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Validating Bluetooth logging as metric for shopper behaviour studies

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Abstract

The ability to track shoppers as they move through retail environments using signals emitted by their communication devices kindles the interest of practitioners and researchers. This data collection method is cheap and has the ability to supply big data for shopper insights. However, this non-probabilistic sampling method can possibly under- or over-represent certain groups of the shopper population. This study assesses the validity of the data describing the length of shopping trips and representativeness of the sample of shoppers carrying Bluetooth-enabled devices. The authors track unique Bluetooth logs in-store and compare to simultaneously collected data from a manual, systematic sample of 324 shoppers observed and interviewed in the same supermarket. A comparison of the results obtained from the two samples (auto-logging and manual systematic) drawn from the same population indicates automated Bluetooth tracking produces very similar ($r = 0.92$, $p < .001$) trip lengths to that observed manually. Basket size, spend and occupation of Bluetooth trackable shoppers are similar to those with no Bluetooth-enabled devices. These findings present compelling evidence that the Bluetooth auto-logging method holds great potential for retail practice and research. An expected under-representation of the oldest demographic (66y.o. and over) in the Bluetooth discoverable sample calls for complementary methods of data collection to minimise representation bias in real-time tracking technologies for shopper research. The benefits of using auto-logging data describing shopping trip length for retail practitioners and researchers are discussed.

Keywords:
Bluetooth tracking
Shopper behaviour
Sampling
Retailing

1. Introduction

Understanding shopper behaviour metrics, such as shopping trip length, number of items purchased, or shoppers' navigation patterns is of great interest to the retail industry due to their direct influence on retailer performance indicators. A range of methods have been employed to obtain those insights: initially surveys, then researcher observation/shadowing and video surveillance (Scamell-Katz 2012, Sorensen 2009a, Millonig and Gartner 2008, Underhill 1999). More recently, radio frequency identification (RFID) or global positing system (GPS) tags (Utsch and Liebig 2012, Hui et al. 2009) fitted to individual shoppers or shopping aids (carts, baskets) have provided insight to retailers and researchers. The increasing pervasiveness of smartphone ownership has given researchers the opportunity to track an individual's movements (Versichele et al. 2012, Stange et al. 2011, Utsch and Liebig 2012, Abedi et al. 2013) and for store owners to track the wireless local area network (WLAN) and Bluetooth signals of their customers. In 2012, 76% of the Australian population owned a smartphone, and 40% of respondents who did not own a smartphone planned to purchase one in the next 12 months (Mackay 2012) – in the US, 56% of adults own a smartphone, and 91% own a mobile phone of some kind (Smith 2013). The majority of smartphones and portable electronic devices use a number of wireless protocols for communication, including Bluetooth (Abedi et al. 2013). These new technologies can be used for real-time auto-logging and are more effective than prior methods because they do not rely on shopper participation, associated observation bias, or shopper memory – the common pitfalls of traditional research methods. Yet, very few studies have examined the trustworthiness of data collected using such technologies. In this research, the authors address this gap by pursuing two objectives: (1) to test the validity of shopping trip length data obtained through Bluetooth logging; and (2) to assess the representativeness of the sample obtained using Bluetooth auto-logging technology in a supermarket research.

A Bluetooth-enabled and discoverable device is an electronic device that has Bluetooth turned on and is actively sending or receiving wireless information. Bluetooth is a technology that enables digital devices to connect to each other wirelessly. It is designed for low power consumption and it is based on low-cost transceiver microchips (Bekkelien 2012). Each discoverable Bluetooth device transmits a unique identifier, known as a media access control (MAC) address. It can connect and communicate with other discoverable Bluetooth devices within a radius of 1m to 100m (O'Neill et al. 2006), which varies according to the power rating of the Bluetooth equipment in the devices (Haghani et al. 2010). Setting up a Bluetooth detector is fairly simple. Retailers can easily purchase a Bluetooth detecting device (beacon) available on the market to track Bluetooth activities indoors. Every time a Bluetooth device passes the detected radius of the sensor, its MAC, Bluetooth device name, and the timestamp of the detection will be recorded (Versichele et al. 2012). These sensors can generate pedestrian counts and time stamps for entry and exit. Traffic counts generated during different times or days, at different areas of a shopping mall can provide insights for shopper behaviour that retailers could not get from their sales or transaction logs. However, as this is a non-random sampling method, it may lead to biased and misleading results when used to estimate behaviours (Heckman 1979). While there has been much discussion of Bluetooth technology as a metric for monitoring pedestrian mobility (Versichele et al. 2012, Kostakos and O'Neill 2008, Millong et al. 2009, Haghani et al. 2010), there has been relatively limited attention paid to the representativeness of the samples obtained using such technology, and researchers have called for studies to

address this lacuna (Versichele et al. 2012, Utsch and Liebig 2012, Stange et al. 2011, Kostakos and O'Neill 2008).

This study aims to explore the validity of Bluetooth tracking data and the degree to which the samples obtained using automated Bluetooth tracking in shopper research represents the true shopper population in the following research questions:

- RQ1: What proportion of supermarket shoppers carry a Bluetooth *discoverable* device?
- RQ2: How ***valid*** is trip length data collected using Bluetooth?
- RQ3: How representative is the sample obtained using Bluetooth detection of supermarket shoppers in terms of ***shopper behaviours*** (shopping trip length, basket size and spend)?
- RQ4: How representative is the sample obtained using Bluetooth detection of supermarket shoppers in terms of ***demographic characteristics***?

2. Literature Review

2.1. Shopper research

Shopping trip length or time spent in-store has been coined as one of the three (along with money and angst) currencies shoppers bring to the store (Sorensen 2009a, Sorensen 2012a). Time affects decision-making through imposing (or not) restrictions on how many categories, brands and how much in-store communication the shopper is exposed to and information attended to (Park et al. 1989, Dhar and Nowlis 1999). These, in turn, influence consideration set sizes, basket sizes and, eventually, the profitability of the store. Yet, the relationship between time and money is not straightforward. While some authors note (the expected) positive correlation – longer time in-store results in more money spent (Thomas and Garland 1993) – others demonstrate that shoppers who find products quicker are more likely to buy additional items (McCann 2012) and stores where time per item purchased is shorter tend to have higher revenues (Sorensen 2009b). Furthermore, Sorensen uses the distribution of time in-store and the trip length congruity measure, to judge store efficiency. The above discussion indicates the importance of having robust measures of shopping trip length for retailing practitioners and researchers.

2.2. Bluetooth tracking

Bluetooth tracking is a versatile method, which has successfully been used to measure visit duration in a variety of settings. Over the past decade, researchers and practitioners have used Bluetooth technology in multiple applications to estimate human and vehicle traffic patterns. Researchers have matched MAC addresses detected from passing vehicles between successive points to provide a measurement of traveling time information for effective management of traffic conditions (Haghani et al. 2010). Versichele et al. (2012) and Stange et al. (2012) used Bluetooth to study pedestrian flow at outdoor public events and major festivals, such as Formula 1 races and the Ghent Festival in Belgium, which demonstrated the advantages of using Bluetooth to track mass event visitors and outlined its deficiencies. A joint Bluetooth/Wi-Fi scanning framework was introduced to

assess the popularity of locations within a university campus and the average time spent 'on-campus' (Vu et al. 2010). Millonig and Gartner (2008) and Sorensen (2009b) have used novel technologies, including Bluetooth, to study patterns of shopper movement through a store, which has enabled the confirmation of assumptions (such as basic navigation patterns and time spent in store) made by practitioners and researchers.

Prior authors acknowledge the fact that Bluetooth tracking methods produce limited and potentially biased samples (Versichele et al. 2012, Kostakos and O'Neill 2008), which raises concerns over the validity of such methods (Stange et al. 2011, Utsch and Liebig 2012). This is because the tracking procedure and conditions are highly selective. To be tracked, a person must first: carry a Bluetooth-enabled device; second, Bluetooth on the device must be turned on (enabled); and third, the device must be sending or retrieving wireless information to be detected. A person's device must satisfy all of the above criteria when passing within the radius of a sensor in order to be detected (Versichele et al. 2012). This selection bias imposes key limitations on the representativeness of the sample, as certain segments of the population may be over- or under-represented (Rice and Katz 2003). Many studies have revealed that the Bluetooth detection rate is low, as only between five to seven per cent of observed individuals are estimated to have a Bluetooth-enabled and discoverable device (Kostakos and O'Neill 2008, Millong et al. 2009).

3. Method

3.1. Sample and procedure

This study was conducted in a typical suburban supermarket in a metropolitan city in Australia. The supermarket had a typical layout (approximately 1,270 square metres) and was a part of a major retail chain. Researchers used three data collection methods in the same store, over the same period of time, to address the research questions. All three methods sample the same population. Methods one and two survey the ***same*** individuals, while method three anonymously samples the same population in terms of temporal and geographic space.

The **first method** was mall-intercept interviews (n=324) to determine the proportion of shopper population carrying a Bluetooth-enabled device (RQ1) and shopper demographic characteristics (RQ4). At the entrance[1] to the supermarket, every fifth shopper (as per systematic sampling (Zikmund et al. 2007)) was approached and invited to accept a sticker with an entry time stamp. The acceptance rate of this sticker was 78%. Shoppers were then required to return the sticker after they completed their shopping trip and participate in a five-minute interview. The compliance rate at the end of the shopping trip (number of interviews over the number of stickers accepted) was 74%. The refusal rate for accepting stickers varied slightly across genders, as male shoppers were 7% more likely to refuse stickers at the entrance compared to female shoppers. This led to fewer male shoppers in the sample compared to the general population (27% in the sample, compared to 47% in the population residing in the neighbourhood surrounding the supermarket (ABS 2011). However, gender distribution in the sample matched the generally female-skewed shopper population described by Baily (2013) (that is, only 28%

[1] Note that the supermarket has the same entry and exit point.

male). The sample recorded a slightly higher proportion of older shoppers (61% aged over 46), which was not unexpected in this study, as it was conducted in a region with an older demographic (49% of the population in the neighbourhood was over 45 y.o.) (ABS 2011). This may have also occurred due to higher refusal rates among younger and middle aged groups, where it was recorded that 60% of refusal shoppers were aged under 45 (refused shoppers' broad age category was determined by researcher observation).

During the exit interview, shoppers were asked to check their phones to determine whether or not their Bluetooth was enabled (interviewers were often required to assist shoppers in this task). Other questions in the interview included demographic characteristics and phone status (with/without phone). Respondents were offered a small incentive (a choice of a mini-size chocolate or a fruit bar) at the end of the interview to thank them for their participation.

The **second method** manually measured the shopping trip length to test the validity of the trip length data collected using Bluetooth (RQ2) and determined representativeness of the Bluetooth trackable sample (compared with shoppers who do not have Bluetooth discoverable devices) in terms of key shopper behaviour metrics (RQ3). Shopper receipt details were requested from the same interviewees surveyed in the first method (n=167) as they recorded the checkout time (used with the entrance sticker to calculate time spent in-store), total dollars spent, and the number of SKUs bought (i.e. basket size). Because some shoppers did not take their receipt at the checkout or lost in the bags of goods, this sample is smaller than the sample for the first method. Researchers compared shoppers with and without their receipts, but there were no differences in key demographic variables.

The **third method** used automated Bluetooth logging (n=141 unique trips with matched entry and exit logs) to compare with manually collected data from interviews. This is used to determine the correlation between the trip length data collected using Bluetooth with data collected manually (RQ2). With permission from the supermarket's management, a laptop with Bluetooth scanning software was installed and placed at the entrance/exit area during three consecutive days (Thursday to Saturday) in February 2014. Unique MAC addresses, time stamps and device names were recorded. These details did not provide any information that could identify a particular shopper, so there was no breach of shopper privacy. The lack of identifiable information in auto-logging data means the researchers can not verify whether the same individuals interviewed and tracked in methods one and two were also the same sample collected from Bluetooth. However, the Bluetooth sample was collected from the same shopper population in terms of the geographical (the store) and temporal (same hours and days of observation) spaces. The University's Human Ethics Committee approved this method, and the study overall.

Bluetooth data was recorded, reviewed and cleaned. From this, 66% of all Bluetooth logs were deemed useable for this study. Logs representing shopping trips above 120 minutes and below two minutes were excluded to reflect the real shopper behaviour, as were logs that tracked staff members who spent a lot longer in the store or accidental "noise" were also excluded. The benchmarks for exclusion were validated by researchers in this study (i.e. it takes a minimum of two minutes to buy at least one item), and by Sorensen (2009a).

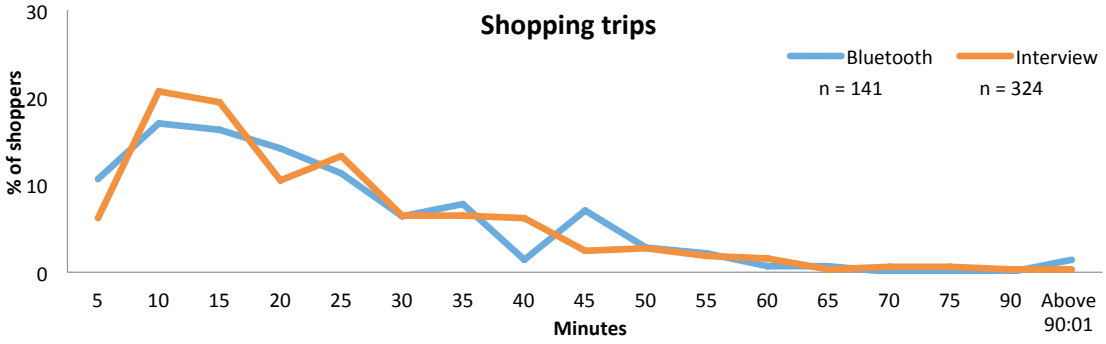
4. Findings

4.1. Shopper behaviour

Addressing RQ1, 74% of shoppers were carrying phones at the time of interview; those who did not have a phone with them claimed they have left it in the car, at home or did not own a phone. Among those who had phones, 76% access the Internet through their phone and 66% of them have smartphones; which are defined as a phone capable of running applications from an online app store. A total of 34% of shoppers had Bluetooth on their phones set to be detectable by sensing equipment. This finding was consistent with observations by Abedi et. al (2013).

To test the validity of trip length data derived form Bluetooth observations against that measured manually (RQ2), researchers compared **shopping trip durations** using (1) auto-tracked data from the Bluetooth scanner set-up in-store with (2) time spent in-store recorded from time entry stickers and shopper receipts.

Figure 1. Distributions of shopping trips from Bluetooth against manually collected data from the interviews



The correlation between Bluetooth and manually collected shopping trip data was very high, making it statistically significant (r (17) = 0.92, p < .001). This finding suggests Bluetooth auto-logging is a valid method for collecting shopping trip length information. The median and mean values for both methods were comparable (16 minutes and 20 minutes for both methods respectively). Looking at the distribution of trip length data collected from both methods (Figure 1), the data revealed similar patterns – a negatively skewed distribution, indicating a prevalence of quick trips over longer ones. Overall, 76% of both samples spent under 30 minutes in-store. This pattern is consistent with those documented by Sorensen (2009a) and Anderson et. al. (2012).

4.2. Shopper demographics

Addressing RQ2, ANOVA analysis found no significant differences in shopping trip lengths between groups of shoppers with Bluetooth-enabled devices versus the remainder of shoppers[2] (Table 1, first two rows, $p_{\text{trip length}}$= .81). Similarly, basket size and expenditure showed no statistically significant differences between shoppers with and without Bluetooth devices (p_{basket} = .11 and p_{spent} = .12).

Table 1. Descriptive statistics and ANOVA results for shopper behaviour

	n	Median (IQR)	Mean (SD)	F (p)
Shopping trip lengths (minutes)				
Bluetooth on	65	20 (20)	24 (16)	
Everyone else	93	15 (25)	23 (19)	.06 (.81)
Basket size				
Bluetooth on	67	17 (20)	23 (18)	
Everyone else	100	13 (21)	18 (16)	2.6 (.11)
Dollars spent ($)				
Bluetooth on	70	65 (77)	85 (68)	
Everyone else	89	61 (76)	69 (61)	2.5 (.12)

No statistically significant differences between groups

** Variation in sample size is due to missing data in some questions.*

Addressing RQ4, distribution of age, employment status, and highest education level are compared across shopper groups based on their phone status, i.e. Bluetooth-enabled vs. everyone else. The reasons for this grouping is to provide practical assessment for how representative Bluetooth auto-logging sample is against those individuals who were not using such technology, but still shop in the same store.

Table 2. Age distribution of shoppers carrying Bluetooth-enabled devices vs non Bluetooth-enabled devices

Groups (%)	18 to 25	26 to 35	36 to 45	46 to 55	56 to 65	66+	Total	χ^2
Bluetooth-enabled	8	15	21	27	24	4	100	
Everyone else	10	9	18	20	19	25	100	16.59*

**$p < .01$*

Shoppers aged above 66 are under-represented in the Bluetooth sample

Shoppers with Bluetooth-enabled devices had a significantly different **age distribution** compared to the remainder of shoppers (χ^2 (5, N = 327) = 16.59, p=.005). Bluetooth-enabled devices were prevalent across all age groups except the older demographic, i.e. above 66 years of age (Table 2). Therefore, this group was under-

[2] i.e. shoppers with no phone, or with a phone but Bluetooth not activated or detectable

represented in the Bluetooth sample. Shopper **employment status** was not statistically different between shoppers with Bluetooth-enabled devices and the remainder of shoppers (p=.37).

Table 3. Highest level of education achieved of shoppers carrying Bluetooth-enabled devices vs non Bluetooth-enabled devices

Groups (%)	Secondary school	Tertiary education	Postgraduate	Total	χ^2
Bluetooth-enabled	31	30	39	100	
Everyone else	24	50	26	100	9.92*

*Note. *p <.01*

Shopper groups with tertiary education level are most under-represented.

Shoppers with Bluetooth-enabled devices have a significantly different highest level of **educational achievement** than the remainder of shoppers (p=.007). Hence, Bluetooth is likely to obtain a sample skewed towards shoppers with postgraduate education, as from the data collection this was the highest qualification (Table 3). However, this occurrence is not an age factor (Table 2), as a chi-square test showed the proportion of shoppers' education level did not differ by age group (χ^2=10.80, p=.20).

5. Discussion and Conclusions

Using technological advancements to track shopper behaviour is a current trend in the retail industry. Practitioners and researchers use aggregated de-identified time data (the length of the entire shopping trip and the time/date stamps, usually derived from Bluetooth, Wi-Fi, RFID or other auto-logging) for a range of managerial tasks: to predict and manage shopper traffic; to plan for checkout staff allocation, opening hours, stocking shelves; to benchmark across stores; and, to estimate shopper trip congruity with the aim of creating more homogeneous traffic patterns associated with better retail returns (Sorensen 2012b). Trip length data with spatial indicators (such as time and location in store from RFID or multiple small-range Bluetooth devices) provides valuable inside into the visitation of different areas within a store, identifying congested or under-utilised sections of the store. In combination with spend, aggregated trip duration data could be used to model shopper efficiency for an entire store, indicating its performance and tracking improvements over time, along the two main shopper currencies (time and money) (Sorensen 2012a).

Given the increasing use of time in-store auto-logging data and its importance for managerial performance metrics, testing the validity of methods used to create such data is an important research agenda. This study has established that the supermarket shopping trip length data obtained using Bluetooth auto-logging, provides very similar results to those collected through systematic manual observations. This suggests that Bluetooth technology is a valid tool for measuring the length of shopping trips and other time-dependent measures of shopper movement and traffic. The advantages of using Bluetooth technology is that it is of low cost, there is the

potential to collect large amounts of data across long time periods, and the non-invasive and unidentified nature of the data, which does not rely on shopper cooperation or memory and protects shopper privacy.

This study also showed that Bluetooth is capable of capturing and reflecting the behaviour of shoppers with minimal bias in terms of basket size and expenditure. Employment status did not differ significantly between the groups who were carrying Bluetooth enable devices (about 34% of the shopper population) and who did not. The one group that was under-represented in the Bluetooth-enabled sample were those aged over 66. Over a third (36%) of all shoppers without a phone were aged over 66. Almost half of the shoppers in this age group did not carry a phone, and they were also the largest age group to not own smartphones. This is consistent with prior research, where seniors aged above 65 are the lowest age group to have a smartphone or mobile phone (Australian Communications and Media Authority 2012, Smith 2013). This phenomena is due to the various barriers in technology acceptance and adoption by older adults (Renaud and Van Biljon 2008). Thus, elderly shoppers are most likely to be excluded from Bluetooth tracking samples.

This bias suggests the need for complementary methods to capture shopper behaviour of older shoppers. Alternatives can include top-up sampling using manual interviewing, RFID tagged trolleys and baskets, or video recording. Bluetooth tracking is likely to be more representative when its target population is younger or more tech-savvy (such as tracking in electronic retailers like an Apple store or Tandy, or fashion retailers like Zara or H&M).

From a methodological and research perspective, this study showed the potential of low cost Bluetooth data collection for producing rigorous shopper data. The research also demonstrated a method for cross-referencing the data from Bluetooth scanners with manual observations to establish its validity and representativeness.

6. Limitations and Future Research

This study focused on auto-logging data collection using signals from Bluetooth-enabled devices, which covered 34% of the shopper population. Another form of technology, Wi-Fi, covers almost twice as many, 65%, of shoppers. This finding is consistent with observations by Abedi, et. al (2013) where Wi-Fi was much more popular than Bluetooth. Our data also shows that shoppers with Bluetooth turned on were also more likely to have their Wi-Fi turned on (84% with Bluetooth turned on had Wi-Fi turned on, whereas only 53% of shoppers with Wi-Fi turned on had Bluetooth on). This prevalence of Wi-Fi technology suggests an alternative to Bluetooth data collection. Furthermore, in our study 38% of respondents said they would use a free public Wi-Fi hotspot, potentially boosting the proportion of customers available for Wi-Fi tracking. Therefore, setting up an in-store public hotspot has further potential to expand the "trackable" shopper population, thus reducing error margin, and potential bias in the sample. Combined with the growing availability and public acceptance of Wi-Fi hotspots, Wi-Fi appears to be a viable alternative for researchers and retailers studying shopper traffic.

For the reasons above, we recommend future research to focus on Wi-Fi tracking with the integration of other in-store observational methods for a more reliable measure. Validation of the Wi-Fi tracking in terms of trip length

against Bluetooth and manual observations is also needed before Wi-Fi can be recommended as the superior method for tracking trip length over Bluetooth.

Technology acceptance should be investigated more thoroughly to further understand user profiles and technology usage, across different shopper demographics and behaviour. It will also be useful to investigate if a younger population are more likely to accept and use technology, but are unlikely to be detected because they are more tech-savvy and know how to make their devices invisible. The age distribution of our overall sample was skewed towards older shoppers because this study was conducted in a suburb with an older population. Therefore, future research is needed in other supermarkets in different metropolitan areas to deliver a more generalised profile of Bluetooth-using shoppers.

Future challenges include the public becoming uneasy and more concerned with their privacy due to events that are occurring in society. For this reason tracking and recording of the unique MAC addresses from interviewee's mobile devices was not undertaken in this study. While potentially beneficial from the research perspective, the collection of this information would have breached the confidentiality of the shoppers. Therefore, this then creates implications for companies that are tracking shoppers, as it is a prerequisite for companies to notify shoppers that they are being tracked and that companies need to give shoppers the option to opt-out. This implication may potentially result in self-selection bias, which in turn effects the data collection and results. Recently, one of the world's leading phone manufacturers announced a new privacy feature for its latest operating system update (Apple's iOS 8). This new operating system gives iOS 8 devices the ability to identify themselves with a random address instead of a unique stable ID, while scanning for known Wi-Fi networks (Apple Inc. 2014). Variable MAC address for Wi-Fi will present a challenge for tracking, which then might deem Wi-Fi to be a less preferred method than Bluetooth. It is recommended that several complementary methods should be used to minimise representation bias in shopper samples.

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