



Response Patterns in Travel Surveys: The VATS Experience

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Abstract

This paper examines two key questions concerning mail-out, mail-back travel surveys involving a travel diary. The first is whether respondents to such surveys are likely to be dominated by travellers with less complex travel patterns. The second is whether repeat reminders, long perceived to be essential in increasing response rate, and the conduct of face-to-face interviews, deemed critical for correcting non-response bias, are effective in rectifying such problems of selectivity bias. Drawing on four years of VATS results, the household and travel characteristics of respondents are analysed with respect to the elapsed time in responding to the survey. The results show that follow-up reminders do play a significant role in raising response rates, especially in increasing the participation rate of families with children. The first reminder, in particular, has the potential of raising the response rate by about 50% above that which would otherwise be obtained. The information obtained from late responses, however, suffers from under-reporting of out-of-home stops and a higher percentage of missing values. By contrast, non-response interviews prove to be a useful supplement to mail surveys, although missing data is also a cause for some concern. The study also reveals that non-respondents from similar family types have comparable trip rates to those of the early respondents.

The findings confirm that travel surveys are susceptible to the risk of selectivity bias in the sample. They also challenge conventional thinking that non-respondents are more akin to late respondents and make fewer trips than respondents. To the extent that under-reporting of trips poses a more serious problem than total non-response in trip generation models, the value of repeat reminders is questioned. Non-response interviews are considered a favoured option when it comes to reducing non-response bias in self-administered, postal surveys.

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Introduction

Travel surveys provide vital information for transport planning. But, unfortunately from the respondents' point of view, travel surveys are among the most onerous surveys to complete. This is particularly true of travel diaries which are a commonly used instrument in travel surveys. The information requested by travel diaries is not only demanding in terms of sheer quantity, but it may also encroach on individual privacy. The complexity of the task is further compounded when a postal, self-administered questionnaire is used to collect travel data. In a non-travel context, Kaldenberg, Koenig and Becker (1994) have found that among elderly persons, age has a significant effect on response rates to a mail questionnaire. This finding is consistent with the tenet that the ability to process information, hence responding to complex questions, declines with age (Phillips and Sternthal 1977). In the context of travel surveys, the time and effort taken to systematically record travel and out-of-home activities is likely to increase proportionately as travel patterns become more complex. Since the complexity of travel patterns increase with the presence of children (Morris and Richardson 1995; 1996; Rosenbloom 1994; Rosenbloom and Burns 1993), the propensity to respond to a travel survey may also decline. A central question facing mail-out, mail-back travel surveys involving a travel diary, therefore, is whether respondents are likely to be dominated by the "less sophisticated" travellers. A corollary to this is whether the use of repeat reminders, long perceived to be essential in increasing response rate (Moser and Kalton 1958; Dillman 1978; and de Vaus 1995), and the conduct of face-to-face interviews, deemed critical for correcting non-response bias (Smith 1983), are effective in rectifying such a possible selectivity bias in the sample.

Based on the results of a carefully administered mail survey with four reminders and a subsequent survey of non-respondents conducted in West Berlin in 1976, Brög and Meyburg (1980) found an overrepresentation of mobile persons when no reminders were issued to obtain a larger sample. Rather than suggesting that this could possibly be due to a reluctance to respond by those with more complex travel patterns, they interpreted this as reflecting the over-enthusiasm of mobile persons to participate in travel surveys. Their argument thus contradicts the logic of a declining tendency to participate in travel surveys with increasing travel complexity. As Brög and Meyburg (1980) have not analysed their data from the perspective of family type, their interpretation may be considered to be inconclusive. Moreover, the analysis of Brög and Meyburg (1980) is based solely on one set of data. The consistency of their results cannot be ascertained.

The Victorian Activity and Travel Survey (VATS) conducted by the Transport Research Centre (IRC) at RMIT since December 1993 provides an opportunity to assess these issues. VATS uses a mail-out, mail-back, self-administered questionnaire. Similar to the 1976 Continuous Travel Survey in West Berlin used by Brög and Meyburg (1980), up to four reminders are also sent to each non-responding household in VATS. In addition, a selected number of households are tagged during sampling for a possible face-to-face interview, should they fail to respond after the fourth reminder. Drawing on four years of VATS results, this paper examines the household and travel

characteristics of respondents with respect to the elapsed time in responding to the survey. The objective is to determine the contribution that follow-up reminders make to increasing the statistical validity of the resulting sample. Further, the paper explores the extent to which non-response bias may be ameliorated by supplementary face-to-face interviews of non-responding households

The Victorian Activity and Travel Survey (VATS)

VATS is a household-based, year-round survey. It seeks information on travel and out-of-home activities from all members of selected households using a mail-out, mail back self-administered questionnaire, which is made up of two forms. The first form is a Household and Person Form, containing questions on household characteristics (such as vehicle ownership and dwelling type), and individual socio-demographic characteristics. The second form is a Travel Form designed to capture all information pertaining to travel stops made outside the home.

The survey area covers all the 31 Local Government Areas within the Melbourne Metropolitan Statistical District. The annual gross sample for the initial years of the survey was 10,950 addressees (or 30 per day). Since July 1998, the daily sample has been increased to 45 addressees, which sums to 16,425 per year.

The survey process comprises six distinct stages: a pre-contact, first mailing and four reminders. The pre-contact is made a week prior to the mailing of the survey questionnaire. The selected addressees are sent a pre-contact letter together with an information brochure notifying them that they have been randomly selected to participate in the survey. The first mailing consists of the survey questionnaire, (comprising the Household and Person Form and six Travel Forms), together with a completed example of a Travel Form, a covering letter and a postage-paid return envelope. A week after the initial mail-out, the first reminder is sent, in the form of a post-card, thanking respondents who have already returned the survey forms and reminding those who have not. A new travel date is assigned to addressees who still have not filled out the forms. The travel day (ie, day of the week), however, remains unchanged. Following that, the second, third and final reminders are issued at weekly intervals. At the time of the third reminder, a full set of survey forms, similar to the package issued during the first mailing, is sent with the reminding letter. In all of these reminders, a new travel date is assigned to all addressees who have not responded.

In addition to the self-administered postal survey, a "non-response" interview is conducted on a selected sub-sample. This sub-sample is a 5% random sample of the original sample. Addresses comprising this sub-sample are tagged and the occupants are contacted for a face-to-face home-interview if they fail to respond after the fourth reminder. Except for cases found to be genuine non-respondents (e.g., invalid addresses), a total of five attempts are made to get in touch with each non-responding, tagged addressee to obtain an interview.

Discounting sample loss, the response rate of VATS averages between 40% and 45% for the past four years. In VAIS, all questionnaires returned, either fully or partially

completed, will be counted as valid responses. As part of the quality assurance process, a follow-up phone-edit is conducted on all incomplete or "questionable" responses where a phone number is supplied by the household. When a phone number is not provided, an office edit is attempted by two trained administrators. On average, almost 95% of the responding households provide a phone number. The extent of item non-response or missing value items is examined later in the paper.

VATS is now in its sixth year of operation. Four years of VAIS data have been released to date: VAIS94, VAIS95, VAIS96 and VATS97. The analyses contained in this study are derived from the four VATS databases currently available.

Response patterns by household type

By grouping the VATS respondents according to their family type, the proportion of each type in the database may then be compared with that of the total population. Table 1 presents the results of this comparison. It is clear that the four VAIS databases consistently contain a disproportionately larger share of couple families without children, but a lower share of one parent families and couple families with children. VATS94, VATS95 and VATS96 are also underrepresented in the proportion of extended families and group households, but are over-represented in the category of 'Other Family'. By contrast, VATS97 has a higher portion of the first two family types but a slightly lower share of the 'Other Family' type. Lone person households are the only group reflecting the expected population share in VATS94 and VATS95. This family type, however, is also underrepresented in VATS96 and VATS97.

Table 1 Distribution of VATS households by family type

(source: 1. CDAIA91 and CDAIA96; 2. compiled from VAIS94, VAIS95, VAIS96 and VATS97; and 3. figures estimated based on trends exhibited by 1991 and 1996 Census)

	Family Type							Total
	One parent family	Couple family without children	Couple family with children	Extended family	Group household	Lone person household	Other family	
1991 Pop Census ¹	9.3%	21.4%	42.1%	1.6%	4.8%	19.9%	0.9%	100.0%
Estimated 94 pop ³	9.6%	21.9%	39.7%	1.1%	4.6%	21.5%	1.6%	100.0%
VATS94 ²	8.2%	23.7%	38.5%	0.9%	3.7%	21.8%	3.2%	100.0%
Estimated 95 pop ³	9.7%	22.1%	38.9%	1.2%	4.5%	22.0%	1.6%	100.0%
VATS95 ²	8.4%	24.7%	37.5%	1.0%	3.9%	22.0%	2.6%	100.0%
1996 Pop Census ¹	9.8%	22.2%	38.1%	1.3%	4.4%	22.6%	1.6%	100.0%
VATS96 ²	8.0%	25.5%	36.1%	1.3%	3.8%	22.1%	3.1%	100.0%
Estimated 97 pop ³	10.0%	22.4%	37.3%	1.4%	4.3%	23.1%	1.6%	100.0%
VATS97 ²	8.8%	25.3%	36.2%	1.9%	5.1%	21.4%	1.3%	100.0%

Note: All the four family type profiles derived from the respective VATS databases are statistically different from their corresponding population distribution at $\alpha = 0.05$

It has long been established that the travel patterns of households with children, especially women, are among the most intricate, characterised by a high level of interpersonal linkages and coupling constraints (see for example Jones *et al* 1983; Wigan and Morris 1981; Morris and Richardson 1995; 1996; Rosenbloom and Burns 1993; Rosenbloom 1994). The response patterns (by family type) exemplified by the four years of VATS data, as such, pose little surprise. They evidently confirm the suspicion that travel surveys requesting a large amount of information are less likely to enlist the participation of families with children.

The role of follow-up reminders and non-response interview

Follow-up mailings of reminders have traditionally been seen as an effective way of reducing non-response bias and increasing response rate. It is important, therefore, to examine how the four postal reminders, as well as the non-response interviews, in VATS have contributed to these two aspects. Table 2 displays the distribution of family types by their survey response time. Almost without exception, couple families without children and lone person families are considerably over-represented among the first wave of respondents (ie, those returning their responses within the first week) in all four sets of VATS data examined. However, such an over-representation seems to be progressively eroded with the inclusion of the later responses generated by follow-up reminders. Typically the groups who are slower to respond are single parent families, couple families with children, extended families, group households and 'Other Family' types. The same situation is observed with non-response interviews, which also see a comparatively higher share of families with children.

Although the VATS data has an over-representation of families without children, Table 2 clearly suggests that, without the follow-up postal reminders, this disparity would be even greater. This is fully borne out by the results of a comparative analysis between the distribution of family types in VATS and in the population. In Table 3, both the total absolute deviation and the maximum deviation between the proportion of each family type in the VATS databases and in the population are computed as successive waves of responses are added to the data. Both the indicators show a monotonically declining trend as successive waves of responses are included. This strongly suggests that the additional households recruited from the follow-up reminders help to bring the representation of family types in the VATS sample closer to the population data. Among the seven family types, it is also observed that as more data are included in the datafiles, the absolute deviation tends to decrease. One of the few exceptions is the 'Other Family' type, which consistently depicts an increasing deviation trend for the four years, although this is a relatively small group overall. Similarly for VATS97, the pattern of deviation for extended families, the group and lone person households increases over the course of the response period, but the magnitudes are comparatively small. Notwithstanding the case of the 'Other Family', which contains a mix of family types, the follow-up mailing of survey reminders would seem to have the effect of reducing bias in the data. They appear to be especially effective in inducing families with children to respond to the survey.

Table 2 Distribution of VATS households by family type and response wave
(source: VATS94, VATS95, VATS96 and VATS97 databases)

Response Wave	Family Type							Total No. of Households
	One parent family	Couple family without children	Couple family with children	Extended family	Group household	Lone person household	Other family	
V Within 1 week	7.5%	27.5%	34.7%	0.7%	3.0%	24.1%	2.6%	3,534
A Between 1 and 2 weeks	7.2%	22.0%	41.9%	1.0%	3.2%	21.5%	3.2%	1,649
I Between 2 and 3 weeks	8.2%	21.0%	42.3%	1.5%	4.4%	19.0%	3.6%	610
S Between 3 and 4 weeks	11.1%	19.9%	41.7%	1.5%	4.3%	18.0%	3.6%	785
9 After 4 weeks	9.3%	16.7%	42.6%	1.6%	7.6%	18.2%	4.1%	516
4 Non-response interview	14.1%	13.0%	41.8%	0.0%	7.6%	15.2%	8.2%	184
Group Total	8.2%	23.7%	38.5%	0.9%	3.7%	21.8%	3.2%	7,278
V Within 1 week	6.8%	28.1%	35.1%	0.8%	2.7%	24.5%	1.9%	2,260
A Between 1 and 2 weeks	8.5%	24.2%	38.5%	0.7%	4.6%	21.1%	2.4%	1,116
I Between 2 and 3 weeks	8.5%	21.5%	38.6%	1.4%	4.6%	21.0%	4.4%	433
S Between 3 and 4 weeks	12.9%	20.8%	39.8%	1.3%	3.9%	17.6%	3.6%	533
9 After 4 weeks	10.2%	16.8%	42.9%	1.2%	6.6%	19.0%	3.3%	422
5 Non-response interview	12.8%	17.9%	38.5%	3.8%	9.0%	16.7%	1.3%	78
Group Total	8.4%	24.7%	37.5%	1.0%	3.9%	22.0%	2.6%	4,342
V Within 1 week	7.3%	27.5%	31.7%	1.5%	2.7%	26.6%	2.7%	2,142
A Between 1 and 2 weeks	8.5%	25.2%	37.9%	0.8%	4.8%	19.8%	3.0%	1,242
I Between 2 and 3 weeks	8.7%	22.9%	42.0%	1.1%	4.8%	16.7%	3.9%	462
S Between 3 and 4 weeks	8.8%	24.7%	39.2%	1.5%	3.1%	19.9%	2.9%	523
9 After 4 weeks	8.1%	20.6%	43.4%	1.9%	6.8%	14.9%	4.3%	369
6 Non-response interview	11.8%	19.7%	36.8%	1.3%	6.6%	15.8%	7.9%	76
Group Total	8.0%	25.5%	36.1%	1.3%	3.8%	22.1%	3.1%	4,814
V Within 1 week	7.0%	28.9%	33.9%	1.5%	3.9%	23.5%	1.4%	1,976
A Between 1 and 2 weeks	10.2%	23.5%	35.9%	1.9%	5.6%	21.6%	1.3%	1,259
I Between 2 and 3 weeks	10.7%	23.0%	39.5%	2.3%	5.7%	18.2%	0.6%	488
S Between 3 and 4 weeks	9.0%	23.2%	39.8%	2.0%	4.8%	20.0%	1.2%	500
9 After 4 weeks	9.1%	19.1%	40.6%	3.4%	9.4%	16.6%	1.9%	320
7 Non-response interview	17.9%	17.9%	40.3%	3.0%	9.0%	10.4%	1.5%	67
Group Total	8.8%	25.3%	36.2%	1.9%	5.1%	21.4%	1.3%	4,610

The VATS experience indicates that about 43% to 50% of the respondents to the mail-out survey (ie, excluding the non-response interviewees) would return their questionnaire within one week of mailing (Figure 1). This means that if no reminders were sent and no non-response interviews were carried out, the response rate would be at most 20%. The first follow-up postal reminder seems to be the most effective, contributing to about 25% of the mail-back responses. Effectively, the first reminder increases the response rate (based on the returns from the first wave) by about 50%. This suggests that if only one reminder was sent, then the final response rate would be about 30% to 32%. As the elapsed time from the first mailing lengthens, the tendency to respond decreases almost exponentially. The second reminder only manages to generate about 9% to 10% of responses. While the second reminder does not seem to have much effect, the third reminder, which is accompanied by a fresh set of questionnaires, appears to reverse the declining trend. However, the effect is only marginally better than the second reminder. The response to the final reminder is the lowest, contributing to only about 7% to 8% of the total responses.

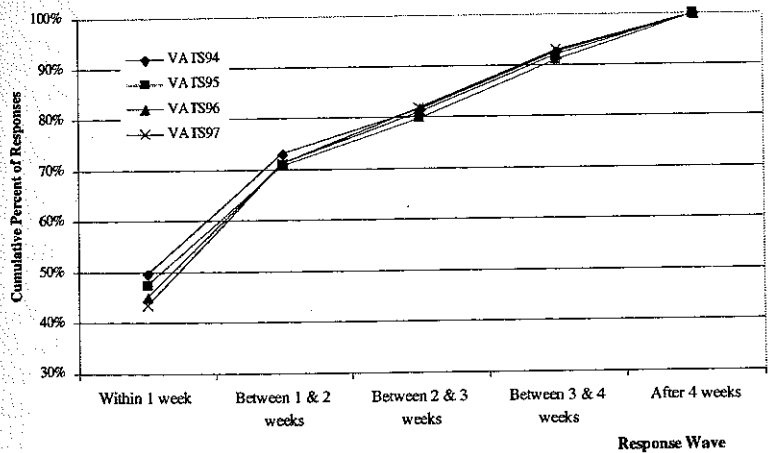


Figure 1. Cumulative responses by response wave

Non-response interviews are conducted among a small subset of the sample, focussing only on tagged addressees that do not respond to the mail survey. As such the objective of non-response interviews is not so much to increase the overall response rate, but rather to reduce non-response bias. This is achieved by recruiting more of the types of families that are less likely to respond to the mail survey. As discussed earlier, the value of these home interviews in fulfilling such a role has been amply demonstrated by increasing the participation rate of families with children, thus minimising the differences between the VATS and population data.

Table 3 Absolute deviation of VATS households from population estimates by cumulative response waves (source: computed from VATS94, VATS95, VATS96 and VATS97 and inferred trends from 1991 and 1996 Population Census)

Response Wave	Family Type							Total Absolute Deviation from Pan Figures	Max Absolute Deviation from Pop Figures
	One parent family	Couple family without children	Couple family with children	Extended Families	Group household	Lone person household	Other family		
V Wave 1	2.1%	5.6%	5.0%	0.5%	1.6%	2.6%	1.0%	18.3%	5.6%
A Waves 1 & 2	2.2%	3.8%	2.7%	0.4%	1.5%	1.8%	1.2%	13.6%	3.8%
I Waves 1 to 3	2.1%	3.3%	2.1%	0.3%	1.4%	1.3%	1.3%	11.9%	3.3%
S Waves 1 to 4	1.7%	2.7%	1.6%	0.2%	1.2%	0.7%	1.4%	9.6%	2.7%
9 Waves 1 to 5	1.6%	2.1%	1.3%	0.2%	0.9%	0.4%	1.4%	8.0%	2.1%
4 Waves 1 to 6	1.4%	1.8%	1.2%	0.2%	0.8%	0.3%	1.6%	7.4%	1.8%
V Wave 1	3.0%	6.0%	3.7%	0.4%	1.8%	2.5%	0.4%	17.8%	6.0%
A Waves 1 & 2	2.4%	4.8%	2.6%	0.4%	1.2%	1.3%	0.5%	13.2%	4.8%
I Waves 1 to 3	2.2%	4.2%	2.4%	0.4%	1.0%	1.1%	0.8%	12.0%	4.2%
S Waves 1 to 4	1.6%	3.5%	2.0%	0.3%	1.0%	0.4%	0.9%	9.6%	3.5%
9 Waves 1 to 5	1.4%	2.7%	1.4%	0.3%	0.7%	0.1%	1.0%	7.6%	2.7%
5 Waves 1 to 6	1.3%	2.6%	1.4%	0.3%	0.6%	0.0%	1.0%	7.2%	2.6%
V Wave 1	2.6%	5.3%	6.3%	0.2%	1.7%	4.0%	1.1%	21.2%	6.3%
A Waves 1 & 2	2.1%	4.5%	4.1%	0.1%	1.0%	1.5%	1.2%	14.4%	4.5%
I Waves 1 to 3	2.0%	4.0%	3.1%	0.1%	0.8%	0.6%	1.4%	12.0%	4.0%
S Waves 1 to 4	1.9%	3.8%	2.6%	0.1%	0.9%	0.2%	1.4%	10.8%	3.8%
9 Waves 1 to 5	1.9%	3.4%	2.0%	0.0%	0.6%	0.4%	1.5%	9.8%	3.4%
6 Waves 1 to 6	1.8%	3.3%	2.0%	0.0%	0.6%	0.5%	1.5%	9.7%	3.3%
V Wave 1	3.0%	6.5%	3.4%	0.0%	0.4%	0.3%	0.2%	13.9%	6.5%
A Waves 1 & 2	1.7%	4.4%	2.6%	0.2%	0.2%	0.4%	0.2%	9.8%	4.4%
I Waves 1 to 3	1.4%	3.9%	1.9%	0.3%	0.4%	1.0%	0.3%	9.3%	3.9%
S Waves 1 to 4	1.3%	3.6%	1.4%	0.3%	0.4%	1.2%	0.3%	8.6%	3.6%
9 Waves 1 to 5	1.3%	3.1%	1.1%	0.4%	0.7%	1.6%	0.3%	8.5%	3.1%
7 Waves 1 to 6	1.2%	3.0%	1.0%	0.5%	0.8%	1.8%	0.3%	8.5%	3.0%

Since the candidates selected for non-response interviews have previously ignored the postal questionnaire and all subsequent reminders, it may be interpreted that these families have little intention of participating in the survey. However, with the assistance of an interviewer, a proportion of these households complete the forms, recording many complex linked trips in a travel log – despite having chosen to disregard earlier appeals. Lastly, since the non-response interview is conducted face-to-face at home, it is generally believed that these interviews generate more reliable responses than mail surveys. This point is examined in the next section.

Travel characteristics of family types by response wave

It is important to establish whether the over-representation of families without children in the VATS sample causes some distortion of the travel profile of the population and whether the follow-up reminders help to minimise such bias if it exists. This section will examine the trip characteristics of different family types by the elapsed time of response to the survey. Table 4 provides the mean daily stop rates per person by family type and response wave for the four VATS databases. (In VATS, a stop is distinguished from a trip. In cases where stops involve a change of travel mode, these are regarded as part of a trip. All other stops which do not involve a mode change, however, are also regarded as trips. For the purpose of this paper, stops and trips are used synonymously.) Ignoring the effect of family type, there is a clear indication of declining stop rates with increasing elapsed time between the first mail-out and survey response. The trend is especially prominent among one-parent families and couple families with children. Even among couple families without children, the tendency of lower reported stop rates among late respondents persists. The declining trend of lower reported stop rates, however, is less conspicuous in the case of the extended families, group households, lone person households and other families. As for the non-response interviews, the figures obtained reveal an overall profile that goes against the declining trend. In most instances, the stop rates recorded among non-response interviewees either revert to or are higher than those of the first wave responses.

Viewed from the perspective of family type, individuals from group households and lone person households display the highest number of stops. They are followed by those in extended families and couple families with children. Members of couple families without children tend to make fewer daily stops overall. The pattern remains relatively stable for all waves of responses and across all four years of data. A two-way ANOVA test on the main and interaction effects of response wave and family type on stop rates shows that both the main effects are statistically significant at $\alpha = 0.05$. The interaction effect, however, is insignificant. These results point to the existence of a systematic reporting pattern endemic to both response time and family type.

One of the reasons for lower reported stop rates among late respondents is that a relatively larger proportion of these respondents report that they do not make any out-of-home stops on the assigned travel day (Table 5). This pattern of a rising share of non-travelling individuals with increasing response time is statistically significant both from the perspectives of family types as well as response wave (ie, categories of response time), but not the interaction between them.

Table 4 Stop rates per day per person by family type and response wave
(source: computed from VATS94, VATS95, VATS96 and VATS97 databases)

Response Wave	Family Type							TOTAL
	One parent family	Couple family without children	Couple family with children	Extended family	Group household	Lone person household	Other family	
V Within 1 week	4.6	3.8	4.3	4.4	4.9	4.4	3.6	4.2
A Between 1 and 2 weeks	3.5	3.4	3.6	2.7	3.9	3.7	3.8	3.6
I Between 2 and 3 weeks	3.2	3.4	3.6	4.7	4.5	3.2	4.0	3.6
S Between 3 and 4 weeks	2.5	3.1	2.8	4.3	3.8	3.6	3.1	2.9
9 After 4 weeks	3.2	3.3	2.9	3.8	4.1	3.0	3.3	3.1
4 Non-response interview	4.7	5.3	4.2	ND	4.4	4.6	5.0	4.4
Group Total	3.8	3.6	3.8	3.9	4.4	4.0	3.7	3.8
V Within 1 week	4.4	4.0	4.6	4.7	5.9	4.7	3.1	4.4
A Between 1 and 2 weeks	4.0	3.4	4.1	4.2	5.7	4.1	4.6	4.0
I Between 2 and 3 weeks	2.9	3.8	3.6	3.9	3.7	4.8	2.3	3.6
S Between 3 and 4 weeks	3.7	3.1	3.1	1.5	4.9	4.1	3.0	3.3
9 After 4 weeks	2.9	3.3	3.2	6.0	4.6	2.6	2.4	3.2
5 Non-response interview	4.2	2.4	4.8	4.5	4.0	4.4	5.2	4.3
Group Total	3.9	3.7	4.1	4.1	5.2	4.4	3.2	4.0
V Within 1 week	4.6	4.2	4.3	4.0	5.0	4.3	4.5	4.3
A Between 1 and 2 weeks	3.4	3.8	3.9	4.1	5.2	3.7	4.0	3.9
I Between 2 and 3 weeks	3.6	3.7	3.4	2.4	5.9	3.8	4.0	3.6
S Between 3 and 4 weeks	3.1	2.9	3.2	4.4	4.5	4.2	2.4	3.2
9 After 4 weeks	3.4	3.1	3.1	3.9	4.7	4.5	3.5	3.3
6 Non-response interview	3.7	4.9	5.1	2.0	5.4	5.2	4.8	4.8
Group Total	3.8	3.9	3.8	3.9	5.1	4.2	4.0	3.9
V Within 1 week	4.1	3.9	4.4	4.7	4.9	4.6	4.2	4.3
A Between 1 and 2 weeks	3.7	3.7	4.0	2.9	4.3	3.8	3.6	3.9
I Between 2 and 3 weeks	3.8	4.0	3.7	5.7	4.1	3.8	2.0	3.8
S Between 3 and 4 weeks	3.0	4.0	3.1	2.3	5.1	4.1	4.0	3.4
9 After 4 weeks	3.3	3.9	3.4	4.5	5.0	4.1	5.3	3.7
7 Non-response interview	3.4	4.3	3.5	2.6	6.7	6.4	2.0	3.9
Group Total	3.7	3.8	4.0	4.0	4.7	4.2	4.0	4.0

Note: A two-way ANOVA test using family type and response wave as factors shown that both the main effects are statistically significant at $\alpha = 0.05$, but the interaction effect is not.

ND = no data.

Among the different family types, those with children seem to be most distinctive. From a share of 16% to 20% of non-travelling individuals during the first wave, the proportion of non-travelling members among single parent families climbs to over 30 percent by the third and fourth waves. Likewise, the proportion of non-travelling household members also jumps from no more than 15% during the first wave to more than 25% in subsequent waves. The trend, again, is not sustained among non-response interviewees. The proportion of non-travelling persons in most family types from non-response interview falls back to the level of the first response wave.

Such a systematic and consistent rise in the proportion of non-travelling persons in subsequent response waves, which is only reversed by the non-response interviews, may be interpreted in two different ways. The first is that more of the late respondents actually did not travel out-of-home on the assigned travel day. This situation would help to simplify the response process to VAIS, increasing the likelihood of response by families with children, which are supposed to have highly complex travel patterns. If this is true, then the sample obtained is actually biased, in the sense that it is skewed toward families with more non-travelling individuals. The second conjecture is that late respondents reported less trips or claimed they make no out-of-home stops on the assigned travel day than they actually did. If this is case, then the reliability of the data is suspect. In short, either interpretation (or their combination) would lead to the inference that the data provided by respondents in waves subsequent to the first are statistically problematic. Between the two interpretations, however, it is believed that the latter is more sustainable, since the declining trend of stop rates is not supported by the results of the non-response interviews.

Not only do late respondents appear to report fewer stops, they also seem to have an inclination toward making longer trips, as Table 6 reveals. Disregarding the effect of family type, average stop distance tends to increase as the elapsed time lengthens between first mailing and survey response. The average stop distance is about 10% to 12% longer among late respondents in most instances. Taking into account the effect of family type, however, the trend becomes less evident.

As for the non-response interview, the general finding is that the average stop distance recorded for individuals in this response category does not seem to follow any set pattern. The lack of consistency in this case may be attributed to the small sample size obtained for each of the seven family types, since a tagged household would not be contacted for interview unless it fails to respond after the fourth reminder. Moreover, the success rate of the non-response interview has been rather low (30%-35% on average), making meaningful representation of certain household types difficult. Because of the lack of a consistent trend in increasing travel distance between successive waves of responses, a two-way ANOVA test on the effects of response wave and family type (and their interaction) on travel distance shows that none of the effects are statistically significant.

Table 5 Percent of VATS respondents reporting no trips on assigned travel day by response wave (source: computed from VATS94, VATS95, VATS96 and VATS97 databases)

Response Wave	Family Type							All Family Types
	One parent family	Couple family without children	Couple family with children	Extended family	Group household	Lone person household	Other family	
V Within 1 week	16.0%	24.8%	15.0%	20.7%	14.5%	23.6%	24.5%	18.3%
A Between 1 and 2 weeks	24.5%	26.7%	19.7%	38.9%	23.7%	29.4%	24.7%	22.4%
I Between 2 and 3 weeks	35.2%	24.8%	23.5%	18.5%	20.6%	40.4%	31.0%	25.8%
S Between 3 and 4 weeks	36.2%	28.6%	27.6%	11.1%	20.0%	28.3%	25.3%	28.2%
9 After 4 weeks	30.1%	30.1%	28.1%	17.6%	24.2%	33.7%	32.9%	28.7%
4 Non-response interview	14.6%	16.7%	14.0%	0.0%	21.3%	17.5%	7.3%	14.7%
Group Total	23.6%	25.6%	19.4%	24.0%	19.4%	26.9%	25.4%	21.7%
V Within 1 week	18.9%	21.3%	13.6%	28.0%	9.2%	19.1%	31.7%	16.7%
A Between 1 and 2 weeks	19.4%	28.5%	15.7%	20.0%	12.1%	21.7%	16.2%	18.7%
I Between 2 and 3 weeks	27.3%	23.1%	24.0%	23.5%	25.0%	22.7%	35.6%	24.7%
S Between 3 and 4 weeks	21.4%	32.0%	21.0%	47.6%	19.0%	29.8%	32.7%	24.0%
9 After 4 weeks	31.3%	24.6%	23.4%	9.1%	15.2%	37.2%	51.6%	25.4%
5 Non-response interview	17.1%	28.1%	17.2%	42.9%	23.8%	22.2%	14.3%	19.9%
Group Total	21.4%	24.4%	17.0%	28.6%	14.5%	22.3%	30.7%	19.6%
V Within 1 week	16.2%	19.6%	13.8%	21.8%	19.0%	23.2%	26.1%	17.0%
A Between 1 and 2 weeks	23.8%	20.9%	20.7%	12.0%	9.9%	31.7%	26.4%	21.5%
I Between 2 and 3 weeks	20.6%	26.7%	22.7%	33.3%	18.5%	19.7%	28.1%	23.1%
S Between 3 and 4 weeks	23.0%	32.2%	24.9%	16.7%	16.7%	27.9%	39.6%	26.4%
9 After 4 weeks	20.7%	33.6%	25.2%	31.8%	17.9%	25.9%	37.3%	26.2%
6 Non-response interview	19.4%	26.3%	8.7%	50.0%	0.0%	14.3%	11.5%	13.3%
Group Total	20.1%	22.8%	18.9%	22.1%	15.2%	25.4%	28.2%	20.6%
V Within 1 week	20.3%	22.3%	13.3%	11.5%	16.9%	16.6%	26.6%	16.5%
A Between 1 and 2 weeks	20.5%	25.0%	16.9%	27.1%	16.8%	24.6%	39.0%	19.8%
I Between 2 and 3 weeks	25.4%	21.0%	22.3%	3.2%	21.8%	29.2%	28.6%	22.4%
S Between 3 and 4 weeks	21.9%	21.6%	26.5%	32.4%	10.0%	22.0%	32.0%	24.4%
9 After 4 weeks	29.5%	26.2%	20.8%	21.2%	18.8%	22.6%	30.8%	22.5%
7 Non-response interview	22.9%	12.5%	29.8%	0.0%	31.6%	0.0%	0.0%	24.8%
Group Total	21.9%	22.9%	17.8%	18.2%	17.5%	20.7%	30.9%	19.6%

Note: A two-way ANOVA test using family type and response wave as factors shown that both the main effects are statistically significant at $\alpha = 0.05$, but the interaction effect is not

ND = no data.

A fairly similar trend is observed for stop travel time. Again, ignoring the effect of family type, mean stop travel time is also observed to increase as the time gap between first mailing and survey response widens (Table 7). In this case, the increase is less than 10% for most instances. Similar to the situation of average stop distance, when the effect of family type is considered, the increase, too, becomes less clear-cut. As such, the results of the two-way ANOVA conducted for mean stop travel time using family type and response wave as fixed factors also found all three effects to be statistically insignificant.

Just like the case of the average stop distance, the mean stop travel time for the non-response interview respondents also depicts no particular pattern across the four years. Again, the small sample size may be an explanatory factor.

Data quality by response wave

The earlier sections have demonstrated that follow-up reminders have the ability to substantially increase response rate. They have also revealed that the quality of the data generated from subsequent response waves may not be as complete as those obtained from the first wave responses, especially in terms of recording the number of stops made. This section will further compare the quality of the survey data by examining the extent of missing values in a selected set of 12 key household and travel variables.

The analysis of missing values is displayed in Table 8. Based on the extent of missing data in the selected household and travel variables, the results of the analysis clearly indicate that the level of missing information increases with the time taken by the household to respond. Using both mean and median percent (of missing value data) as indicators, the extent of missing information embedded in the data derived from subsequent waves can be as high as more than twice the level found in the first wave. The standard deviation and maximum percent value also suggest that data from subsequent responses in mail survey also tend to have a larger spread of missing information among the variables chosen. This observation is equally applicable to responses obtained from non-response face-to-face interviews.

A two-way ANOVA conducted to test the effects of response wave and variable type on the proportion of missing values in the selected variables shows that the main effect of both factors is statistically significant. The interaction effect between the two factors, however, is not. This finding shows that the percentage share of missing values inherent in a particular variable and for a specific response wave is not unique to the joint effect of the two. Rather, it is the outcome of their individual influence. It thus confirms a relationship of declining data reliability with increasing response time.

Table 6 Average daily stop distance (km) per person by family type and response wave (source: computed from VAIS94, VAIS95, VAIS96 and VAIS97 databases)

Response Wave	Family Type							Group Total
	One parent family	Couple family without children	Couple family with children	Extended family	Group household	Lone person household	Other family	
V Within 1 week	5.5	7.1	7.1	4.9	7.9	5.4	7.4	6.8
A Between 1 and 2 weeks	7.3	9.6	7.4	6.1	7.4	6.3	6.9	7.6
I Between 2 and 3 weeks	5.3	8.3	8.0	5.6	7.3	7.6	6.2	7.7
S Between 3 and 4 weeks	8.4	9.2	8.2	12.1	4.9	8.7	6.7	8.3
9 After 4 weeks	4.7	7.0	7.7	6.2	6.1	8.1	11.3	7.4
4 Non-response interview	8.4	7.1	6.4	ND	3.1	8.0	6.8	6.7
Group Total	6.3	7.9	7.4	6.6	6.9	6.2	7.4	7.3
V Within 1 week	7.3	8.9	7.9	6.6	6.7	7.6	8.0	8.0
A Between 1 and 2 weeks	11.9	8.7	8.9	19.5	5.1	9.6	7.1	9.0
I Between 2 and 3 weeks	6.6	9.2	10.4	2.8	8.8	8.4	14.3	9.7
S Between 3 and 4 weeks	5.2	9.9	8.1	7.2	5.5	6.3	7.2	7.7
9 After 4 weeks	9.9	9.3	9.2	9.3	19.3	9.8	14.9	10.1
5 Non-response interview	8.6	9.9	8.7	14.0	10.6	6.1	10.7	8.9
Group Total	8.2	9.0	8.5	9.1	8.2	8.1	9.0	8.5
V Within 1 week	6.5	8.8	7.6	8.2	7.2	6.1	6.4	7.6
A Between 1 and 2 weeks	6.9	9.5	9.5	9.9	8.0	6.6	7.6	9.0
I Between 2 and 3 weeks	12.1	10.3	8.5	15.0	6.2	8.2	13.6	9.2
S Between 3 and 4 weeks	7.2	8.7	8.3	9.7	13.2	7.3	6.6	8.3
9 After 4 weeks	6.8	8.0	7.5	5.4	8.1	8.6	6.1	7.5
6 Non-response interview	4.0	10.5	5.8	6.8	6.7	5.2	8.3	6.4
Group Total	7.3	9.1	8.2	8.7	7.9	6.6	7.8	8.2
V Within 1 week	7.1	7.7	8.7	6.7	7.2	6.3	8.5	8.1
A Between 1 and 2 weeks	9.5	11.1	9.2	6.8	8.4	7.8	6.7	9.3
I Between 2 and 3 weeks	6.4	10.8	8.5	9.4	7.3	6.9	6.9	8.5
S Between 3 and 4 weeks	15.2	8.4	8.8	6.7	5.9	8.4	8.1	9.2
9 After 4 weeks	5.3	9.3	8.5	8.1	5.9	8.1	3.0	8.0
7 Non-response interview	9.1	8.9	7.0	8.6	7.0	9.2	1.5	7.7
Group Total	8.7	9.0	8.8	7.3	7.3	7.1	7.3	8.6

Note: A two-way ANOVA test using family type and response wave as factors shown that both the main effects and interaction effect are statistically insignificant at $\alpha = 0.05$.

ND = no data

Table 7 Average daily travel time (minutes) per stop per person by family type and response wave (source: computed from VATS94, VATS95, VATS96 and VATS97 databases)

Response Wave	Family Type							Group Total
	One parent family	Couple family without children	Couple family with children	Extended family	Group household	Lone person household	Other family	
V Within 1 week	16.0	18.8	17.5	16.5	18.8	16.3	19.1	17.6
A Between 1 and 2 weeks	20.2	23.0	17.8	25.4	21.7	18.8	18.5	19.0
T Between 2 and 3 weeks	14.7	18.2	19.0	19.0	17.7	20.7	18.1	18.6
S Between 3 and 4 weeks	19.6	22.2	20.2	22.7	15.8	21.2	18.0	20.3
9 After 4 weeks	15.3	20.0	20.3	16.5	17.9	22.3	22.3	19.8
4 Non-response interview	19.3	16.7	15.9	ND	42.8	23.5	16.7	18.9
Group Total	17.3	19.9	18.1	20.1	20.4	18.0	18.9	18.5
V Within 1 week	16.5	18.8	16.9	15.3	19.8	18.8	18.2	17.5
A Between 1 and 2 weeks	20.0	18.7	18.6	25.8	18.4	20.3	17.9	18.9
T Between 2 and 3 weeks	17.6	20.2	19.4	12.9	21.2	18.6	26.5	19.6
S Between 3 and 4 weeks	15.0	21.2	18.2	13.8	15.3	17.5	17.1	17.9
9 After 4 weeks	21.7	23.6	17.9	19.1	29.7	20.3	23.4	19.9
5 Non-response interview	20.4	15.4	17.4	28.1	19.6	15.5	17.8	17.7
Group Total	17.7	19.3	17.8	17.6	20.3	19.0	19.5	18.3
V Within 1 week	15.2	18.8	16.6	19.6	17.8	15.9	16.8	17.0
A Between 1 and 2 weeks	17.7	19.1	18.0	21.4	19.5	17.4	17.0	18.2
T Between 2 and 3 weeks	21.2	19.6	17.4	33.6	18.5	18.5	23.8	18.6
S Between 3 and 4 weeks	16.4	17.7	17.8	22.7	25.1	19.6	17.8	18.1
9 After 4 weeks	24.2	19.0	17.5	17.0	16.4	18.4	18.9	18.3
6 Non-response interview	11.1	18.2	14.5	17.5	16.4	15.2	13.8	14.6
Group Total	17.3	18.8	17.2	20.7	18.9	16.9	17.9	17.6
V Within 1 week	17.8	20.4	17.7	16.8	19.7	17.5	20.0	18.4
A Between 1 and 2 weeks	20.2	20.4	19.2	19.8	19.6	18.7	13.9	19.5
T Between 2 and 3 weeks	16.6	28.1	18.2	22.4	17.0	16.0	16.3	19.6
S Between 3 and 4 weeks	27.8	17.3	20.5	19.0	16.1	20.9	14.1	20.4
9 After 4 weeks	15.5	19.7	18.6	17.7	14.4	18.7	27.5	18.2
7 Non-response interview	18.3	13.8	15.7	23.2	17.2	14.7	10.0	16.2
Group Total	19.6	20.8	18.5	18.7	18.3	18.1	17.9	19.0

Note: A two-way ANOVA test using family type and response wave as factors shown that both the main effects and interaction effect are statistically insignificant at $\alpha = 0.05$.

ND = no data.

From the perspective of both the mean and median percent of missing values, it evidently suggests that late postal responses are less complete than early responses. However, it must be pointed out that the sample sizes of later waves of responses, which form the bases of the respective percentage calculation, are significantly smaller than that of the first wave, as evident from Table 8. Pooling four years of data together, responses returned within one week are one and three-quarter times to over six times more than those coming in after one week. In comparison, the differences in mean and median percent of missing data between the first and subsequent response waves are not as great. This implies that, in percentage terms, the extent of missing data among subsequent waves of postal responses may have been over-exaggerated.

This rationalisation is evidently valid in the case of the non-response interview, which only has a fraction of the sample size of the first response wave. Another reason explaining the proportionately higher percentage of missing data in non-response interviews may be due to the very nature of a face-to-face interview itself. The presence of a "stranger" at home may create an awkward or embarrassing situation which prevents the disclosure of information that is "sensitive" (such as income) or "private" (such as stop purpose or destination). A third reason for the comparatively larger percentage of missing information among non-response interviewees could be attributable to the absence of a follow-up phone interview to edit the data. In VAIS over 85% of the responses returned via the mail are phone-edited when a phone number is supplied. This, however, is not done in the case of the non-response interview.

Table 8 Missing value analysis by response wave for VATS94-VATS97
(source: computed from VATS94, VATS95, VATS96 and VATS97 databases)

		Sample Size		Extent of Missing Data in Selected Variables (%)			
		No. of households	No. of stops	Mean	Standard deviation	Median	Maximum
Response Wave							
Mail Survey	Within 1 week	9,912	107,486	1.6%	1.5%	1.2%	5.8%
	Between 1 and 2 weeks	5,266	54,431	2.0%	1.7%	1.9%	6.6%
	Between 2 and 3 weeks	1,993	20,241	2.7%	2.1%	2.3%	7.6%
	Between 3 and 4 weeks	2,341	20,659	2.6%	2.0%	2.2%	7.9%
	After 4 weeks	1,627	15,044	2.7%	2.1%	2.5%	9.1%
	Non-response interview	405	5,758	2.7%	2.8%	1.6%	11.3%

Summary of findings and conclusion

Based on four years of VATS results, this study has found that follow-up reminders do play a significant role in increasing response rate and enlarging the participation rate of families with children. The first reminder, in particular, has the potential of raising the response rate by about 50% above that which would be obtained if no reminder was issued. While follow-up reminders are valuable in these respects, the quality of the data

collected during these subsequent waves does require careful evaluation. One of the most contentious issues is the tendency for late respondents to under-report their out-of-home stops. While the patterns may not be statistically significant, the VATS results do suggest that late respondents are inclined to only report major stops such as those of longer travel distance or travel time. Further, the information obtained from late postal responses also suffers from a relatively higher percentage of missing values. However, the significance of this should not be over-emphasised, given the vast differences in sample size of the respective waves of response in comparison to smaller differences in extent of missing data.

In sharp contrast, non-response interviews are considered a useful supplement to mail surveys, providing a validity check on the responses obtained from different waves. The quality of the data from non-response interviews, though variable owing to the small sample size in the VATS databases, has shown to be comparable to the responses from the first wave in most instances. The relatively small sample size targeted for non-response interviews in VATS together with the absence of subsequent phone-edits may have contributed to the finding that non-response interviews have levels of missing data that are comparable to those from late postal respondents.

The findings in this study confirm the fear that, due to the complexity of the information elicited, mail travel surveys in particular suffer from the risk of selectivity bias in the sample. Households with rather complex travel patterns, such as those with children, appear less inclined to participate in travel surveys involving the use of a travel diary. While the adoption of repeat reminders may help to rectify the problem partially, by appealing to these "less-willing" respondents to return the questionnaire, it does so at expense of data quality, in particular underreporting of trips. This finding challenges the conventional thinking "that late respondents are closer to non-respondents on a continuum of respondents to non-respondents" (Thakuriah et al. 1993, p. 70). Such a premise is supported by the argument that late respondents make fewer trips than early respondents (Brög and Meyburg 1980). Underreporting of trips may be interpreted as an example of item non-response. To the extent that such underreporting poses a more serious problem than total non-response in trip generation models (Thakuriah et al. 1993), the value of repeat reminders can be questioned. On the other hand, non-response interviews, which seem to fare better in terms of obtaining reliable information, should be given greater emphasis as an option for reducing non-response bias in self-administered, postal surveys.

Based on the experience of VATS, a reduction in follow-up reminders, say from four to three, compensated by a simultaneous increase in the proportion of households targeted for non-response interview may be a more cost-effective strategy for mail travel surveys. As a further test on the value of repeat reminders in reducing non-response bias, the TRC at RMIT is currently conducting additional studies on the cost effectiveness of repeat reminders using the four years of VATS data (Kam 1998). One of these involves a comparative analysis of the weighted travel and household information obtained from the cumulative responses of successive response waves to test the statistical validity of the resulting data on the assumption that the survey has less than four reminders.

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