Optimizing the Day and Time of the First Dial in Random-Digit-Dial Telephone Surveys

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Abstract

In telephone surveys, the day and time of a first call attempt can have a strong impact on the call outcome, and telephone calls should therefore be placed at times which maximize both the chance of completing an interview and the final response rate. In a random-digit-dial (RDD) survey, however, these can be competing interests, since the best day and time to identify eligible respondents and complete interviews might not be the best day and time to identify ineligible respondents and out-of-scope telephone numbers. For example, businesses are more easily identified during the daytime whereas households are more easily identified during the evening. Therefore if likely businesses can be distinguished from likely households before dialing, the first-call time can be scheduled accordingly. In this paper, we investigate the possibility of using information known prior to dialing, such as the listed/unlisted status or geographic location of the telephone number, to optimize the day and time the first call should be placed for a national RDD survey. We use data from the National Immunization Survey (NIS), a nationwide, list-assisted RDD survey conducted by NORC at the University of Chicago for the Centers for Disease Control and Prevention.

1. The NIS

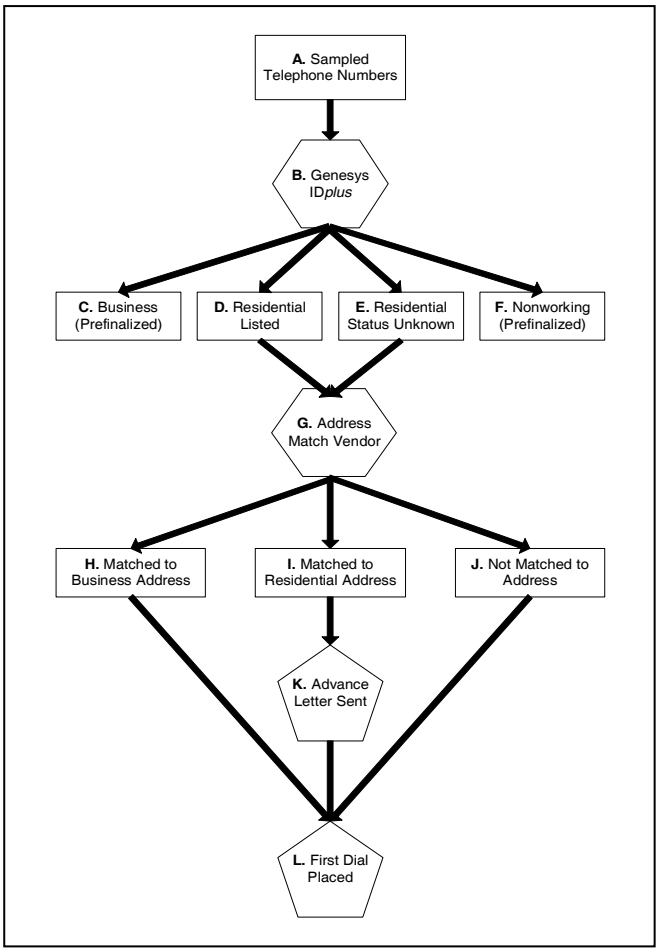
The NIS is conducted yearly to measure vaccination rates of young children nationally, in each state, and in several local areas. It consists of two phases: a random-digit-dial component that seeks to identify households with children aged 19 to 35 months, collect socio-demographic data, and obtain consent to contact the immunization providers of sampled children; and a provider component wherein questionnaires are mailed to each child's providers seeking immunization information about the child.

Telephone numbers for the random-digit-dial component are selected from banks of 100 consecutive telephone numbers that contain at least one directory-listed residential number. Cellular telephone exchanges are excluded from this sampling frame.

Before they are dialed, the sampled telephone numbers go through several stages of processing, as shown in Figure 1. First, all sampled telephone numbers are sent through Marketing Systems Group's GENESYS ID*plus* system (Marketing Systems Group, 2005) to remove known businesses and nonworking numbers. GENESYS ID*plus* classifies each number as business, nonworking, residential-listed, or residential-status-unknown. Businesses and nonworking numbers identified in this way (approximately 40% of sampled numbers) are finalized as such and are not dialed. The remaining numbers are reverse-matched to addresses; those matched to residential addresses are mailed an advance letter. The numbers (including those that did not receive an advance letter) then receive their first dial for the NIS.

Because less than one third of telephone numbers are working residential numbers, and because less than

Figure 1: NIS Pre-Dial Processing



five percent of households contain a 19 to 35 month old child, the NIS must sample and dial an extraordinary number of telephone numbers to complete about 30,000 interviews each year. In 2006, over 5 million numbers were sampled and over 2.8 million received at least one dial. In this paper, we analyze 2006 NIS first dials to determine the optimal time of day for the first dial.

2. NIS First-Dial Time

The NIS places calls seven days a week, 9:00AM to 8:59PM local respondent time. In 2006, cases were not assigned a predetermined first-dial time; instead, a case received its first dial at a time when an interviewer was available to make the call and no other previously-dialed cases were scheduled to be called. Because time zones enter and leave the 9:00AM to 8:59PM calling window at different times throughout the day, and because interviewer staffing levels were not always in sync with the volume of calls to be dialed, the time at which a case was most likely to receive its first dial differed somewhat by time zone. For example, cases in the Eastern time zone were more likely to receive their first call during the day, while cases in the Central time zone were more likely to receive their first call at night. Therefore, any analysis of the effect of first-dial time on call outcome must take time zone into account to avoid confounding the call time effect with a geographic effect. Within a time zone, however, cases received their first dial at essentially random times; that is, aside from the time zone in which the case is located, there was nothing specific to any case that affected its first-dial time. For this paper, all analyses were conducted separately for each time zone. (Because of a lack of data in Alaska and Hawaii relative to the other time zones, cases in these two states were excluded from our analysis.)

3. Optimal First-Dial Time: Contact

In 2006, 29.5% of cases in the Central time zone were contacted on their first dial, where contact is defined as a human being answering the telephone. Figure 2 shows the contact rate by respondent call hour for weekday and weekend first dials. (We define "call hour" as the hour in which the call was placed; for example, the 8PM call hour stretches from 8:00 PM to 8:59 PM.) For weekday calls, the first-dial contact rate varied from about 23% during the midday hours to nearly 32% during the 8PM hour, with a steady increase from the 3PM to 8PM hours. For weekend first dials, the call time did not have much effect on the contact rate, although the rates were slightly higher during the 7PM and 8PM hours. Although not shown here, we observed the same pattern for the Eastern, Mountain, and Pacific time zones. These results are consistent with those reported by other researchers (e.g., Weeks et al., 1987).

4. Optimal First-Dial Time: Finalization

Figure 2 suggests that first dials should be placed during the 7PM and 8PM hours, because those are the times at which the highest contact rates are achieved. However, "contact" might not be the best call outcome to consider when trying to determine the optimal first-dial time; for example, it is unproductive – and possibly counterproductive – to make contact at a time when the respondent is not cooperative. Instead, it may be better to consider the first-dial finalization rate. In the NIS, a case is finalized on the first dial if on the first dial the case is determined to be a business, or if it is determined to be a household and the household either screens ineligible or screens eligible and completes the interview on the first dial. The finalization rate can be thought of as a total cooperation rate, where cooperation entails both answering the phone and being a willing respondent on the call.[1]

Figure 3 shows the first-dial finalization rate by the respondent call hour for weekday and weekend calls to the Central time zone. Although the pattern is the same as that in Figure 2, the size of the effect is much smaller. Whereas contact rates for weekday calls were 30-40 percent higher at night than during the daytime, finalization rates for those same calls were only 10-15 percent higher at night than during the day; similarly, for weekend calls the contact rates were 10-15 percent higher at night than the day, but the finalization rates were only about 5 percent higher at night. (Note this suggests that when contact has been made on the first call, a case has a greater chance of finalizing on that

[1] In the NIS, while contact is a prerequisite to finalizing a case that is a household, businesses are finalized either if contact is made and the respondent identifies the telephone number as belonging to a business or if an answering machine is reached and the message identifies the phone number as belonging to a nationally-recognized company. Because such a small proportion of businesses are nationally-recognized companies, essentially contact is a prerequisite for finalizing business numbers, as well. Some RDD surveys allow *any* business to be finalized based on an answering machine message; the time-of-day effects for finalizing businesses that are discussed in this paper may differ for such a survey. That is, the results discussed and the conclusions drawn in this paper assume that contact is a prerequisite for finalization of both households and businesses.

call if the call was made during the day rather than at night.) This finalization rate pattern was similar for the Mountain and Pacific time zones, but in the Eastern time zone, the finalization rate for weekday calls was essentially constant across call time.

Figure 4 shows first-dial finalization rates for weekday and weekend calls, separated by type of finalization (i.e., finalized business vs. finalized household), by respondent call hour for the Central time zone. Not surprisingly, a case was much more likely to be finalized as a business during the weekday daytime and more likely to be finalized as a household during the night.

Figure 4 suggests that if we could know *a priori* which cases were likely to be businesses and which were likely to be households, we could gain efficiencies by making weekday first dials to likely businesses during the day and to likely households during the weekday night and on the weekend. This strategy has been employed by Statistics Canada, which reports increases in first-dial contact rates of about 5 percentage points when using the billing type of the phone number (business vs. residential) to guide the first-dial time (Reedman and Robinson, 1997).

While Figure 4 shows that first-dial finalization rates vary by whether the case is business or a household, one can imagine that other characteristics of a case could affect the best first-dial time. To the extent that these characteristics can be known *a priori*, they can be used to maximize the probability of finalization on the first dial for each case. This idea is discussed in the next section.

5. Modeling the Finalization Rate

To better understand how the first-dial finalization rate for different first-dial times varies by case characteristics, we modeled the finalization rate using information known for each case prior to dialing. In addition to the data gathered during the NIS pre-dial processing (see Figure 1), several pieces of "environmental" data are available on the sampling frame. These data are based on the 2000 U.S. Census tract-level information, aggregated to the telephone exchange level. (The telephone exchange for a case is equal to its area code plus the first three digits of the phone number.) Each telephone number in the sampling frame has associated with it data that are specific to its telephone exchange, such as the median income for households in the telephone exchange, the percent of the population in the telephone exchange that is Hispanic, etc.

We modeled first-dial finalization in the Central time zone for weekday calls using a logistic regression model:

$$\text{logit}(p_i) = X_i'\beta$$

where p_i is the probability of finalization on the first dial for the *i*th case, X_i is a vector of covariates for the *i*th case, and β is the vector of parameters. The covariates considered for the model were the information collected during pre-dial processing, the environmental information, the first-dial time, and the interactions between the first-dial time and the other covariates. Although Figures 3 and 4 show finalization rates by first-call hour, in fitting the model we divided the day into three shifts: daytime (9AM to 5PM), evening (5PM to 7PM), and night (7PM to 9PM). The full list of covariates considered for the model and their definitions is given in Table 1. "Listed," "Posbiz," and "Adv_ltr," are determined as part of the pre-dial processing in at nodes D, H, and K of Figure 1, respectively. The other covariates in Table 1 are based on the "environmental" data and indicate whether the case's environment is in the upper half among all the dialed cases with respect to the characteristic of interest. For example, "Hispanic_p_upper" is equal to 1 (0) if the percentage of the population that is Hispanic in the case's telephone exchange is above (below) the median of the Hispanic percentages associated with the telephone exchanges of all of the dialed cases.

The covariates remaining in the final model and the parameter estimates are given in Table 2, along with the Type 3 effects. The parameter estimates are given in Table 3. For a given sample that is about to be dialed for the first time, the only thing we can control is the time of that first dial; therefore we are particularly interested in the effect of "Shift" and the interactions of "Shift" with the case characteristics. The first-dial shift and its interactions with advance letter status, residential listed status, and business listed status all significantly affect the probability of finalization on the first dial, with residential-listed numbers and those sent an advance letter more likely to finalize – holding all else equal – if the first call is placed at night rather than during the day. Business-listed numbers are more likely to finalize on daytime calls. This is not surprising because residential-listed and advance-letter status are good indicators that a number belongs to a household, business-listed status is a good indicator that a number belongs to a business, and, as Figure 4 shows, households are more likely to finalize on night calls and businesses more likely to

finalize on daytime calls. Cases in telephone exchanges in the upper half with respect to the percentage of college graduates among the population and the percentage of homes that are owner-occupied were also more likely to finalize on night calls than day calls, all else equal, but the size of these effects are much smaller than the advance letter and residential and business listed effects.

Note that the parameter estimates shown in Table 3 imply that the odds ratio for finalizing a Central-time-zone, weekday case on a night first dial versus a day first dial is:

$$\begin{aligned}&\exp(-0.1323\\&+0.1734*Adv\_ltr\\&-0.4208*Posbiz\\&+0.1119*Listed\\&+0.0422*College\_graduate\_upper\\&+0.0443*Owner\_occupied\_p\_upper)\end{aligned}$$

Since this odds ratio is less than 1 if *Posbiz*=1, regardless of the values of the other covariates, this suggests that a business-listed telephone number that is to be dialed for the first time on a weekday should be called during the day, regardless of whether the telephone number is residential-listed, whether an advance letter was sent, etc. Also note that if the telephone number is not business-listed (*Posbiz*=0) and an advance letter was sent (*Adv_ltr*=1), the odds ratio is greater than 1, regardless of the values of *Listed*, *College_graduate_upper*, and *Owner_occupied_p_upper*, indicating that a case that is not business-listed and that was sent an advance letter should always be called for the first time at night rather than during the day.

The model discussed thus far was limited to cases in the Central time zone which received first dials on a weekday. We also modeled the finalization rate for weekday first-dial cases in the Eastern, Mountain, and Pacific time zones using the covariates in Table 1. The results are similar to those from the Central time zone model: advance-letter status, residential-listed status, and business-listed status had by far the largest interaction effects with first-call shift, with residential-listed and advance-letter cases finalizing with greater probability at night than during the day – all else equal – and business-listed numbers finalizing with greater probability during the daytime than at night, holding all else equal.

We then modeled finalization in each time zone for weekend first-dial cases, again using the covariates in Table 1. As in the weekday model, in the weekend model the advance-letter status, residential-listed status, and business-listed status had a significant interaction with first-dial shift in the Central time zone, and business-listed status had a significant interaction with first-dial shift in the Eastern, Mountain, and Pacific time zones; while the direction of these effects were the same as in the weekday model – all else equal, advance-letter and residential-listed cases finalize with higher probability at night, and business-listed cases finalize with higher probability during the day – the sizes of these effects were much smaller.

6. Evaluating the Usefulness of the Model for Scheduling First Dials

The models discussed in Section 3 suggest that by assigning a case to be dialed during the shift with the highest predicted probability from the model, we may be able to finalize more cases on the first dial. To evaluate the extent of the potential gain in efficiency, we randomly divided the cases in the Central time zone that received their first dial on a weekday into two groups – a "learning" group containing 2/3 of the cases and a "testing" group containing the remaining 1/3 of the cases. We then fit the model from Section 3 to the learning group and applied the parameter estimates to the testing group to get three predicted probabilities of finalization for each case, one for each shift in which the first dial could be placed. We then identified the shift for which the predicted probability of finalization was greatest.

Table 4 shows, for cases in the testing group in each time zone, the actual 2006 distribution of first calls across shifts, the observed 2006 finalization rate, the distribution of first calls across shifts if the calls were placed during the shift with the highest probability of finalization according to the models, and the predicted finalization rate if each case was called during the shift with the highest probability of finalization according to the models.

For example, during the course of the 2006 NIS, for Central time zone cases receiving first dials on a weekday, 24% received their first dial in the daytime shift, 10% in the evening shift, and 66% in the night shift, and an actual first-dial finalization rate of 16.2% was achieved. If we instead dialed these cases during the shift with the highest predicted probability of finalization, we would make 33% of the calls during the daytime shift, 0% during the evening shift, and 67% during the night shift. By averaging the predicted probabilities for the "best" shift over the testing cases,

we get a predicted finalization rate of 19.1%, or about an 18% gain in efficiency over the operation of the NIS weekday calls in the Central time zone in 2006.

Table 4 shows that by using models to predict the best shift for the first dial, we could increase the first-dial finalization rate for weekday calls from the observed 15.2% to the predicted 17.8%, or about a 15% increase in first-dial efficiency. For weekend first-dials, the effectiveness of the use of the models is much smaller, raising the finalization rate from 13.7% to 14.5%, for roughly a 6% increase in efficiency. Table 4 also shows that, according to the models, first dials should be concentrated in the daytime and night shifts, and almost no first dials should be made during the evening shift. These results suggests that the model is serving mainly to separate business numbers from household numbers before the first dial.

7. Summary

The time of the first dial to a case in a survey can have a substantial impact on the outcome of that dial. In the 2006 NIS, contact rates were much higher for first dials made in the late evening than for those made in the day. However, because the best time to make contact is not necessarily the best time to gain cooperation after contact, it may be better to maximize the first-dial finalization rate. In the NIS, among all cases, finalization rates were somewhat higher in the night than during the day, but much higher in the night for households and in the day for businesses. This pattern holds for both weekday calls and weekend calls, although the effect of the call time on the finalization rate is smaller for weekend calls.

If any information is known about each case before dialing, efficiencies might be gained by using this information in scheduling the first dial. In the NIS – holding all else equal – cases with residential-listed phone numbers and those sent advance letters were most likely to finalize on first dials placed between 7PM and 9PM, while those that were business-listed were most likely to finalize between 9AM and 5PM. We believe this is because these case characteristics serve to separate the businesses from the households. By using the case characteristics to schedule the first dial, the NIS could increase first-dial finalization rates significantly for weekday calls and marginally for weekend calls.

References

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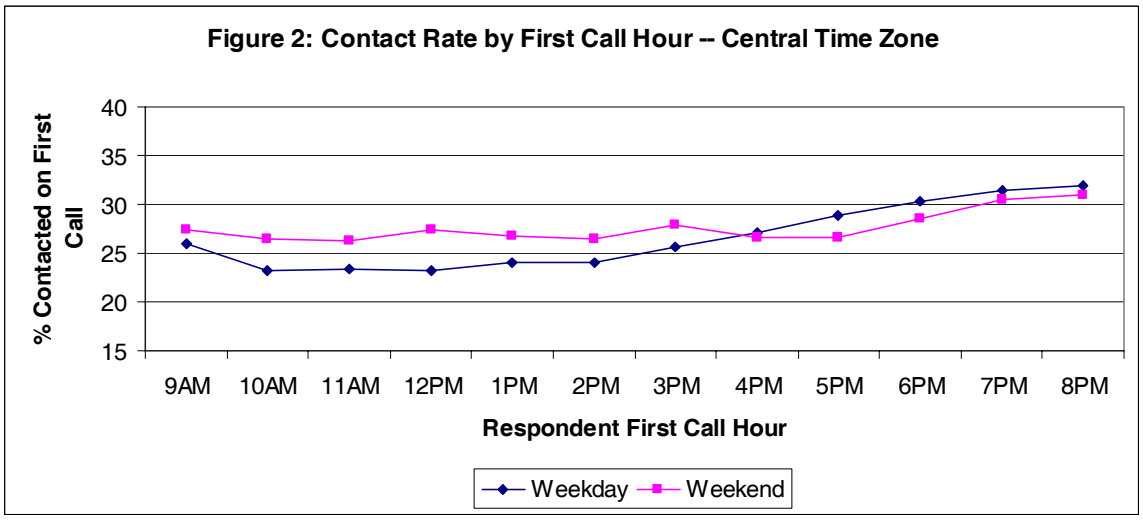
Figure 2: Contact Rate by First Call Hour -- Central Time Zone
% Contacted on First Call
40
35
30
25
20
15
9AM
10AM
11AM
12PM
1PM
2PM
3PM
4PM
5PM
6PM
7PM
8PM
Respondent First Call Hour
Weekday
Weekend

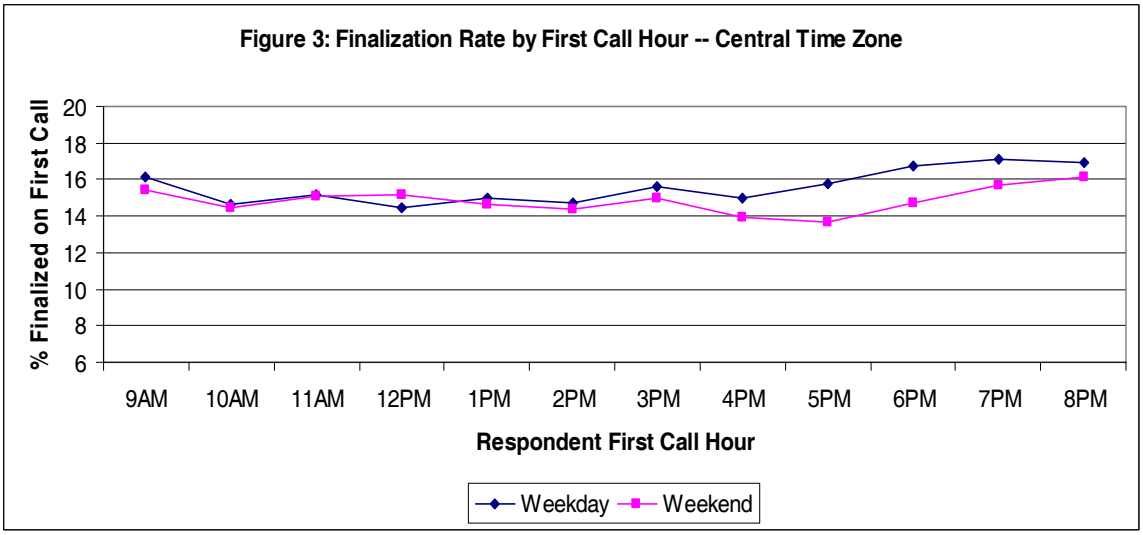
Figure 3: Finalization Rate by First Call Hour -- Central Time Zone
% Finalized on First Call
20
18
16
14
12
10
8
6
9AM
10AM
11AM
12PM
1PM
2PM
3PM
4PM
5PM
6PM
7PM
8PM
Respondent First Call Hour
Weekday
Weekend

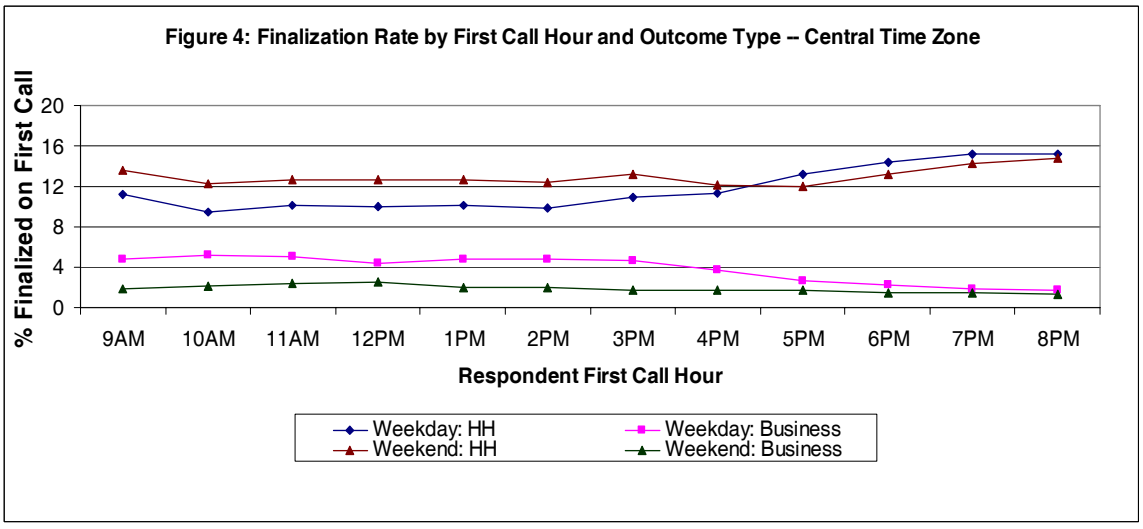
Figure 4: Finalization Rate by First Call Hour and Outcome Type -- Central Time Zone
% Finalized on First Call
20
16
12
8
4
0
9AM
10AM
11AM
12PM
1PM
2PM
3PM
4PM
5PM
6PM
7PM
8PM
Respondent First Call Hour
Weekday: HH
Weekend: HH
Weekday: Business
Weekend: Business

Table 1: Covariates Considered for the Finalization Model

Name	Definition
Shift*	First-dial shift: 9AM-5PM, 5PM-7PM, 7PM-9PM
Adv_ltr	Advance letter sent (Node K of Figure 1)
Posbiz	Phone number matched to business address (Node H of Figure 1)
Listed	Phone number is residential-listed (Node D of Figure 1)
MSA	Is inside a metropolitan statistical area
North_division	Is in one of the northern census divisions for the time zone
College_graduate_upper	Percentage of the population in the telephone exchange that are college graduates is in the top half among dialed cases
Median_years_educ_upper	Median years of education for the population in the telephone exchange is in the top half among dialed cases
Median_HH_income_upper	Median income for the households in the telephone exchange is in the top half among dialed cases
Median_home_val_upper	Median home value in the population in the telephone exchange is in the top half among dialed cases
Median_rent_upper	Median rent in the telephone exchange is in the top half among dialed cases
Owner_occupied_p_upper	Percentage of owner-occupied homes in the telephone exchange is in the top half among dialed cases
Approx_median_age_upper	Median age of the population in the telephone exchange is in the top half among dialed cases
Percent_listed_upper	Percentage of phone numbers in the telephone exchange that are listed is in the top half among dialed cases
Household_density_upper	Household density in the telephone exchange is in the top half among dialed cases
White_p_upper	Percentage of the population in the telephone exchange that is White is in the top half among dialed cases
Hispanic_p_upper	Percentage of the population in the telephone exchange that is Hispanic is in the top half among dialed cases
Black_p_upper	Percentage of the population in the telephone exchange that is Black is in the top half among dialed cases

*The two-way interactions of Shift with each of the other covariates were also considered for the model.

Table 2: Finalization Model, Central Time Zone, Weekday Calls – Type 3 Effects

Parameter	DF	Chi-Square	P-Value	Parameter	DF	Chi-Square	P-Value
Adv_ltr	1	1256.8203	<.0001	Percent_listed_upper	1	190.2455	<.0001
Posbiz	1	1830.4079	<.0001	White_p_upper	1	97.897	<.0001
Listed	1	905.6158	<.0001	Hispanic_p_upper	1	55.99	<.0001
MSA	1	88.5632	<.0001	Shift	2	171.88	<.0001
North_division	1	348.5142	<.0001	Shift*Adv_ltr	2	299.4248	<.0001
College_graduate_upper	1	6.4486	0.0111	Shift*Posbiz	2	605.9806	<.0001
Median_home_val_upper	1	36.4855	<.0001	Shift*Listed	2	114.0484	<.0001
Median_rent_upper	1	10.6862	0.0011	Shift*College_graduate_upper	2	15.1241	0.0005
Owner_occupied_p_upper	1	3.9466	0.047	Shift*Owner_occupied_p_upper	2	19.5608	<.0001

Table 3: Finalization Model, Central Time Zone, Weekday Calls – Maximum Likelihood Estimates

Parameter		DF	Estimate	Std. Error	Chi-Square	P-Value
Intercept		1	-2.567	0.0207	15418	<.0001
Adv_ltr		1	0.5319	0.015	1256.8	<.0001
Posbiz		1	0.8509	0.0199	1830.4	<.0001
Listed		1	0.4548	0.0151	905.62	<.0001
MSA		1	-0.1033	0.011	88.563	<.0001
North_division		1	0.17	0.0091	348.51	<.0001
College_graduate_upper		1	0.0333	0.0131	6.4486	0.0111
Median_home_val_upper		1	-0.0759	0.0126	36.486	<.0001
Median_rent_upper		1	-0.0426	0.013	10.686	0.0011
Owner_occupied_p_upper		1	0.0256	0.0129	3.9466	0.047
Percent_listed_upper		1	0.1321	0.0096	190.25	<.0001
White_p_upper		1	0.1095	0.0111	97.897	<.0001
Hispanic_p_upper		1	-0.0751	0.01	55.99	<.0001
Shift	Day (Ref. Cat.)	1	--	--	--	--
	Evening	1	-0.1216	0.0302	16.218	<.0001
	Night	1	-0.1323	0.0197	44.963	<.0001
Shift*Adv_ltr	Day (Ref. Cat.)	1	--	--	--	--
	Evening	1	0.098	0.026	14.207	0.0002
	Night	1	0.1734	0.0169	105.2	<.0001
Shift*Posbiz	Day (Ref. Cat.)	1	--	--	--	--
	Evening	1	-0.00036	0.0345	0.0001	0.9916
	Night	1	-0.4208	0.0231	331.8	<.0001
Shift*Listed	Day (Ref. Cat.)	1	--	--	--	--
	Evening	1	0.0581	0.026	5.0014	0.0253
	Night	1	0.1119	0.0172	42.554	<.0001
Shift*College_graduate_upper	Day (Ref. Cat.)	1	--	--	--	--
	Evening	1	-0.00954	0.0185	0.2659	0.6061
	Night	1	0.0422	0.0124	11.605	0.0007
Shift*Owner_occupied_p_upper	Day (Ref. Cat.)	1	--	--	--	--
	Evening	1	0.00067	0.019	0.0012	0.9719
	Night	1	0.0443	0.0126	12.287	0.0005

Table 4: Evaluating the Usefulness of the Finalization Models

Time Zone	Day Type	Actual 2006 Distribution of First Dials			Actual 2006 Finalization Rate	Best Distribution of First Dials Under the Model			Predicted Finalization Rate Under the Model
		Daytime	Evening	Night		Daytime	Evening	Night	
Eastern	Weekday	62%	18%	21%	14.5%	38%	7%	55%	16.9%
	Weekend	56%	16%	29%	12.8%	14%	0%	86%	13.5%
Central	Weekday	24%	10%	66%	16.2%	33%	0%	67%	19.1%
	Weekend	37%	19%	43%	15.3%	25%	0%	75%	16.3%
Mountain	Weekday	23%	15%	62%	16.3%	32%	22%	46%	18.8%
	Weekend	35%	19%	46%	15.6%	10%	0%	90%	16.6%
Pacific	Weekday	33%	49%	17%	14.8%	10%	0%	90%	17.7%
	Weekend	49%	28%	23%	13.8%	11%	0%	89%	14.9%
Total	Weekday	43%	19%	38%	15.2%	33%	6%	62%	17.8%
	Weekend	49%	18%	33%	13.7%	16%	0%	84%	14.5%