectively.
- *Number of scans*. Respondents were willing to pay more for a device providing unlimited scans ($76.55) or scans at least once per week ($79.19). Getting scans once per month reduced average WTP by $87.08 and getting scans once per year reduced average WTP by $68.67. Unexpectedly, respondents expressed a slightly higher WTP for weekly scans, compared to unlimited scans, but the difference was not statistically significant. This would indicate respondents considered unlimited and weekly scans to be comparable. Similarly, differences between monthly and yearly scans were not statistically significant. This suggests respondents may not view frequency as a continuum, but rather as a binary feature: frequent or not frequent.
- *Number of chemicals*. Respondents were willing to pay a $159.77 premium for a device that can detect 200 chemicals. Values are reduced by $21.27 for devices covering only 30 chemicals, and by $138.50 for devices covering only "a few" chemicals.
- *Nature of results*. Respondents place a premium of $130.49 on devices that provide both an exposure level and context, i.e., an interpretation of the risk associated with that level. The value they place on a device is reduced by $7.84 for devices that provide only exposure level and by $122.65 for devices that only indicate whether chemicals are detected or not.

[12] The reported results for the statistical analysis include the estimated model and the alternative-specific constants for selecting "no device"; results for selecting "Device B" are not included since they are meaningless. There are no alternative-specific constants for "Device A" since the model must set one to be a "base" option to allow the model to estimate.

Table 4. Estimated Alternative Specific Logistic Regression Model and Associated Willingness to Pay Values

Levels of attributes and Respondent Characteristics	Statistical Model		Estimated WTP		
	Regression Coefficient	z-statistic	Estimate	95% Confidence Interval	
				Lower bound	Upper Bound
Device worn on body	1.093	(0.71)	$28.47	-$58.28	$115.22
Biomonitoring device	-	-	-$28.47	$58.28	-$115.22
Immediate results	1.621***	(3.44)	$154.37	$35.15	$273.59
Results in one week	0.974	(-0.24)	-$8.44	-$79.91	$63.03
Results in one month	-	-	-$145.93	-$229.62	-$62.25
Unlimited scans	1.271	(1.05)	$76.55	-$41.10	$194.20
Scans once per week	1.281*	(1.95)	$79.19	-$13.14	$171.52
Scans once per month	0.762	(-1.33)	-$87.08	-$211.72	$37.56
Scans once per year	-	-	-$68.67	-$229.49	$92.16
200 chemicals	1.648***	(3.44)	$159.77	$42.71	$276.83
30 chemicals	0.936	(-0.50)	-$21.27	-$104.09	$61.56
Just a few chemicals	-	-	-$138.50	-$261.41	-$15.60
Results with exposure level and context	1.504***	(2.76)	$130.49	$17.61	$243.37
Results with exposure level	0.976	(-0.20)	-$7.84	-$85.52	$69.84
Results indicate detected or not	-	-	-$122.65	-$221.97	-$23.33
Price	0.997***	(-2.65)			
Alternative-Specific Constants for selecting "no device"					
Female	1.371	(1.24)	-	-	-
Work exposure	0.371***	(-3.14)	-	-	-
Home exposure	1.544	(1.33)	-	-	-
Child at home	0.710	(-1.30)	-	-	-
Pregnant/Planning	0.716	(-0.85)	-	-	-
Concern over exposure	0.812***	(-5.11)	-	-	-
Experience with health effects	0.779**	(-2.46)	-	-	-
College educated	0.539**	(-2.20)	-	-	-
Health habits	0.938**	(-2.37)	-	-	-
Income	0.852	(-1.23)	-	-	-
Minority population	1.066	(0.25)	-	-	-
Married	0.996	(-0.01)	-	-	-
Considers self healthy	0.866	(-1.11)	-	-	-
Age	1.341***	(2.92)	-	-	-
N	1,848	-	-	-	-
Chi-Squared	168.3	-	-	-	-

Exponentiated coefficients; *z* statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Overall, respondents value getting immediate results and getting data on a large number of chemicals as the most important factors. Getting information on exposure level along with interpretation of that exposure level was the third most valuable attribute. Additionally, it appears that respondents need a "premium" feature in the devices. For example, the three attributes with three levels each featured a large positive WTP for the top level then negative values for the second and third levels. The one attribute with four levels featured moderately high values for the top two categories and negative values for the bottom two. Thus, top levels of the attributes are earning large premiums relative to the lower ones, and lower levels for these attributes reduce respondents' WTP for the devices.

The statistical model also controls for several demographic and respondent characteristic factors by using alternative-specific constants. We have included those constants for the alternative of selecting no device. These estimates provide insights into the factors associated with increasing or decreasing respondents' likelihood of selecting "none" in the choice questions. The estimated values enter the likelihood equation negatively; that is, positive values are associated with decreasing the likelihood of selecting "no device." The following were found to decrease the likelihood of selecting "no device" (i.e., increase the likelihood of selecting a device):[13]

- **Being exposed to chemicals at work** – Respondents who reported being exposed at work were 2.7 times more likely to purchase a device compared to those who were did not report they were exposed at work.
- **Having a higher level of concern about chemical exposure** – Respondents who indicated they were most concerned about chemical exposure were three times as likely to purchase a device compared to those with the lowest levels of concern about chemical exposure.
- **Having a larger number of medical conditions/chemical exposure incidents** – Those who experienced the largest numbers of medical or chemical exposure incidents were 5 or more times as likely to purchase a device.
- **Having at least a college degree** – Respondents with college degrees were almost twice as likely to purchase devices.
- **Indicating they have higher numbers/frequencies of healthy habits** – Those who indicated that they had several "healthy habits" were three times as likely to purchase a device.
- **Being younger** – The youngest respondents were most likely to want to purchase a device and the likelihood of purchasing a device declined by 25 percent for each 10-year increase in age.

Estimated Market Price for Selected Devices

The estimated WTP values in Table 4 provide useful information about how consumers value different attributes of personal chemical monitoring devices. Those WTP estimates, however, cannot be added up to obtain the value of an individual device having a specific set of features. The estimates in Table 4 are made holding all other attributes constant. To calculate the value for a device with a specific set of features requires estimating the value of a regression equation (absent the price term) for the specific configuration, and then dividing that value by the negative of the price term. As noted in the design

[13] The values in the bullets to follow are based on transforming the estimated alternative-specific constant coefficients for selecting "no device" in Table 4 into odds ratios.

section, there are 216 distinct device combinations that could be formulated with the set of attributes and levels we used.

Table 5 contains estimated WTP values for four sample device configurations. As discussed above, "premium" features appeared to be influential in shaping consumers' WTP for such devices. To help in understanding this, we included at least one "premium" (top level) feature in each example device (cells shaded in light blue).

- Device #1 has a WTP of approximately $80. It has two top level features (immediate results and unlimited scans), but only offers data on 30 chemicals, and does not provide context information (whether the exposure level is of high, medium, or low concern.) Additionally, even though it offers the highest frequency of scans (unlimited), this frequency level is not associated with a high WTP value (see Table 4), keeping device #1 lower in WTP value than devices #3 and #4.
- For Device #2, we switched Device #1 from a biomonitoring to an external device, downgraded the time to get results to one week, downgraded the number of chemicals to "just a few", and upgraded the nature of results to include context on the exposure level (frequency of scans is the same between #1 and #3). This resulted in a slightly higher average WTP of $113 compared to #1.
- For Device #3 we used the top level for time to get results, number of chemicals, and nature of results; we also used the third (of four) levels for frequency of scans, to get a WTP of $293.
- Finally, for Device #4, we configured the device with the levels in Table 4 that have the largest WTP values for each attribute;[14] this resulted in the maximum WTP value for a device of $459.

Although these four devices each feature positive average WTP values, some combinations result in negative average WTP values. For example, using the lowest WTP values in Table 4 for each attribute results in a WTP of -$477.

[14] For each attribute except frequency of scans, this is the top level; for frequency of scans, the largest value was for one week.

Table 5. WTP Values for Select Hypothetical Devices

	TYPE	TIMELINESS	SCANS	CHEMICALS	RESULTS	AVG. WTP
1	Wearable	**Immediate results**	**Unlimited scans**	200 chemicals	Exposure level and interpretation	$80
		One week	One scan per week	**30 chemicals**	**Exposure level only**	
	Biomonitoring	One month	One scan per month	Just a few chemicals	Detect only	
			One scan per year			
2	**Wearable**	Immediate results	**Unlimited scans**	200 chemicals	**Exposure level and interpretation**	$113
		Results within a week	One scan per week	30 chemicals	Exposure level only	
	Biomonitoring	Results within a month	One scan per month	**Just a few chemicals**	Detect only	
			One scan per year			
3	**Wearable**	**Immediate results**	Unlimited scans	**200 chemicals**	**Exposure level and interpretation**	$293
		Results within a week	One scan per week	30 chemicals	Exposure level only	
	Biomonitoring		**One scan per month**			
		Results within a month	One scan per year	Just a few chemicals	Detect only	
4	**Wearable**	**Immediate results**	Unlimited scans	**200 chemicals**	**Exposure level and interpretation**	$459
		Results within a week	**One scan per week**	30 chemicals	Exposure level only	
	Biomonitoring		One scan per month			
		Results within a month	One scan per year	Just a few chemicals	Detect only	

Table 6 provides a distribution of the estimated average WTP values over the 216 device configurations. Overall, 32 percent had a positive WTP value, with 21 percent of the configurations having an estimated average WTP above $100.

Table 6. Distribution of Average WTP Values over Device Configurations

WTP Range	Number of Device Configurations	Percentage of Device Configurations Falling in Price Range	Percentage of Device Configurations Falling in Price Range (excluding WTP ≤ $0)
≤ $0	146	68%	N/A
$0 - $100	25	12%	36%
$100 - $200	23	11%	33%
$200 - $300	15	7%	21%
$300 - $400	4	2%	6%
$400 - $500	3	1%	4%

As noted above, larger values for WTP tend to be driven by the presence of premium features. Table 7 shows the average, minimum, and maximum WTP values for devices by number of premium features. Having two premium features is the minimum level for device configurations to have an average WTP above $100, but having two premium features does not guarantee being above $100 – or even above $0. Having three premium features almost guarantees being above $100, with a minimum WTP value of $99.17.

Table 7. Average, Minimum, and Maximum Average WTP Values by Number of Premium Features

Number of Premium Features	Number of Device Configurations	Average WTP Value	Minimum Average WTP Value	Maximum Average WTP Value
0	32	-$393.43	-$615.87	-$170.98
1	80	-$197.74	-$452.24	$10.05
2	72	$6.82	-$199.10	$172.86
3	28	$216.46	$99.17	$320.72
4	4	$429.26	$399.47	$459.05

Note: there are four devices with the maximum number of premium features since (a) "type" does not have a defined premium level and (b) number of scans has two levels defined as premium based on the estimated WTP values.

Demographic and Characteristic-Specific Estimates

Finally, we developed a set of estimates specific to five demographics or characteristics of the respondents:

- Women
- Men
- Age 45 and younger
- Older than 45
- Pregnant or expecting to be pregnant within a year or has a child in the home
- Exposed at work (self-reported)

To develop these estimates, we limited the sample to the specific group (e.g., just women).[15] In estimating the statistical models, we also removed the specific characteristic from the set of control factors among the alternative specific constants.[16] The results of these analyses are presented in Table 10 and 11. For context, Figure 2 provides a distribution of job categories of those who indicated they are exposed at work.

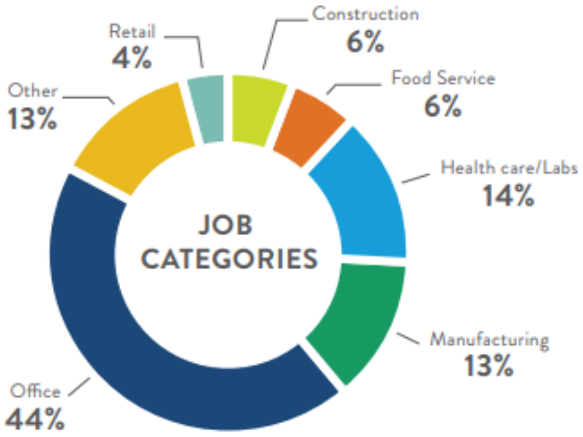

Figure 2. Job Categories of Those Exposed at Work

[15] ERG also maintained the restriction of using just those who were "very confident" in the responses to the WTP questions in these analyses.

[16] For example, in the model for estimating the values among women, we removed the yes/no indicator for "women" from the set of alternative specific constants.

Table 10. Estimated Alternative Specific Logistic Regression Model Results for Demographics and Characteristics Analyses

Levels of attributes	Women	Men	Younger than 45	45 and older	Pregnant/Planning or Child in Home	Exposed at Work
Wearable device	1.061 (0.34)	1.193 (0.88)	1.084 (0.51)	1.032 (0.14)	0.817 (-1.08)	0.909 (-0.38)
Immediate results	1.904*** (2.89)	1.463* (1.92)	1.698*** (3.16)	1.496 (1.39)	1.512** (2.20)	1.362 (1.34)
Results in one week	0.860 (-0.84)	1.069 (0.44)	1.073 (0.53)	0.781 (-1.08)	0.998 (-0.01)	1.049 (0.28)
Unlimited scans	1.361 (0.90)	1.200 (0.54)	1.436 (1.28)	1.175 (0.37)	1.732* (1.69)	1.445 (0.95)
Scans once per week	1.305 (1.34)	1.372* (1.73)	1.222 (1.35)	1.199 (0.66)	1.156 (0.85)	1.206 (0.84)
Scans once per month	0.687 (-1.20)	0.801 (-0.74)	0.682 (-1.57)	0.992 (-0.02)	0.983 (-0.06)	0.975 (-0.07)
200 chemicals	1.953*** (2.99)	1.474* (1.86)	1.891*** (3.58)	1.326 (1.00)	1.659** (2.44)	1.740** (2.17)
30 chemicals	0.847 (-0.83)	1.049 (0.25)	0.961 (-0.24)	0.913 (-0.37)	0.669** (-2.04)	0.744 (-1.14)
Results with exposure level and context	1.849*** (2.65)	1.288 (1.22)	1.526** (2.33)	1.594 (1.59)	1.306 (1.37)	1.090 (0.34)
Results with exposure level	1.095 (0.49)	0.892 (-0.64)	0.960 (-0.27)	1.034 (0.14)	1.025 (0.14)	1.037 (0.15)
Price	0.997* (-1.73)	0.997* (-1.96)	0.996** (-2.51)	0.998 (-0.91)	0.995*** (-2.87)	0.998 (-1.08)
N	873	975	1263	585	1092	720
pseudo R^2						
Chi-Squared	79.68	93.30	110.5	61.34	103.4	58.01

Exponentiated coefficients; *z* statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 11. Estimated Willingness to Pay Values for Demographics and Characteristics Analyses

Level	Women	Men	Younger (Less than age 45)	Older (Age 45 or older)	Pregnant/ planning or child in home	Exposed at work
Wearable device	$19.46	$52.59	$22.37	$13.64	-$41.93	-$42.42
Biomonitoring	-$19.46	-$52.59	-$22.37	-$13.64	$41.93	$42.42
Immediate results	$210.48	$113.58	$147.50 #	$176.66	$85.79 #	$136.95
One week for results	-$49.48	$20.03	$19.52	-$108.26	-$0.32	$21.19
One month for results	-$161.00	-$133.61	-$167.02 #	-$68.40	-$85.47 #	-$158.14
Unlimited scans	$100.74	$54.43	$100.82	$70.54	$114.05 #	$163.21
One scan per week	$86.97	$94.33	$55.87	$79.48	$30.13	$83.12
One scan per month	-$122.63	-$66.18	-$106.50	-$3.54	-$3.59	-$11.34
Once scan per year	-$65.08	-$82.59	-$50.19	-$146.48	-$140.59	-$234.99
200 chemicals	$218.71	$115.89	$177.46 #	$123.53	$105.00 #	$245.59
30 chemicals	-$54.24	$14.40	-$11.07	-$39.74	-$83.37	-$131.23
Just a few chemicals	-$164.47	-$130.29	-$166.39 #	-$83.80	-$21.63	-$114.36
Exp. Level with context	$200.92	$75.61	$117.72 #	$204.44	$55.47	$38.04
Exp. Level no context	$29.64	-$34.17	-$11.36	$14.60	$5.22	$16.06
Exposed or not	-$230.55	-$41.44	-$106.36 #	-$219.04	-$60.68	-$54.10

= Statistically significantly different from zero at the 95% level of significance.

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Appendix A:

Personal Chemical Monitoring Devices Survey

This research study is being conducted by Eastern Research Group, Inc. on behalf of the environmental nonprofit organization Environmental Defense Fund (EDF).

Your participation is absolutely voluntary and you may stop at any time.

The survey will take approximately 20 minutes of your time to complete.

You will not be individually identified and your responses will be used for statistical purposes only (e.g., "20 percent of respondents said…").

If you have questions about your rights as a participant in this survey, or are dissatisfied at any time with any aspect of the survey, you may contact surveyhelp@erg.com.

Are you currently employed?

- ○ Yes
- ○ No

What is your gender?

- ○ Female
- ○ Male
- ○ Non binary/ 3rd gender

What is your age?

- ○ Under 18 years
- ○ 18 to 24 years
- ○ 25 to 34 years
- ○ 35 to 44 years
- ○ 45 to 54 years
- ○ 55 to 64 years
- ○ Age 65 or older

Introduction to Personal Chemical Monitoring Devices

Chemicals are released into the air we breathe and the water we drink. They are found in the food we eat and the products we use and encounter every day. Through these exposures, chemicals can enter our bodies. Some types of chemical exposures can be harmful and lead to adverse health outcomes.

Because of the potential consequences of exposure to harmful chemicals, there is a growing interest in understanding one's own chemical exposures. Technological advances have led to the creation of a new product category known as ***Personal Chemical Monitoring Devices (PCMDs)***. There are three main types of these devices:

- **Sampling unit**. These devices are worn by individuals for a set period of time and are then sent to a lab for analysis. The individual would receive information on chemical exposures from the lab results.
- **Sensor unit**. These devices are also worn by the individual, but provide almost immediate exposure results.
- **Biological sampling unit**. These devices require the user to collect a biological sample (blood, urine), which is then sent to a lab. The individual would receive information on chemical exposures from the lab results.

The first two (sampling units and sensors) measure *external* chemical exposures—chemicals that a person comes into contact with but may not be taken into the body. The third type (biological sampling units) measure *internal* exposures—chemicals that are present in the body.

PCMDs can be designed with a variety of features, some of which determine the device's cost. Some of the ways the devices may vary include:

- *How long it takes to get results* – Some devices can provide almost immediate results while others could take several days or weeks to get the results.
- *How often you get the results* – Some devices can perform continual scanning while others provide less frequent scans.
- *The number of chemicals the device provides information on* – Some devices may cover only a few chemicals while others can cover a few hundred.
- *Nature of the results:* Some devices may indicate only whether you were exposed to a chemical or not. Others may provide numerical values for exposure levels, or indicate whether your exposure is of low, medium or high concern.

The goal of this survey is to collect information from people like you that can be used to inform decisions about the development of PCMDs. We are interested in what you think of the devices and the information they can provide to individuals. The survey is also designed to assess how much people like you value the service provided by these devices.

Before we ask about your preferences for personal chemical monitoring devices, we'd like to ask a few questions that will help us understand you better.

To what extent do you agree or disagree with the following statements?

	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
I am at risk of chemical exposure daily	○	○	○	○	○
I am worried about my exposure to harmful chemicals	○	○	○	○	○
I want to know what I am being exposed to	○	○	○	○	○
I am in good health	○	○	○	○	○

Please provide a yes/no response to the following:

	Yes	No	Not sure	Prefer not to say
Have you ever been diagnosed with cancer?	○	○	○	○
Have you ever been hospitalized for chemical exposure?	○	○	○	○
Have you ever been exposed to chemicals at a level that has worried you?	○	○	○	○
Do you have a compromised immune system?	○	○	○	○
Do you have any serious chronic medical conditions (e.g., asthma, diabetes)?	○	○	○	○
Do you have any medical conditions that limit your activities?	○	○	○	○

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How frequently do you take part in the following?

	Never	Rarely	Sometimes	Often	Always
Eat organic	○	○	○	○	○
Exercise	○	○	○	○	○
Measure my vital signs (e.g., blood pressure, heart rate)	○	○	○	○	○
Smoke	○	○	○	○	○
Eat healthy	○	○	○	○	○
Wear a personal fitness monitor (e.g., Fitbit)	○	○	○	○	○
Track what I eat for dietary reasons	○	○	○	○	○

What best describes the place where you usually spend your workdays?

- ○ Office
- ○ Home office
- ○ Food service/restaurant
- ○ Factory
- ○ Warehouse
- ○ Laboratory
- ○ First responder
- ○ Construction site
- ○ Oil and gas processing
- ○ Chemical manufacturing/processing
- ○ Farm, garden, nursery
- ○ Retail stores
- ○ School/educational facility
- ○ Health Care Facility
- ○ Transportation
- ○ Waterfront/Ports
- ○ No fixed location (e.g., mobile or varies day-to-day); Please describe: _____
- ○ I am unemployed

○ Other; Please describe: _____

Are you currently exposed to chemicals in your workplace?

○ Yes

○ No

○ Not sure

Do you handle chemicals in your workplace?

○ Yes

○ No

○ Not sure

What best describes your home environment?

○ Urban

○ Suburban

○ Rural

Q8 **Do you live near any of the following? (Check all that apply)**

- ☐ Industrial facility or factory
- ☐ Oil and gas development site (e.g., fracking site)
- ☐ Agricultural fields
- ☐ A road with lots of traffic
- ☐ Hazardous waste site
- ☐ Commercial port
- ☐ Other; Please describe: _____

Are you currently exposed to chemicals in your home?

- ○ Yes
- ○ No
- ○ Not sure

Do you handle chemicals in your home?

- ○ Yes
- ○ No
- ○ Not sure

In the next section, we will ask you to select from different types of devices that have different features. This is similar to the choice you have to make in selecting between new cell phones or in buying a home. *Keep in mind that we are not asking you to purchase any of these devices, only to respond as if you were actually considering doing so.*

Each option you can choose from has different features and each has a price. Ultimately, you need to choose the one that you think offers you the best set of features for the price. You can also choose to not purchase a device, and we provide that option as well.

Please think carefully about how you would choose in the situation we provide. The results will be provided to decision-makers who may decide to offer these devices. We want to be able to provide them with information on what people prefer.

There are no right or wrong answers. We have found some people decide to purchase these types of devices, and others do not. Both will have good reasons for choosing one way or the other.

The table below provides two potential personal chemical monitoring devices, the features of those devices, and the associated cost. You can choose to select one of the two or choose neither one (i.e., none).

Category	None	Device A	Device B
Type of device	No data on chemical exposure is available, but no cost is incurred either.	•	•
How long it takes to get results		•	•
How often you get results covered		•	•
Number of chemicals		•	•
Nature of Results		•	•
Cost	$0	$____	$_____
Selection	☐	☐	☐

Note: Features of Device A and Device B are populated from pairings tables (Table 2 in this report).

How confident were you in the choice you made?

- ○ Very confident
- ○ Somewhat confident
- ○ Somewhat unsure
- ○ Not at all confident (e.g., randomly picked one)

[If respondent selected neither device]

You chose to select neither Device A nor Device B. What was your reasoning?

- ○ I don't really have a specific reason why.
- ○ I can't afford it.
- ○ I don't think the expected benefits are worth it.
- ○ Other; Please describe: _____

The table below provides <u>two more</u> potential devices to choose from, the features of those devices, and the associated cost. As before, you can choose to select one of the two or choose neither one (i.e., none). When reviewing this second set, assume that the first sets we asked about above are no longer relevant and that these are your only choices.

Category	None	Device A	Device B
Type of device	No data on chemical exposure is available, but no cost is incurred either.	•	•
How long it takes to get results		•	•
How often you get results covered		•	•
Number of chemicals		•	•
Nature of Results		•	•
Cost	$0	$____	$_____
Selection	□	□	□

Note: Features of Device A and Device B are populated from pairings tables (Table 2 in the report).

How confident were you in the choice you made?

- ○ Very confident
- ○ Somewhat confident
- ○ Somewhat unsure
- ○ Not at all confident (e.g., randomly picked one)

[If respondent selected neither device]

You chose to select neither Device A nor Device B. What was your reasoning?

- ○ I don't really have a specific reason why.
- ○ I can't afford it.
- ○ I don't think the expected benefits are worth it.
- ○ Other; Please describe: _____

In making your decisions about devices, what factor was <u>most</u> important?

- ○ No factor was "most important"
- ○ Type of device
- ○ How long it takes to get results
- ○ Number of chemicals
- ○ How often you get results
- ○ Nature of results
- ○ Cost

In making your decisions about devices, what factor was <u>least</u> important?

- ○ No factor was "least important"
- ○ Type of device
- ○ How long it takes to get results
- ○ Number of chemicals
- ○ How often you get results
- ○ Nature of results
- ○ Cost

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If you had information on chemical exposure provided by these devices, what would you do with it?

_____

_____

_____

_____

_____

How likely do you think it is that the results of this survey will shape the development of the market for personal chemical monitoring devices?

- ○ Very likely
- ○ Somewhat likely
- ○ Somewhat unlikely
- ○ Very unlikely
- ○ I don't know

Do you have children living at home?

- ○ Yes
- ○ No

How many children do you have in the following age ranges?

- ○ 0-2 years of age _____
- ○ 2-5 years of age _____
- ○ 5-10 years of age _____
- ○ 10+ years of age _____

Are you or your partner/significant other currently pregnant or planning to get pregnant within the next year?

- ○ Yes
- ○ No

What is the highest level of education you have completed?

- ○ Elementary, junior high or some high school
- ○ High school graduate/GED
- ○ Some college/vocational school
- ○ College graduate
- ○ Some graduate work
- ○ Master's degree
- ○ Doctorate (of any type)
- ○ Other degree _____

Are you, yourself, of Hispanic or Latino origin or descent, such as Mexican, Puerto Rican, Cuban, or other Spanish background?

- ○ No, I am not of Hispanic or Latino origin or descent.
- ○ Yes, I am of Hispanic or Latino origin or descent.

Which of the following best describes your race?

- ○ White
- ○ Black or African American
- ○ American Indian or Alaska Native
- ○ Asian
- ○ Other

Thinking specifically about the past 12 months, what was your annual household income from all sources?

- ○ Less than $24,999
- ○ $25,000 – $49,999
- ○ $50,000 – $99,999
- ○ $100,000 – $199,999
- ○ $200,000 or more

Are you married?

- ○ Yes
- ○ No