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Feasibility of using web surveys to collect time–activity data

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Time–activity data are traditionally collected by telephone interviews or through paper diaries, which are time consuming and costly. As a potential alternative that may greatly save staff time, a web survey to collect time–activity data was developed and tested in this study. We collected 24-h recall web diaries from 151 parents of young children mostly under 55 years of age (who also answered for their children) and 55 older adults ($\geq$55 years of age) both on a weekday and a weekend day every 3 months during an 18-month period. The performance and reliability of the web surveys collected were evaluated, including the survey-completion rate, and the percentage of surveys with unreasonable time being reported as spent sleeping and with missing reports of being in transit between locations. We also compared the web-survey data with time–activity information we collected from the same subjects in telephone interviews and found that these data sources were fairly consistent with each other. However, we observed slightly more compliance issues for the web than the telephone survey, but most of these issues could be addressed and minimized by refining some questions or the survey interface. Our study suggests that it is critical to reduce participants' burden and improve survey interface design for optimal compliance and data quality. In conclusion, web surveys are a promising method to consider for time–activity data collection.
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Introduction

Time–activity data are an essential component of risk assessment models aiming to estimate exposure to contaminants in the environment. Traditionally, the collection of time–location/activity data has relied on retrospective telephone surveys (Klepeis et al., 2001; Leech et al., 2002; Abraham et al., 2006; Robinson and Martin, 2009) or paper diaries, either filled out retrospectively or contemporaneously (Schwab et al., 1992; Echols et al., 1999; Freeman et al., 1999; Schweizer et al., 2007; Nethery et al., 2009), which are labor-intensive and costly. Lately, Global Position System (GPS) recording devices have been used to collect time-use information (Elgethun et al., 2003; Wiehe et al., 2008; Vazquez-Prokopec et al., 2009). These methods require little effort from participants and meantime provide ''objective'' data that are not subject to recall bias as traditional methods are. However, these ''objective'' methods usually require conversion of geographic coordinates into the descriptions of real locations and activities. In addition, it has been reported that subjects may forget to wear the device or may encounter technical issues with the devices, for example, signal loss or batteries running out.

Given the increasingly universal usage of the internet and smartphone devices, web-based surveys can provide a relatively straightforward new method for collecting retrospective or concurrent time–activity data. The advantages of web surveys are well recognized. First, web surveys can reduce staff burden and increase efficiency (Fricker et al., 2005; Chang and Krosnick, 2009). Second, web surveys could reduce human error and allow better data quality assurance by controlling acceptable input and item skips (Kiecker and Nelson, 1996; Biemer et al., 2004). Third, web surveys can be completed at any time convenient for the respondents. Respondents can complete the survey at their own pace, allowing them enough time to deliberate, and thereby potentially improve reporting accuracy (Chang and Krosnick, 2009). Lastly, data collected by web surveys are available online right after a survey is completed. No data input (subject to human error) or downloading is required. Therefore, it is of interest to use web surveys for time–activity data collection, especially in large and long-term follow-up studies.

A few studies have employed web surveys to collect time-use data (Kan and Pudney, 2007), but the information on the

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reliability and efficiency of web surveys used for this purpose is still very limited (Juster et al., 2003). Kan and Pudney (2007) reported that "stylized" methods, including web surveys, are subject to larger random measurement errors and additional systematic errors compared with diary-based methods. However, given the potential advantages of web surveys, research exploring the feasibility of using them in time–activity studies and possible improvements is justified.

As a part of the Study of Use of Products and Exposure Related Behavior (SUPERB) (Hertz-Picciotto et al., 2010), we employed both telephone and web surveys to retrospectively collect time–activity data from California residents. We present estimates of the efficiency and reliability of a retrospective web-based time–activity survey by comparing results with those from the traditional telephone interview. Our goal was to obtain some information on the validity of time–activity data collected by web surveys and thus provide guidance to design of future time–activity studies.

Methods

Study Population

SUPERB enrolled a total of 655 households in a telephone survey that collected data on time–activity, usage of consumer products, and food consumption (Hertz-Picciotto et al., 2010). Among the enrolled households, we recruited 250 for additional web surveys. Because of feasibility issues in designing and testing these web surveys, we only targeted participants who were able to complete the survey in English. We recruited from two subcohorts. One group of 186 households was recruited from a cohort of 499 households in northern California with at least one child under age 8, in which one parent and one child (not necessarily the younger one) each were enrolled. Participant households were recruited by contacting a random sample from birth certificate records of children born between 2000 and 2005. The second subcohort consisted of 64 out of originally 156 households of older adults (mostly $\geq$55-year-old) living in the southern portion of the Central Valley of California. These households were selected randomly from tax assessors' housing unit records.

Data Collection

Participants completed both interviewer-administered telephone-based 24-h time–activity surveys and web-based 24-h time–activity surveys, recalling the activities from the day before the survey, from midnight to midnight. Subjects were allowed to report any length of activity in the units of minute. However, web and phone interviews did not necessarily capture the same day. The telephone survey was completed twice, once for a weekday and once for a weekend day. The northern California parents responded for themselves and for their children. Telephone interviews were conducted by trained interviewers. The interviewer asked the participant to report their first activity of the previous day and then to report all subsequent activities. Once the entire day's activities were recorded, the interviewer read the activities back to the participant for confirmation. In order to not slow down the conversational speed of the interview, interviewers recorded time–activity diaries on paper during the telephone interview, and later typed these data into a database. The telephone surveys were conducted between June 2006 and April 2008, and the web surveys were conducted between October 2007 and September 2009.

For our self-administered web-based surveys, participants were asked to complete multiple 24-h recalls of yesterday's activities for weekdays and weekend days over an 18- or 15-month period (please note: a small number of participants ($N = 20$) joined the study too late to complete the 18-month survey, and thus were asked to complete a 15-month survey.). This design was chosen to allow us to capture longitudinal and seasonal variations of time–activity patterns. Specifically, in the first month participants completed a consumer product use survey, the second month they provided one 24-h weekday time activity and food recall, and in the third month they provided a 24-h weekend day time activity and food recall, instead; this cycle of web surveys (referred to as waves) then started over again and was repeated 5–6 times. Parents responded for their children due to concerns about the amount of reading required by the web surveys. We offered to provide the equipment, online services, and an in-person orientation about computer use and the web survey to 12 participants who lacked a computer or internet service but agreed to participate in the web surveys. Study participants received an incentive for their participation in both telephone surveys and web surveys. In order to improve retention in the web surveys, participants were also entered into a raffle each time they completed a survey.

Two different web-based survey interfaces were used in this study. We initially used a calendar-style interface (Appendix I see online), which allowed participants to fill in time blocks and select a corresponding location and activity from available categories. This interface allowed participants to make changes if they entered information incorrectly. However, as some participants found this cumbersome and one of our study goals was to try to develop useful tools, a dialogue-style interface (Appendix II see online) was implemented beginning November 1, 2008 to determine whether this would provide a better data collection platform. In the dialogue-style web survey, participants were asked to record their first activity at the beginning of the 24-h period, then their second activity, and so forth, requiring the participants to recount their day in a linear fashion similar to the telephone interviews. Unfortunately, the dialog-style interface did not allow participants to go back to change previous inputs. Rather, they were asked to leave notes in a

comment area at the end of the survey if they had made mistakes.

Participants accessed web surveys through a study website with a unique ID and password. The survey system sent periodic e-mail reminders about upcoming survey elements and a thank-you e-mail upon completion of each survey. In contrast to telephone interviews where the participants' answers were read back to them for confirmation, no timely manual review of the data was completed in the web-based surveys.

The 24-h diary focuses on determining the amount of time spent in different types of location but collects very little information on specific activities to minimize participants' burden. The location categories were primarily compiled from the National Human Activity Pattern Survey (NHAPS) (Klepeis et al., 2001) and a California Air Resource Board study (Wiley et al., 1991), and included the following locations: residential locations including home, garage, or someone else's home; school/childcare locations; places where people work, shop, eat, or do errands, that is, office buildings, multipurpose stores, grocery stores, shopping mall/other stores, restaurants, beauty salon, medical facility, industrial facility, auto-related repair shop, dry cleaners, and bar or nightclub; various other locations listed as options are public parks, health clubs, public buildings, religious institutions, amusement parks, farm, hotel, and construction site. Information on various modes of transportation was also collected. Limited information on specific activities was asked so as to differentiate between sleeping, working (paid or unpaid), play (vigorous or not, for children), and being awake engaged in other things.

Research protocols and consent forms of this study were approved by the Institutional Review Board of the University of California at Davis. A detailed description of the design and approach of the overall SUPERB study can be found in Hertz-Picciotto et al. (2010).

Data Analysis

Data quality was evaluated through a number of measures, including survey-completion rates and percentage of diaries with various compliance issues. Diaries reporting data for <24 h were identified and fixed when possible. Only complete diaries were included in further analyses. There is concern that individuals reporting over the web may not provide information as accurately as they would to an interviewer over the phone. Thus, we examined the frequency of diaries reporting unusual and thus potentially inaccurate sleep time, for example, reports of no sleep or <3 h of sleep over a 24-h period. We also examined the frequency of location changes without any reported means of transportation between different locations or alternatively reports of using a mode of transportation that did not result in a change in location.

As a measure of the extent of detail reported and the consistency of reporting, we counted the number of time–location–activity records and the frequency of location changes reported during a 24-h survey period, and also examined variations in the number of location-activity records reported for a recall day and the number of location changes per recall day for and across each wave (1–6) and after changing from one to the other web-survey interface. As these count data followed a Poisson distribution, a Generalized Linear Mixed Model was used for analysis, with day-type (weekday *vs* weekend), season (warm season from May to October *vs* cool season from November to April), and wave number or type of survey interface as fixed effect estimates and individual participants as a random effect estimate. We further examined how often diaries reported very few changes in location/activity, for example, ''home asleep from midnight to 8AM, and home awake from 8AM to midnight'', which could either be accurate descriptions of activities or the result of a participant trying to fill in the survey in the shortest amount of time possible.

Finally, we compared the web-survey data at the group level with the telephone interview data collected from the same subgroup of participants, and we assumed that the overall information collected should be similar in both types of surveys. The Wilcoxon–Mann–Whitney test was used for this comparison. We also matched the data of the first recall diary collected via web survey to the telephone survey data for each individual participant and examined how these correlated. All analyses were conducted using SAS 9.2 (SAS Institute, Cary, NC, USA). All P-values <0.05 were considered as being ''statistically significant''.

Results

Survey-Completion Rate

Of the 250 households who initially enrolled in the web-survey component of our study, 44 households did not provide any time–activity recall diaries (although some of these participants completed web surveys on other topics, such as consumer products or foods). The 356 participants who completed some of the time–activity survey component translated into 206 households, because northern California households included both an adult and a child survey each (Table 1).

During the study, the number of participants withdrawing increased over time. In addition, some participants skipped one monthly survey, but completed a survey in the following month. In a limited number of cases (2.6% of all diaries), participants made a good faith effort but were unable to access the survey on the last survey day of the month because of computer problems, internet connection failures, or account access problems that could not be resolved in time.

Considering all three of these factors, a larger proportion of older adults completed diaries than families with younger children (Table 2). Almost half of the older adult participants

Table 1. Demographic characteristics of the participants.

	Children	Parents of young children[a]	Older adults
N	150	151	55
Age	1–2 years — 33.3% 3–5 years — 57.3% 6–8 years — 8.7% 9 years — 0.7%	19–24 years — 2.7% 25–34 years — 35.1% 35–44 years — 57.0% 45–60 years — 5.3%	<55 years — 3.6% 55–64 years — 60.0% 65–74 years — 18.2% 75–84 years — 18.2%
Sex			
Male	51.3%	14.6%	34.6%
Female	48.7%	85.4%	65.5%
Race/Ethnicity			
White	64.0%	64.2%	85.5%
Asian	10.7%	10.6%	—
Other	12.7%	12.6%	7.3%
Hispanic	12.7%	12.6%	7.3%
Education[b]			
High school or lower		15.9%	12.7%
College degree or some college		51.7%	61.8%
Master, doctor, and professional degree		32.5%	25.5%
Job status[b]			
Employed		51.0%	40.0%
Stay-at-home parent		37.8%	—
Unemployed		1.3%	5.5%
Retired and have no paid employment		0.7%	49.1%
Other		7.3%	5.5%
Missing		2.0%	—

[a]One parent did not fill in any information for the child.
[b]For adults only.

Table 2. Survey-completion rate (%) for the web surveys of SUPERB[a].

Population subgroup	No. of diaries completed	Completed all surveys[b]	Completed all but one survey	Completed between 50% and "all but one survey"	Completed <50% of the surveys
Parents of young children ($N=151$)	1953	16%	7%	32%	45%
Older adults ($N=55$)	504	49%	16%	11%	24%

[a]The percentages were calculated based on the total number of diaries collected ($N=206$). In some cases, participants missed one survey but continued in the next month.
[b]There are a total of 12 surveys during the 18-month period or 10 surveys during the 15-month period.

completed all surveys required (18 or 15 months) compared with no more than 16% of parents of younger children. Overall, we collected 2457 diaries out of 4208 total possible (if the 206 adult participants who enrolled had completed all diaries required for themselves and/or their children). Out of 206 households, 56% of parents of young children and 24% of older adults withdrew before the study ended, with 28% of parents withdrawing within the first six months. The withdrawal rate from the annual telephone survey was lower for adults with children but similar for older adults, with 32% of the parents and 23% of the older adults withdrawing before the second year of data collection. Comparisons of retention/withdrawal rates according to socio-economic factors suggested that older female adults were more likely to drop out than older males ($P=0.02$); while race/ethnicity, education, number of children in the households (tested only for households with young children), and employment status did not influence the drop-out rate for families.

Incomplete Diaries

We observed a small number of incomplete diaries ($N=13$, 0.5% of the 2457 diaries collected by the web surveys), that is, diaries with less than 24 h for the recall day reported during the web surveys; some of these occurred due to internet connection failures. A similar percentage of incomplete diaries was observed in the telephone surveys (0.6% of the 873 diaries collected by telephone surveys).

Reported Hours of Sleep

While the vast majority of diaries reported between 3 and 16 h of sleep within a 24-h period, a small number provided less plausible numbers of hours, that is, hours outside this range, which is an arbitrary standard set by the authors. Reports of such implausible sleep hours occurred more often in web (3.2%) than in telephone surveys (1.0%) (Figure 1). Some diaries with unusual sleep time were obvious entry errors because subjects selected incorrect activities, such as indicating two subsequent ''awake at home'' time periods, with the second period beginning after 10 PM or the first starting at midnight and ending after 6 AM, or missed reporting sleep hours, such as ending their reported recall with the location as ''being at home'' sometime after 10 PM. After correcting such mistakes, implausible sleep hours decreased to 2.7% in web surveys and 0.4% in telephone surveys.

Some diaries ($N = 31$, 1.3%) indicated 24 h of sleep, and the majority (97%) of these occurred with the dialog-style interface. As there was no way to change reported information once reported in this interface, participants may have mistakenly entered this information. In the calendar-style interface, we found more days that reported too much (≥ 16 h) or too little (≤ 3 h) sleep than in the dialog-style interface. We observed this issue early in the study, and added a warning about missing sleep records to the web survey, after which missing sleep records dropped by 20%.

Evaluating the Number of Location Activities Reported per Day

The number of location-activities reported per day and the number of location changes per day were used as indicators of survey compliance or accuracy of reporting on days with a very busy schedule rather than omitting activities and locations that take time to report (Schwab et al., 1992).

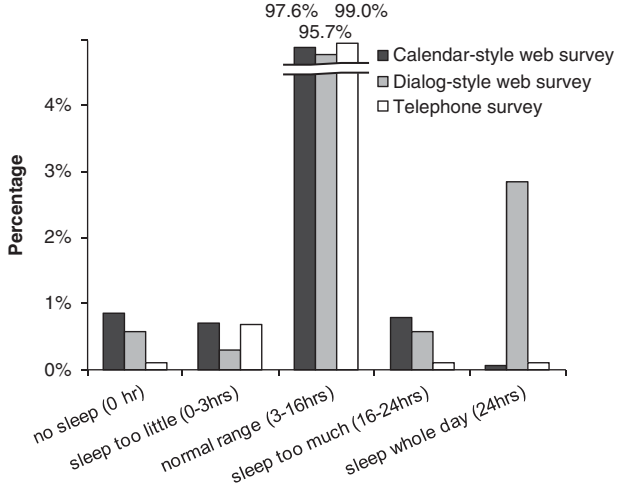

Figure 1. Comparison of sleep time reported in web surveys and telephone surveys.

On average, participants reported 10–11 location activities per day and 6–8 location changes per day. Adults reported more location-activity records and location changes per day for themselves than for young children (Table 3). The variation in the number of daily location-activity records and daily location changes adhered to our expectation such that there were more location-activity records and location changes on weekdays than on weekend days, and more in the warm season compared with the cold season. Among parents of young children, females had more records and location changes per day than males, and participants without employment had more records per day than employed participants; however, these differences were statistically significant for parents of young children but not for older adults.

We also investigated the diaries with an unexpectedly low number of records per day. A small number of participants (5.6%) reported no or very few changes in location or activity (two or less) during the day. For example, a diary with no changes could report ''asleep at home'' all day or ''awake doing other things at home'' all day. A typical diary reporting two changes would record ''asleep at home'' — ''awake doing other things at home'' — ''asleep at home''. We found more diaries with no or very few changes in the web surveys than in the telephone surveys (1.1%). The percentage was especially high in the dialog-style version of web surveys (Figure 2), partly because the dialog-style interface did not allow respondents to go back to correct mistakes, which was a limitation of this interface.

To determine changes in participant compliance over time due to a loss of enthusiasm with time and also participant compliance for the two interfaces, we evaluated the consistency of the number of location-activities reported per day and the number of location changes per day both over time and between the two survey interfaces, using the Generalized Linear Mixed Model. No significant variation over time or between the two web-survey interfaces was observed, suggesting consistent compliance and enthusiasm over the study period as long as subjects did not decide to completely drop out of the study.

Comparison of Data Collected

The data collected by the web surveys and the first-year telephone surveys (one for a weekday and one for a weekend day) from the same participants are presented in Table 3, and Figure 3 compares time spent at home by type of day and age group. On average, diaries collected via telephone interview reported more location-activity records and location changes per day than the web surveys ($P < 0.0001$), even after stratifying by age group and day-type. Diaries collected by telephone also contain more time spent in transit. If we further break down the time spent in transit by age group and day-type, a difference between survey methods only remained for parents of young children on weekdays

Table 3. Summary of time–location/activity data (min/day) collected by web surveys and telephone surveys by age group and day type.

Variable	Web Survey								Telephone Survey							
	Weekday				Weekend				Weekday				Weekend			
	Mean	SD	Med.	90th%	Mean	SD	Med.	90th%	Mean	SD	Med.	90th%	Mean	SD	Med.	90th%
Parents of young children	$N=492$[a]				$N=449$				$N=185$				$N=187$			
No. of records per day	11	5	11	17	10	4	9	15	16	6	15	22	13	5	12	18
No. of location changes per day	8	4	8	14	7	4	7	13	11	5	11	18	9	4	9	14
Residential	1092	242	1120	1395	1184	236	1240	1440	1044	240	1076	1352	1180	181	1192	1420
School/childcare	48	122	0	175	13	74	0	0	35	93	0	126	3	18	0	0
Transit	80	72	70	155	74	84	60	155	98	76	82	181	76	68	60	165
Work/shopping/eating/errands	175	218	60	540	74	120	25	195	171	212	69	516	68	111	26	196
Various other locations[b]	45	91	0	140	96	168	5	240	76	130	13	238	102	134	56	270
Own home	1074	243	1095	1385	1131	264	1185	1440	1018	243	1049	1340	1127	223	1149	1399
Sleep (activity)	524	114	510	660	563	107	555	690	491	79	480	595	543	116	540	675
Work (activity)	199	241	0	545	54	149	0	260	189	237	0	524	29	105	0	0
Young children	$N=496$				$N=453$				$N=187$				$N=188$			
No. of total records per day	10	4	10	15	9	4	9	15	14	5	14	20	13	4	13	17
No. of location changes per day	6	3	5	11	6	4	5	11	8	4	7	13	7	4	7	11
Residential	1126	228	1140	1440	1235	211	1275	1440	1124	216	1140	1428	1241	183	1261	1440
School/childcare	187	205	168	480	15	72	0	0	177	203	56	508	4	35	0	0
Transit	59	73	45	120	63	81	45	150	59	52	50	120	58	61	45	140
Work/shopping/eating/errands	28	69	0	90	35	54	0	115	30	52	0	113	29	56	0	90
Various other locations[b]	39	101	0	120	93	160	0	240	40	79	0	126	99	145	58	232
Own home	1103	228	1110	1440	1169	256	1215	1440	1077	224	1066	1428	1181	218	1215	1440
Sleep (activity)	663	102	660	780	676	88	670	780	664	97	660	780	672	92	675	780
Older adults	$N=242$				$N=238$				$N=63$				$N=63$			
No. of total records per day	11	5	11	17	11	4	10	16	15	6	14	22	13	5	12	20
No. of location changes per day	8	5	7	14	7	4	6	13	9	4	9	13	9	4	9	14
Residential	1123	268	1193	1440	1194	234	1250	1440	1108	253	1135	1440	1174	224	1211	1430
School/childcare[c]	16	68	0	0	5	39	0	0	47	150	0	92	0	0	0	0
Transit	78	84	60	150	86	103	60	195	82	87	62	190	99	116	60	246
Work/shopping/eating/errands	142	209	53	540	49	76	0	155	150	186	57	468	49	60	30	144
Various other locations[b]	81	169	0	235	106	184	0	300	42	83	0	140	110	148	40	310
Own home	1115	258	1173	1440	1152	261	1205	1440	1077	284	1122	1440	1113	232	1158	1395
Sleep (activity)	517	138	495	660	540	120	513	690	486	77	480	585	513	97	510	630
Work (activity)	158	231	0	525	28	101	0	85	184	231	0	525	9	47	0	0

[a]The number of diaries collected under each category.
[b]In telephone surveys, the ''various other locations'' category includes ''not recorded'' and ''don't know'' options, which were not included in the web surveys. Thus, data spent in ''various other locations'' cannot be compared directly between methods.
[c]Older adults may work in these places or pick up grandchildren.

($P=0.0061$). In addition, participants reported spending more time in daycare/school and at work on weekend days in the web surveys than in the telephone surveys, but this comparison depended on a small number of people reporting being at these places on weekend days. Differences were not statistically significant for comparisons by age group and we saw no further statistical difference for the time–location/activity data collected by web and telephone surveys.

We also examined correlations between responses in the first wave of the web survey only and corresponding responses in the first-year telephone surveys. The number of records per day and the time–location/activity data for weekdays were moderately correlated for two types of surveys (Table 4), with Spearman correlation coefficients ranging from 0.23 to 0.58 ($P<0.0001$). The time budget patterns on weekend days were less consistent, probably because the two types of surveys were conducted about half year apart with the same subject, and people's weekend activity may be very different in different seasons. Only reported sleep time was moderately correlated on weekend days ($R=0.46$, $P<0.0001$).

Missing Transit or Stop Records

In web surveys, respondents sometimes skipped reporting any mode of transit between different locations, or reported driving for more than 30 min from their home and back without interim stop(s), or reported several continuous driving trips without stops (Figure 4). Some continuous trips might be explained by participants picking up or dropping off children, or using drive-through services on their way. As part of our evaluation of the web surveys, we reviewed all the data a few months after data collection had

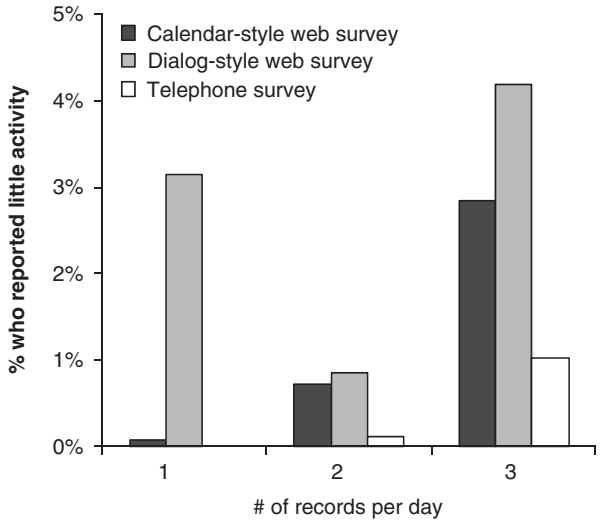

Figure 2. Percentage of diaries with few activities in web surveys and telephone surveys.

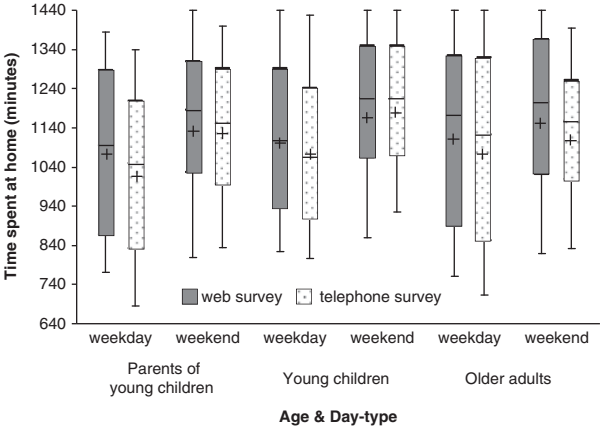

Figure 3. Comparison of time spent at home (average minute per day) between web surveys and telephone surveys, by age group and day type. (Note that web surveys could contain multiple days for each participant in each type of day).

Table 4. Spearman correlation coefficients (R) between weekday time–location data in the first wave of the web surveys and telephone survey[a] (survey $N = 296$).

Variables	R^b
Count of total records	0.23
Count of location changes	0.32
Residential	0.41
School/childcare	0.42
Transit	0.29
Places for work/shopping/eating/errands	0.32
Own home	0.41
Sleep (activity)	0.55
Work (activity)	0.58

[a]On average, the telephone survey was conducted with the same subject about 0.65 year earlier than the first round of web survey.
[b]For all R, $P < 0.01$.

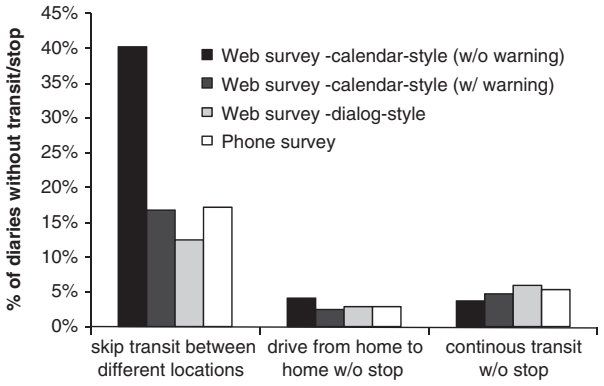

Figure 4. Comparison of occurrence rate of missing reporting transit or stop(s) in web surveys and telephone surveys.

started and found that in 40% of the diaries, respondents had skipped reporting any mode of transit between locations at least once. To correct this problem, automatic interactive warnings were added to the web survey when the participant failed to enter transit between stops or stop(s) while driving. After this addition, missed transit information dropped to a percentage similar to telephone surveys (17%), and dropped even further to 13% when the dialog-style interface was implemented. Similarly, lack of information about stop(s) for back and forth driving from home dropped from 4.1% to 3.0% once warnings were added, compared with 3.0% in telephone surveys. There was no warning added to remind participants to fill in a stop between two transit records, thus the occurrence increased over time, from an average of 4.4% in the calendar-style interface to 6.0% in the dialog-style interface. Nevertheless, this percentage was not much higher than in telephone interviews (5.4%).

Exit Survey

When participants either completed the study or withdrew from the study, they were given an exit survey to provide us with feedback. A total of 102 exit surveys were completed online right after the participants completed the study, and 35 were received in anonymous format by mail from those who dropped out. About 83% of the participants were satisfied with the ease and clarity of the web survey for collecting time–location/activity data. Overall, 48% of participants preferred the web surveys; more specifically, 60% of younger adults, 49% of older adults, and 24% of those who dropped out. On the other hand, 25% of the participants, including 13% of the subjects who stayed in the study until the end, and 69% of those who dropped out preferred the telephone interviews. Even though our web survey recorded both time–activity information and dietary data at the same time, the majority of the parents of young children were still able to complete the web survey for both their children and themselves in 1 h or less (87%). Yet, only 20% of the older adults reported being able to complete the web survey for themselves only in this amount of time. Thus, parents of young children seem to

be more adept at efficiently using web surveys than older adults and they were more likely to favor web surveys and needed less time to complete each survey. Similar findings were also reported in Fricker et al. (2005).

Unavoidably, participants sometimes missed a monthly survey; the most common reasons were family responsibility (20%), work schedule (15%), forgetting (15%), technical difficulty (11%), too time-consuming (11%), and vacations (9%). In particular, for younger adults, given their responsibility of raising children, family responsibility (23%), work schedule (17%), and forgetting (20%) were the three leading causes for missing surveys. In contrast, older adults reported vacation (15%), technical difficulties (11%), and forgetting (11%) as the major reasons. The most common reasons for withdrawal were "survey took too long" (38%), "personal circumstances did not allow enough time" (21%), and "too many surveys" (11%). Note that these comments were based on their experience with the combined web surveys that included the dietary components, and not solely for time–activity data collection. Overall, 24% of participants admitted that they sometimes selected days that had less activity for completing the survey, and a smaller portion of participants (4%) stated that they usually used this strategy.

Discussion

This paper presents an extensive evaluation of survey compliance and data quality for our web surveys, important information when determining whether to employ web surveys for large-scale time–activity data collection efforts. Our study demonstrates that web surveys provide similar quality of data as telephone surveys. We observed some compliance issues (for example, when people used strategies that allowed them to report fewer activities or when they forgot to report activities), which occurred in a small percentage of surveys, but they could be reduced by improving survey design (for example, inserting warnings as was shown to improve compliance). Results of this study may help researchers to understand issues related to collecting data via web surveys and shed light on design of future time–activity studies.

Participant Retention

Web surveys are generally subject to low-response rates and to participant attrition (Couper, 2000; Fricker et al., 2005; Chang and Krosnick, 2009). As longitudinal web surveys are scarce, information on the attrition rates in web surveys is very limited. Clinton (2001) reports an $\sim$10% withdrawal rate for the participants recruited within a 6-month period in a web survey on public opinions. In our study, 9% of the older adults dropped out during the first 6 months of the study, which is similar to the withdrawal rate reported by Clinton (2001). However, attrition was more severe among parents of young children—more than half of the households withdrew before the study ended. The reasons for the high drop-out rates among the households with young children potentially were: (1) these parents have more family responsibilities, making it more difficult for them to find time to comply with survey schedule and to remember this additional commitment and (2) participation required completion of surveys for both their children and themselves. Some participants complained in the exit survey that they were asked to fill out parent and child time–activity data separately even though the adult and the child spend all day together, making the completion process more tedious and laborious and thus discouraging them from participation. Parents noted in the exit survey that family responsibility, work schedule, and the long time it took to complete the survey were the leading reasons for withdrawal and missing a survey appointment. Therefore, strategies should be developed to reduce participants' burden in future studies, in order to improve retention.

Data Quality

The strength of web surveys is that they do not require an interviewer, which could significantly reduce researchers' labor requirements if a large number of surveys need to be conducted and bring about substantial cost savings compared with telephone surveys (Schonlau et al., 2004; Chang and Krosnick, 2009). Interviewers, even when trained and supervised, are also known to introduce some errors and biases in the data collection process, due to wording and habits as well as some careless behavior (Kiecker and Nelson, 1996; Chang and Krosnick, 2009). We noticed that in our telephone surveys interviewers made some typing or recording errors and this adds costs due to increased data cleaning efforts needed. In contrast, data are electronically recorded in web surveys, avoiding secondary errors from data entry and are instantly ready for analysis.

However, the absence of interviewers also entails drawbacks as illustrated by more web diaries reporting fewer activities or location changes, unusual sleep time, and missing transit information. Some of these diaries might have been accurate while others indicate that subjects forgot or neglected to report activities without the intervention of a trained interviewer. The percentage of such omissions, nevertheless, was low and was further reduced with the help of automated warnings. Thus, appropriate warnings can be programmed to check for anticipated irregularities and when these occur "ask" the participant to check their response, that is, a web survey can mimic some of the interactive features of an interview, whereas this is not feasible during paper and pencil data collection that takes place outside of a face-to-face encounter. Some participants intentionally select survey days with little activity to minimize reporting effort, as reported in the exit survey, but such intentional misreporting is unavoidable and can happen in any survey type.

In our evaluation of these survey methods, we sought to determine whether web surveys can provide the same data quality as the traditional telephone surveys. In the web surveys, participants generally reported slightly longer time spent in a residence, at their home, and sleeping than in the telephone surveys. However, as presented before, the time–activity data collected by the two approaches were not statistically different. The time spent at home, sleeping, and working were moderately correlated for these two approaches ($R = 0.41$–0.58). The only statistically significant difference was that parents of young children reported less transit time on weekdays in the web survey, which can be attributed to the high occurrence (40%) of skipping transit at the beginning of the study before the warnings were implemented (the study started with weekday recall among parents of young children). The incorporation of warnings and our new survey interface diminished this difference in the later phase of the study.

Another issue is that, participants reported fewer records per day in the web survey than in the telephone survey, suggesting that the presence of interviewers did encourage participants to provide more detailed time–activity recall. To compare with available data, the events collected in the web diaries were divided by clock hours (minimum 24 clock-hour events per day) and the number of events recorded was calculated. The criterion of "<30 records per day" has been used as a screening tool by Graham and McCurdy (2004) to determine whether a subject was truly engaged in providing accurate recording. Approximately 10% of the person-days of data in CHAD have <30 records per day, while studies using the recall method tended to have more diaries with <30 records, for example, 16–17% of the NHAPS diaries have <30 records (Graham and McCurdy, 2004). We observed 47% of the diaries having <30 records per day in our retrospective web survey. However, a major reason for this high proportion was our decision to not differentiate specific activities within a given location other than for the few categories listed previously to reduce participants' burden.

Survey Interface Design

We designed two types of interface for our web surveys. The calendar-style interface was used at the beginning of the study but some participants indicated that they found it confusing, and thus it was replaced by a dialog-style interface. The dialog-style interface appears to be better than the calendar-style one in terms of clarity though it has other shortcomings. Unreasonable sleep time and missing transit mode issues were improved in the dialog-style interface, which might be attributed to the improved interface design and the embedding of warnings. However, the number of diaries with little activity, including recordings of sleeping for a whole day, increased, and unfortunately the dialog-style interface did not allow the respondent to go back to change and correct answers. In the future, this feature should be improved in the dialog-style interface, such that respondents are encouraged to report details and are allowed to go back and modify a previous entry.

Limitations

Generally speaking, web surveys tend to overrepresent urban residents and more educated and wealthier people, at least partly due to the requirement of access to internet and relevant knowledge (Schonlau et al., 2004; Fricker et al., 2005; Chang and Krosnick, 2009). Our web-survey cohort also was more highly educated than the general population, even though they were recruited from a larger cohort who participated in the telephone surveys and, equipment or training was provided for those who need it. We conducted comparisons between web surveys and telephone surveys based on the same subcohort of participants to avoid differences between the two populations. However, it is important to note that the telephone survey data used in this analysis were not collected on the same days as the web-survey data, thus the comparison of time spent in a location or on an activity only provides partial reference for evaluating the web survey. It is recommended to further evaluate web surveys against other objective measures or monitors, for example, GPS or accelerometer, to determine the accuracy of web-survey data.

Another limitation is that a large number of parents of young children could not complete all required surveys due to the time limitations and family responsibilities, which reduces our power to evaluate consistency of reporting over time. Parents of young children are an extremely time stressed subgroup, given the extra time spent on child care and housework (Craig and Mullan, 2010). Kan and Pudney (2007) also pointed out that the systematic error in "stylized" methods, including web surveys, was particularly significant for women with dependent children, which is a big proportion of our study population. Future studies should consider the high workload and thus potential high attrition in this subgroup, and minimize participants' burden as much as possible.

Conclusion

This study examined the feasibility of using web surveys to collect time–activity data. Based on our results, the data collected by web surveys are fairly consistent with telephone surveys. We found more survey compliance issues in the web-based than in the telephone interview survey, but most of these issues occurred rarely and could be minimized by refining and re-designing the questionnaires or survey interface. More efforts are needed to design and test survey interfaces and reduce participants' burden, in order to improve survey compliance and data quality in web surveys. In addition, we observed a high attrition rate among parents

of young children, which should be considered in future studies. In summary, given that web surveys may provide similar quality of data as telephone surveys with less effort and cost, it seems promising to use web surveys in future time–activity studies.

Conflict of interest

The authors declare no conflict of interest.

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