Improving Adherence to Area Probability Sample Designs: Using LAPOP's Remote Interview Geo-locating of Households in real-Time (RIGHT©) System

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High quality area probability sample designs are essential building blocks of representative face-to-face survey research. Yet, no matter how well designed a sample may be, if field personnel are unable or unwilling to conduct interviews in the locations specified by the design, much of the utility of scientific sampling is negated. After all, the essence of area probability sampling is the assignment of a specified number of interviews to a *designated location* based on probability proportional to size (PPS) criteria.[1] How can researchers know that each interview has actually been carried out in its specified location? This *Methodological Note*[2] describes an innovative system developed by LAPOP to help ensure that the sampled geographic locations are rigorously adhered to in the field and, when that is not happening, provide a cost-effective real-time method of detecting and correcting deviations.

This *Note* is intended for several audiences: survey researchers who wish to adopt and dialogue over our innovations, students who benefit from learning about key challenges and their solutions in the study of public opinion, and AmericasBarometer consumers who seek information on our many layers of quality control. In what follows below, we first briefly state the challenge of ensuring that interviewing takes place in designated locations. We then introduce our solution to this challenge: the Remote Interview Geo-locating of Households in real-Time (RIGHT©) system. The remainder of the report describes, in turn, each of the five core components of RIGHT©, with references to their most notable achievements in the 2016/17 round of the AmericasBarometer surveys.

Why is Interviewing in the Designated Location a Challenge?

Locating area assignments is not a simple task. Fieldwork personnel need to know and coordinate over the fundamentals of a sample design, census codes, and maps. Some interviewers will fail to interpret this information correctly. Despite their best intentions, these enumerators

may end up in a location that is outside of the pre-selected area.[3] In other instances, interviewers might intentionally and surreptitiously avoid an assigned area out of concerns that relate to convenience, security, and/or participation rates. That is, interviewers may prefer to work in areas that are closer to transportation or other amenities, appear more secure, and/or are likely to have more accessible, eligible, and willing participants.[4]

Using RIGHT© to Ensure Compliance with the Sample Design

To help ensure that interviewers collect data in the designated geographic locations, standard methods used by LAPOP and others include intensive training and motivational techniques. However, while necessary, we have found that these practices are not sufficient to ensure complete compliance with our sample designs. For this reason, LAPOP has developed the Remote Interview Geo-locating of Households in real-Time (RIGHT©) system. This location monitoring system operates as a component of a broader, integrated quality control system we call the Fieldwork Algorithm for LAPOP Control over survey Operations and Norms (FALCON©). RIGHT© has five core components: the: 1) Location Consistency Check, 2) Geo-fence Module, 3) Distance Audit Module, 4) Electronic Device Configuration Module, and 5) Interviewer Path Tracking Module. We describe these components in detail below.

RIGHT© and FALCON© rely on GPS-enabled handheld electronic devices and software that geotags interviews.[5] While we have experience with a variety of off-the-shelf software platforms for computer-assisted personal interviewing (CAPI) in the field, we have standardized on one platform, SurveyToGo, which we have found to have robust capabilities, customizability, and stability at both the level of the mobile device and the level of the cloud server. Thus, the discussion and examples in this report center on applications, extensions, and procedures using this

software.

To summarize the core results of our initial implementation of the RIGHT© system in the 2016/17 round of the AmericasBarometer, we found a considerable proportion (17%) of electronic questionnaires that were either initially opened in the wrong location, had problems with the geo-fence design, and/or failed to register GPS data.[6] In a select number of these cases, we found that some open source files we used to draw electronic geo-fences were not accurate, thus returning "false positives" (i.e., valid interviews appearing outside the geo-fence).[7] In other cases, we found evidence of interviews conducted in the wrong location or interviewers deactivating the location services of handheld devices. Thanks to steps taken concurrent to the implementation of RIGHT©, quality control personnel were able to quickly identify those interviews and take corrective measures while teams were still in the field.

RIGHT© Component 1: The Location Consistency Check

Our first step to ensuring adherence to the sample design consists of a location query that is presented to the enumerator prior to approaching any household in a designated geographic area. This check prevents enumerators from carrying out interviews if they provide the wrong answer to the query. For this component to work, LAPOP programs the sample, that is, the locations pre-selected for study, into the software used for fieldwork. On the ground, fieldwork office personnel distribute work areas among the project-trained enumerators. Those areas then appear on the interviewers' mobile screens, and form the basis of the Location Consistency Check query.

As depicted in Figure 1 using an example from Jamaica, the first screen interviewers see upon opening and logging into the program displays their assigned work areas (segments). The name of each segment in the list includes multiple pieces of identifying information in order to

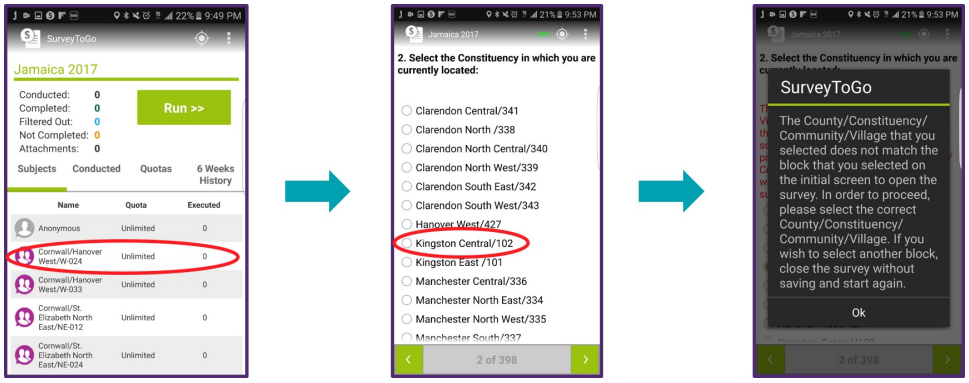

Figure 1: RIGHT©'s Location Consistency Check (here showing non-matching selections returning an error warning)

maximize the chances interviewers will select the correct segment. Each segment shown on the device includes, at minimum, the name of the PSU (for the AmericasBarometer, that typically means the municipality) and the name of the stratum (e.g., the province, department or region), in addition to the segment codes.

After selecting a segment, the interviewer is prompted with a question that requires them to select from a list of all PSUs (constituencies in the case of Jamaica). If the selected segment on the first screen matches the municipality indicated on the second, the program allows the enumerator to proceed with the interview. On the other hand, if the two selections do not match, the system responds with an error message (see the third panel in Figure 1) and blocks them from advancing to the next question until the discrepancy is resolved. The interviewer can correct an erroneous selection or consult with a supervisor to obtain the correct selection information. This process increases our confidence that the interviewer is in the correct place.

While useful, this Location Consistency Check is only a first step in assuring that the fieldwork locations correspond to the sample design. It is not foolproof because it relies on interviewer-supplied responses to queries from their mobile devices. Interviewers can indicate that they are in the assigned location, when in fact they are not. Only with GPS

information, described below, can we be certain of the geographical accuracy of the fieldwork.

RIGHT© Component 2: The Geo-fence Module

Global Positioning System (GPS) technology allows survey researchers to record with relative exactitude where each interview takes place.[8] LAPOP requires survey firms to provide interviewers with GPS-enabled devices to take advantage of this capability and implement the Geo-fence Module.

The first step in developing out this component is to maximize the ability of field devices to obtain GPS readings. We do this in two ways. First, we configure the devices to use *assisted* GPS. This configuration utilizes three radios in each handheld device to read coordinates: (1) the true GPS hardware, (2) the mobile phone data network (typically GSM), and (3) nearby Wi-Fi signals (to which the device does *not* need to be logged in). We have found that the combination of radios dramatically increases our success rate and sharply reduces the time it takes to get a GPS reading compared to GPS hardware alone.[9,10] Second, we program in instructions to interviewers that require them to attempt captures of GPS coordinates at least three times during the course of each interview: at the start of the approach module,[11] right before the beginning of the actual survey (that is, after an individual consents to be interviewed), and at the conclusion of the interview. Figure 2 shows the percentage of interviews we were able to geotag in the 2016/17 round of the AmericasBarometer.

In the latest AmericasBarometer, the only country with more than 10% of total interviews not geotagged was Jamaica, at 11%. In Nicaragua, El Salvador, Haiti,[12] Mexico, and Uruguay, we were able to geotag over 99% of interviews. In Panama, the Dominican Republic, Brazil, Honduras, Peru, Costa Rica, Paraguay, Colombia, Guatemala, and Bolivia, we geotagged between 95 and 99% of interviews. Finally, in Chile, Guyana, Argentina, Ecuador, and Venezuela, we have GPS coordinates for 90-95% of inter-

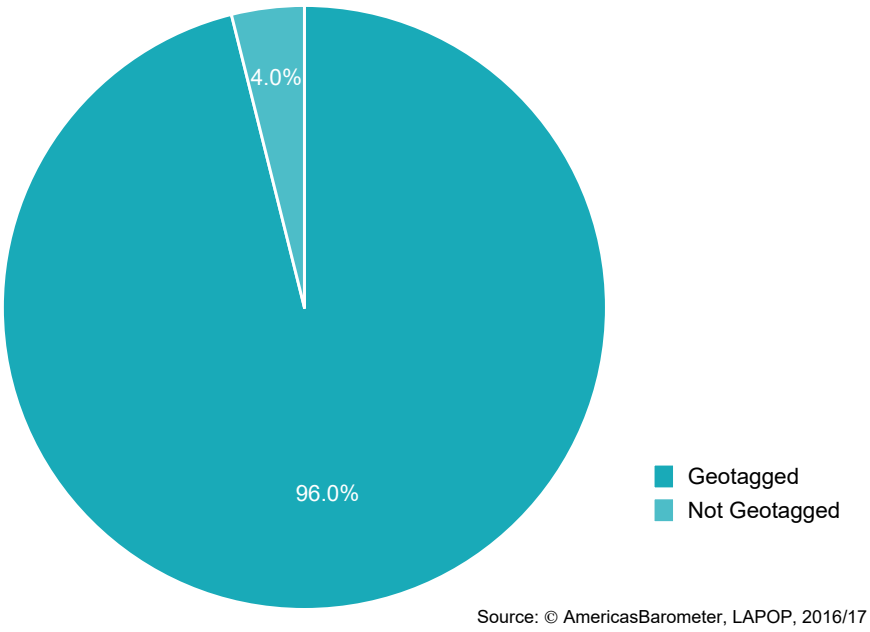

Figure 2: Percentage of Interviews with GPS Information, AmericasBarometer 2016/17

views.[13] This relatively high success rate in retrieving GPS coordinates shows that this tool is reliable, and can be effective in monitoring the location of interviews.

To implement the geo-fencing module, the next step is to develop and place geo-boundaries—in the form of circles—around the fieldwork areas selected in the sample design, the parameters of which we program into the software used in the field. The size of each circle equals the smallest area that can completely encompass the shape of the given work area polygon. Polygon sizes are determined by the level of disaggregation of the files used to draw the boundaries (i.e., "shapefiles").[14] In most cases for the AmericasBarometer, the polygons (and hence the geo-fences) encompass municipalities.[15]

Once the geo-fences and related programming are in place, whenever an interviewer attempts to initiate a survey outside the geo-fence, an alert on their device informs them that they are outside the assigned location's

Figure 3: RIGHT©'s Geo-fence Module (here, showing a segment in Costa Rica)

boundaries. We do not prevent the interview from proceeding as we did with the Location Consistency Check discussed above, because there can be a variety of legitimate reasons for interviewers to be outside the fence. For example, the interviewer may be straddling the line or have crossed the geo-fence boundary but still be on the correct block, a portion of which extends beyond the fence. So as not to delay fieldwork in cases like this, we allow the interview to proceed as long as the interviewer has selected an appropriate response to the system alert. These responses can then be viewed in the office to determine if the violation was a legitimate one (see below on the DAM module).

The flip side of geo-fence issues arise because the geo-fences are circles and the municipalities or segments are polygons, and thus, it is possible for an interviewer to be located outside the selected polygon but inside the fence. This would constitute an error not detected by the geo-fence, but a minor one since the interview would be taking place in an area contiguous to the selected polygon (see Figure 3).

Figure 4 shows the percentage of interviews in which the geo-fence triggered the out-of-bounds alert in the 2016/17 round of the Americas-

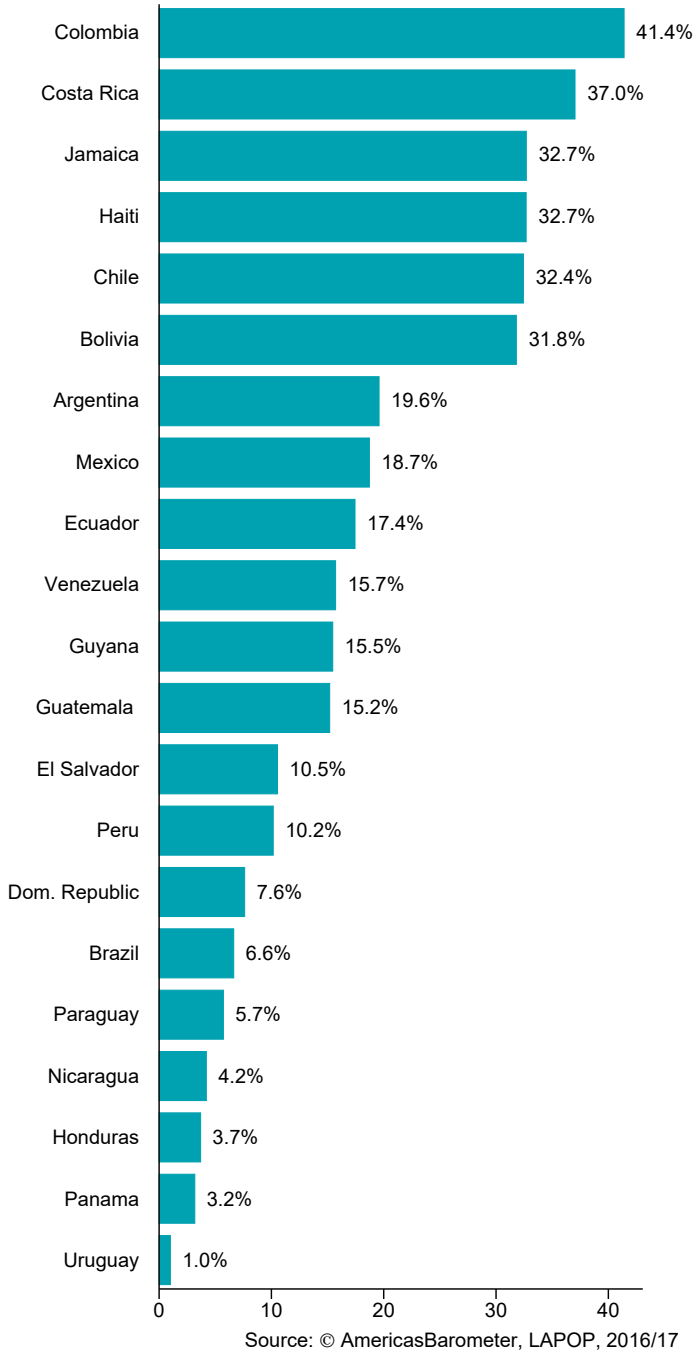

Figure 4: Percentage of Interviews with RIGHT© Out-of-Bounds Alerts (includes non-geotagged interviews), AmericasBarometer 2016/17

Barometer.[16] The figure shows Colombia and Costa Rica with the highest out-of-bounds instances. It is important to note that these are two of the countries with geo-fences at the census segment level and therefore, with the tightest circles. The lesson here is that the smaller the geo-fence, the more likely that the interview will register as out-of-bounds.

When interviews are flagged as out-of-bounds, the survey teams and/or LAPOP implement one of four decisions: (1) Interviewers relocate themselves to the right place; (2) Survey firms inform us of errors (e.g., when the shapefiles are wrong), in which case we can correct the geo-fences and approve erroneously flagged interviews;[17] (3) LAPOP approves a substitution; or (4) Interviewers continue in spite of being in the wrong place, and the survey firm or LAPOP cancels those interviews and requests fieldwork teams collect replacement interviews in the correct location.

RIGHT© Component 3: The Distance Audit Module (DAM)

Via a script that we developed in-house, LAPOP software automatically measures the distance between the location of an interview and the closest point of the geo-fence. The script, which we call the Distance Audit Module (DAM), makes use of the most recent set of coordinates registered by the electronic handheld device, and subtracts these from the coordinates of the closest point in the geo-fence. If the value returned in the system is *negative*, then quality control auditors know the interview was conducted within the limits of the fence. A *positive* number indicates that the interview was out-of-bounds. The information is auto-uploaded to the cloud server the moment the interview is complete using the nearest data signal.

When auditors spot a positive number, they review the actual location of the interview using Google or Bing maps. Since local firms have more knowledge of the work areas in their own countries, often it is the local team that studies the maps to see if, in fact, the interviewer was in

the wrong location, or if it is a matter of a shapefile or GPS error. After examination, auditors may cancel interviews that were conducted outside the fence. Table 1 shows that we did not cancel the majority of out-of-bounds AmericasBarometer interviews. After careful scrutiny and in consultation with the fieldwork firms, we determined that, in the vast majority of these cases, interviews were conducted in the correct locations.

RIGHT© Component 4: The Electronic Device Configuration Module

At times, LAPOP has discovered that electronic devices were not appropriately configured at the conclusion of training to geotag interviews. In those cases, the geo-fence and distance audit modules typically did not have sufficient information to operate. Whether this occurred because of oversight from fieldwork personnel or a deliberate decision by the interviewer or supervisor to turn off the GPS and other location services (by activating airplane mode, for example), the fact is that some interviews are not geotagged for reasons other than flaws in the assisted GPS system in handheld devices. To address this challenge, we developed out a fourth component to the RIGHT© system: the Electronic Device Configuration Module.

The CAPI software that we use, SurveyToGo, comes equipped with a system that keeps a log of all the actions recorded on the handheld devices. The logs include information regarding the network interface status, which allows us to see if the Wi-Fi and cellular networks are up or down during each interview. Additionally, we can see if the location services (i.e., GPS) are enabled or disabled. Finally, we can see if the app settings were configured according to LAPOP protocols (i.e., allowing the system to use mobile and Wi-Fi networks, in addition to GPS hardware) to geotag interviews.

Via our protocols, the CAPI *app* settings are configured during training

and are locked with a code that is not given to the interviewer. The settings are thus, tamperproof. The team can check all device settings before fieldwork begins. The settings are checked for inconsistencies with an automated program we developed in R, and any discrepancy is immediately reported back to the training supervisor, who can unlock the deviant device, reset it, and then relock it.

However, we have no control over the *device* settings (as opposed to the *app* settings). This means that fieldwork personnel can access and disable important elements of the device that need to be enabled in order to capture GPS coordinates (i.e., Wi-Fi, GPS, and/or the mobile data). With RIGHT©'s electronic device configuration module, we can determine whether "airplane mode" has been activated on the device due to a wayward interviewer's attempt to thwart the geo-fence system.

In the 2016/17 AmericasBarometer, we found no cases for which location services (mobile and Wi-Fi networks, and GPS hardware) had been turned off in seven countries (El Salvador, Haiti, Mexico, Nicaragua, Paraguay, the Dominican Republic, and Uruguay). We found fewer than five cases each in Guyana, Honduras, Panama, Argentina, Costa Rica, and Bolivia. In Jamaica, Ecuador, and Brazil, we found between five and 15 cases. In Colombia and Guatemala, we found 29 and 37 instances, respectively. Finally, in Venezuela we found 107 cases.[18] Venezuela proved to be an especially difficult case for us given the economic, criminal, and political turmoil in which the country is immersed. Therefore, the relative frequency of attempts to subvert the system did not surprise us, and the system detected each of them.

In the course of the 2016/17 AmericasBarometer, following scrutiny of each of these cases and conversations with the local firms, we canceled (and replaced) all the interviews in which we found evidence of interviewers tampering with the device settings in order to prevent the geotagging of interviews.

RIGHT© Component 5: The Interviewer Path-tracking Module

The final component in our monitoring system allows us to review an image of the route interviewers walk during any given data collection period. The Interview Path-tracking Module is most useful for collecting data on the steps taken from household to household, as enumerators work to find individuals eligible and willing to be interviewed. We also use these records ("the approach module") in computing response rates. To track interviewers' paths, we program the system to collect GPS coordinates automatically at the beginning and at the end of each contact attempt.

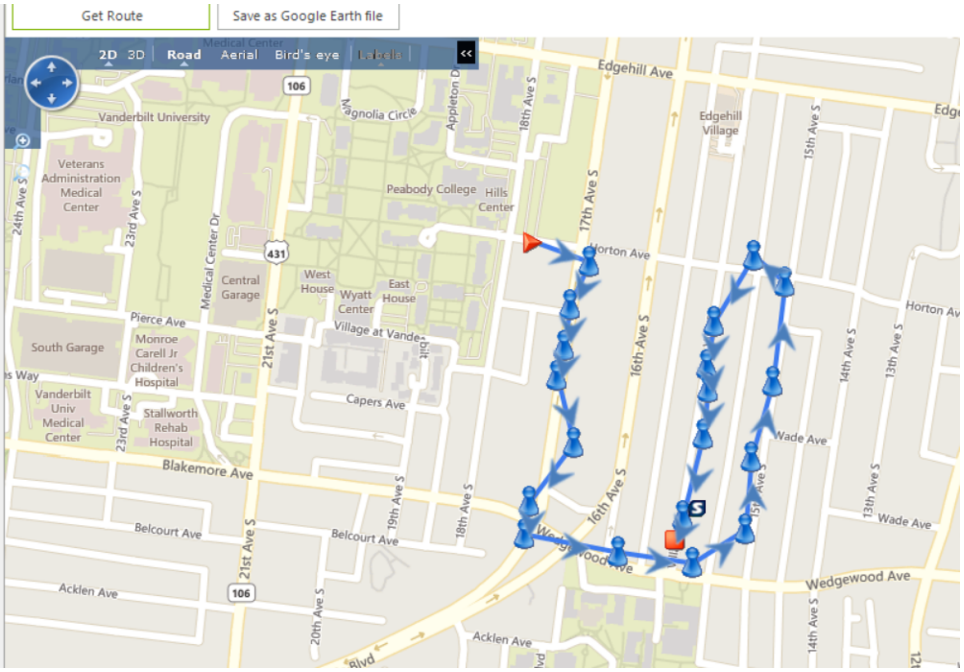

Figure 5: RIGHT©'s Interviewer Path-tracking Module

Following the path of interviewers can mitigate two common contact-tracking issues: *underreporting* and *delayed reporting*. In the former, interviewers manually report only one attempt (100% success rate), when

in fact many have been made. The latter occurs when interviewers report all of the attempts prior to the successful one in one quick burst just as a successful interview is about to begin.

LAPOP developed code, in R, to instantly identify suspicious success rates. We capture GPS coordinates, along with every question of the approach module, prior to the beginning of the actual interview. We use these data to review that interviewer's path, and determine if they have been moving while trying to find a respondent willing to cooperate. Figure 5 provides an example (conducted near our research center in Nashville, TN) of how the interviewer path-tracking module appears in the RIGHT© system.

Conclusion

With the transition from paper-based to electronic-based questionnaires, LAPOP has been able to use technological advances to take survey quality control to the next level. This *Methodological Note* documents our efforts to make sure enumerators carry out interviews in project-selected locations. Our remote interview location monitoring system provides interviewers with enough information to determine whether they are located in the right place, immediately before the beginning of an interview. If enumerators are out-of-bounds, they can adjust their location before it is too late to avoid the mistake. In cases in which interviewers choose to go ahead and carry out the interview even though the location flag was triggered, office auditors have the ability to spot those interviews, assess how far out-of-bounds they were conducted, and (if appropriate) ask fieldwork personnel to replace them while they are still in the field. A crucial aspect of this set of procedures is that they are conducted effectively in "real time," that is, while the fieldwork is in progress. As a result, we do not have to wait until fieldwork has concluded to find out post hoc that an interview was carried out in the wrong location, at which point it is usually too costly or too late (given a project deadline), to take action to replace interviews that warrant cancellation. While we continue to

refine RIGHT©, this report underscores and details an unprecedented system to help survey firms and research projects achieve the highest possible adherence to area sample designs.

Notes

1. It is rare in public opinion research to have a complete listing of the names and addresses of the universe of respondents, which, if present, could be used as a sampling frame instead of area-based probability designs. See the classic work by Kish (1965).

2. An earlier, abbreviated, paper containing some elements of this *Note* was published in the *Newsletter from the Survey Research Laboratory*, University of Illinois at Chicago, Volume 48, Number 1, 2017.

3. In some countries, for example, it is possible to find different towns with similar or identical names. Our system can identify this error and give teams the opportunity to correct it.

4. With respect to security, crime concerns are salient in many places where we conduct survey research. We work with local firms to develop security plans and cover this material in training. Furthermore, when a local team determines that it is not safe to enter a given area, we identify and approve a substitution. Because so-called "hot spots" are geographically concentrated, the number of substitutions in a typical national survey is low. We will provide more detail on these hot spots in a future *Methodological Note*. Even though precautions are taken, interviewers can face an incentive to deviate from the sample design and select safer neighborhoods for interviews. Another factor that may increase incentives for deviation from sample design is the increasing number of individuals who decline to be interviewed or are inaccessible (such as in the case of gated communities).

5. LAPOP releases only truncated GPS coordinates in order to protect the anonymity of respondents.

6. The 2016/17 round of the AmericasBarometer included 43,454 interviews in total in 29 countries. RIGHT© was fully implemented in Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, the Dominican Republic, Uruguay, Venezuela, and part of Haiti. This report focuses on the 38,722 interviews conducted in those countries

using electronic devices for data entry in the field.

7. When the auditing team identifies an interview outside the geo-fence, they communicate with the survey firm before rejecting the interview to make sure it was indeed carried out in the wrong location. In some cases, fieldwork teams have demonstrated that an apparent problem was at the level of the open-source shapefile and not the interviewer's error. We do not, of course, reject such interviews. Occasionally (in less than 4% of the cases), devices were unable to capture GPS coordinates even though they were in good working order and configured correctly. We attribute this error to the current limits of GPS technology implemented on devices of reasonable cost.

8. We say "relative exactitude" to acknowledge current limits to GPS hardware and software.

9. One common misconception we have confronted among fieldwork firms is that GPS hardware will only work when connected to the internet. In reality, GPS hardware can receive coordinates from a satellite without internet or cellular data connections. GPS receivers only need a reasonably clear view of the sky for capturing readings. In very cloudy weather, urban canyons, and the interior of buildings, GPS readings can become less reliable or impossible.

10. In theory, GPS-alone may provide somewhat greater accuracy, generally a difference of a meter or two, but that level of precision is not required in most survey sampling. The benefits of more connections with assisted GPS offset such gains in precision.

11. The approach module is a built-in module at the beginning of the electronic questionnaire that helps interviewers keep track of all the attempts carried out until reaching the definitive respondent.

12. In Haiti, electronic interviews were carried out only in part of the country (mainly Port-au-Prince). The rest of the country was surveyed using paper due to concerns about the unavailability of electricity to recharge the devices.

13. We are still studying intra-country variation in the percentage of geotagged interviews.

14. Building geo-fences requires three pieces of information: shapefiles, centroids, and radii. First, we obtain shapefiles (electronic files that provide polygons of geographic areas) from census offices and open source websites (the main open source website LAPOP accesses for shapefiles is http://www.gadm.org/). Then, we use ArcGIS to geotag the most efficient center (i.e., the centroid) of each selected polygon. Finally, we use ArcGIS

to compute radii that will produce the most efficient circles around municipalities or segments. The process is semi-automated, requiring some input from our geo-fence designers. This information is then programmed into the electronic data collection software, along with a script to auto-identify out-of-bounds interviews.

15. For additional precision, ideally we would also have access to the intra-municipal census segment shapefiles (blocks or collection of streets or paths). Indeed, in the cases of Chile, Colombia, Costa Rica, Ecuador, and Mexico, these shapefiles have been made available to us, and the geo-fences that we construct encompass the census segments. In Panama, they encompass *corregimientos* (the lowest administrative sub-divisions, below the district level). Generally speaking, in order to effectively implement our RIGHT© system, researchers need to specify the level of precision that is required by their particular study. In surveys that require great precision in the correct location of each interview, such as those that measure the impact of certain communicable disease vectors, it may be critical to ensure that the interview location is specified and verified down to the location of the dwelling unit. In other cases, where the focus is on more general parameters (such as a study of perceptions of the condition of the economy or trust in institutions, issues that lie at the heart of much of LAPOP's research), it is important for maintaining the integrity of the sample design that the respondent be accurately located only within a given primary sampling unit (PSU); typically, this is a municipality. For each study in which the RIGHT© system is implemented, researchers need to determine at the outset of the given study how much geographical deviation from the sample design is an acceptable trade-off, given the costs of very precise specification of boundaries and of monitoring and correcting for deviations.

16. The alert is also triggered when the device is not able to retrieve valid GPS coordinates in the first manual capture.

17. At least half of the interviews flagged by location in Brazil, Haiti, Honduras, Ecuador, Panama and the Dominican Republic had one or more shapefile problems (i.e. "false positives" or erroneous flags). Upon further examination using Google maps, and verifying with the firm, we approved these interviews.

18. We could not count the number of cases in Chile and Peru due to errors in downloading the logs.

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Acknowledgements

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Appendix

Table 1: Results of RIGHT©'s Distance Audit Module, AmericasBarometer 2016/17

Country	# of Out-of-Bounds Interviews	Min. Distance (km)	Max. Distance (km)	# of Cancelled Out-of-Bounds Interviews
Argentina	67	0.06	779.94	1
Bolivia	303	0.13	9.80	17
Brazil	89	0.06	96.90	8
Chile	140	0.49	9.96	7
Ecuador	189	0.00	91.43	17
El Salvador	71	0.03	9.61	4
Guatemala	24	0.25	6.05	3
Haiti	234	0.04	75.78	21
Honduras	40	0.17	64.00	2
Jamaica	8	0.01	3.80	2
Mexico	226	0.00	98.86	16
Panama	28	0.10	97.25	0
Paraguay	30	1.85	8.51	0
Peru	160	0.11	95.27	38
Dominican Republic	59	0.07	78.24	0
Uruguay	1	269.62	269.62	1
Venezuela	29	0.10	142.66	22