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Kasturi Jajarayah


Robert John KAUFFMAN

Singapore Management University, rkauffman@smu.edu.sg

Archan MISRA

Singapore Management University, archanm@smu.edu.sg

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Exploring Variety Seeking Behavior in Mobile Users

Kasthuri Jayarajah
Singapore Management
University, 80 Stamford Road,
Singapore 178902.
kasthuri@smu.edu.sg

Robert Kauffman
Singapore Management
University, 80 Stamford Road,
Singapore 178902.
rkauffman@smu.edu.sg

Archan Misra
Singapore Management
University, 80 Stamford Road,
Singapore 178902.
archanm@smu.edu.sg

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Abstract

Understanding the personality traits and current attitudes of individual consumers is crucial for retailers and mobile advertisers. In this paper, we investigate the phenomenon of “variety seeking tendencies” in mobile users in their (1) online (represented by their App usage behavior), and (2) physical (represented by their location visits) worlds. We show that different categories of users exhibit different levels of variety. Further, by analyzing at various time scales, we show that there exists correlation between when a person is likely to visit new places in the real world and when he/she is likely to explore new Apps in the online world.

Introduction

Deriving an individual's “*variety-seeking*” mindset or propensity is a problem of great interest to the behavioral science and marketing disciplines, as such mindsets shape the responses of individuals to different types of stimuli (such as product advertisements or promotions for ‘novel products’ [1]). We thus investigate a speculative research question: *can any inferences about such abstract behavioral attributes, specifically a variety-seeking (or avoiding) mindset, be inferred from mobile sensing data?*

More specifically, we look at the *Device Analyzer* dataset [2], and determine the relationship between (a)

the diversity of *physical locations* visited, and (b) the diversity of *mobile Apps used* by an individual. We then utilize prevailing consumer behavioral theories [3] to relate such physical world and phone-usage based diversity to an individual's likely *variety seeking tendencies (VST)* at different instants.

Methodologically speaking, we first apply entropy-based measures to capture the overall randomness of physical-world locations and App usage patterns of each individual, and identify three different types of users—those with *low*, *medium* and *high* randomness. Subsequently, we carefully analyze the data, both at an individual and aggregate level, to make the following **key contributions**:

- Over the whole 6 month window, we show that there exists a fairly strong positive correlation (across each user type) between the overall randomness of physical location visits and phone App usage.
- Performing more-specific time-of-day analysis, we find that visits to new locations typically occurred during the afternoon or early evenings, whereas usage of new Apps was highest in the evenings.
- Finally, by performing sequential analysis on a weekly basis, we find strong correlation in the *evolution of variety*: when individuals visit new places, their likelihood of using new Apps is much higher.

Distinct from prior studies, these findings provide intriguing, preliminary evidence that uncertainty (or novelty) in location and App usage behavior is fairly correlated, and may be reflective of an individual's intrinsic

VST (either overall or during specific time periods). As “variety seekers” are often more responsive to marketing of newer products, such findings may have significant implications for mobile and in-App advertising strategies.

Related Work

Personality studies in consumer research:

Understanding of the VST, or the *exploratory behavior* of consumers has gained traction over the last 2-3 decades in consumer research—e.g., [1] combined theories from psychology and marketing to study its implications in the consumer choice context. Works such as [3] tried to quantify VST using count-based models, considering attributes such as number of brands, switching between brands and total purchases, using retail sales data.

Personality studies in mobile and ubiquitous computing:

More recently, approaches such as [4] have attempted to infer the Big-Five personality traits of phone users (e.g., Extraversion, Openness, etc.) using smartphone logs, such as call/text data, locations visited, contacts, etc.

Understanding online vs. real behavior: There has been a surge of interest, in recent times, in understanding how people behave online and in real (*competing* and *complementary*) for a variety of types of behaviors: big-five personality traits [5], social behavior [6] and retail shopping [7]. However, there have been no attempts, to the best of our knowledge, that attempt to study VST in this context.

Application usage, human mobility and recommender systems:

App usage on smartphones (e.g., [8]) and human mobility using Call Detail Records (e.g., [9]) have been studied extensively. Based on learned contexts, researchers have focused on systems that recommend new

Total no. of users	17000+
With 6+ months data	1467
With app interaction data	1359
With location data	1163
With both	1078
Data with invalid dates	0.24%

Table 1: Breakdown of the dataset.

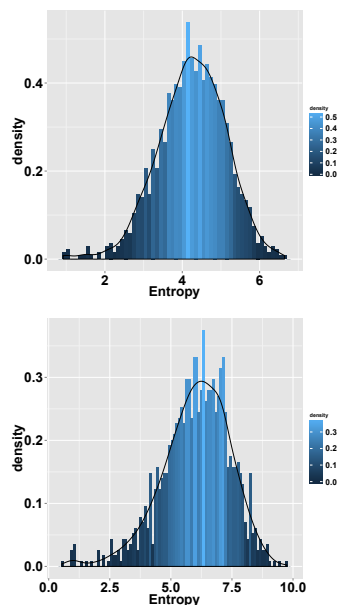


Figure 1: Histogram of entropy values of the population for number of app interactions (top), and number of location visits (bottom). The plot shows presence of low, medium and high variety seekers in the population.

Apps (e.g., [10]), and new venues (e.g., [11]), respectively. While these works focus on “*what*” to recommend, we are motivated by finding the VST mindset of an individual, which helps ascertain “*when*” to recommend.

Data Description

The Device Analyzer dataset [2] is a collection of smartphone usage data from over 17000 users. For this work, we consider users (numbering 1078) who have contributed data over at least six months and for whom both App interaction and location information is available with reliable wall-clock times (See Table 1).

Application usage

The Device Analyzer App collects information on application starts at 2 Hz for 10% of the screen ON sessions [2]. We assume that a user has interacted with an App if the App was launched and no other App is launched within the next 3 seconds (to remove out unintentional launches) within a screen ON session. We filter out the highest occurring App for each user, as we experimentally confirmed that this corresponded to the “Launcher” or “Home Screen” application.

Location visits

The Device Analyzer App collects the hashed coarse location (operator, LAC and Cell ID combination) of the user with a scan period of 5 minutes. Similar to the application usage case, and as shown in previous studies, users are mostly bound to their “Home” and “Work” locations. As our focus for this work is on understanding variety, we discard records relating to the inferred “Home” and “Work” sites based on repetition and stay time. However, we do not extract out the transitory cells between “Home” and “Work”, as travel routes may also reflect a users’ tendency to seek variety. We further filter

out visits where the user spent less than 15 minutes at a location in order to subdue the effects of noise and the ping-pong hand-overs often observed at cell boundaries.

Empirical Evaluation: VST

In this section, we establish a means for measuring VST, investigate the presence of differing levels of VST in the sample population, and study time-of-day effects of such VST measures. We empirically establish the significant correlation in the VST level of an individuals’ online behavior (App usage) and physical world movement (location visits).

Discovering Typologies

We use entropy to measure the extent of one’s tendency to seek variety. First, we look at the distribution of the number of times an App was launched for every user over the data collection period. As the entropy is lower bounded by 0 (if only one App was ever used) and upper bounded by the log value of the number of different Apps (if usage was uniformly distributed), it provides an indication of the “randomness” of an individual’s App usage behavior. We repeat the same for location visits with respect to the number of times a location is visited. Figure 1 shows the density plots of the entropy values of the population which show the presence of *low* (less than the 1st quartile), *medium* (between 1st and 3rd quartiles), and *high* (greater than the 3rd quartile) variety seekers within the population. Intuitively, *high* entropy reflects people who behave like ‘traveling salesmen’ and low entropy captures people with highly predictable visit/usage patterns. Similarly, we also discovered the presence of morning, day, evening and overnight variety seekers based on “when” the users exhibited maximum variety.

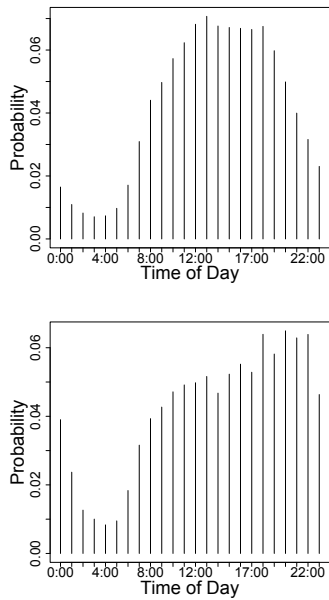


Figure 2: Probability distribution of the population visiting new places (top), and using new Apps (bottom) across different hours of the day. VS - Location Variety Seekers.

Time-dependency of VST

To understand the variation in variety seeking over different time windows, we labeled the data into (1) four time of the day windows: morning (06:00 to 11:59), day (12:00 to 17:59), evening (18:00 to 23:59), overnight (00:00 to 05:59), and (2) two day-of-the-week windows (weekday vs. weekend), and observed the entropy values for the population separately for App interactions and location visits.

In both cases, the distribution of the population entropy shows variation across the four times of the day; t-tests and F-tests confirmed that although the variances were similar, the means of distributions were statistically different (at $p=0.05$) across the different time windows. While users did not show much difference in the App interaction behavior across weekdays and weekends, they were more likely to visit a variety of physical-world locations on weekends and Fridays rather than on other weekdays. This is evidence that time has an effect on the VST of people.

Time-of-Day Effects on VST

Next, we observed the days/times when the people in the population (1) started using “new” Apps, and (2) visited “new” places. As ground truth of App installations was limited (available only for 16 out of 1467 users), we utilize the first months App *usage* data as baseline for the previously installed (or more specifically, recently used) Apps. Similarly, to compensate for the lack of location data prior to the installation of the Device Analyzer App, we use the locations visited by each user during the first month of their respective data collection period to create the baseline of previously visited places. We make the following observations:

1. For the population, over the entire collection period, most new visits were made during the afternoon and early evenings (5 - 6 PM) whilst new Apps were tried out during early lunch hours (11 AM to noon) and heavily over entire evenings (See Figure 2).
2. Trying out new Apps was consistent across days; however, more new locations were visited on Saturdays and Fridays (followed by Sundays) compared to weekdays.
3. Morning, day and evening variety seekers were more likely to visit new locations during different times of the day: around 10 AM, 1 PM and 7 PM, respectively (See Figure 3). However, all types of variety seekers were more likely to try out new Apps in the late evenings as seen in (1).

Online vs. Physical World VST

We now investigate further the relationship, if any exists, between a person’s appetite for variety in terms of App usage and physical movement. We hypothesize that, if a user is currently exhibiting higher levels of VST, then it should manifest in his/her explorations in both the online and physical worlds. This analysis is motivated by our interest in discovering complementing and/or competing personae displayed by people in the two worlds.

Fine-grained VST Correlation

First, we segment data into 168 buckets for each user (24X7 buckets, with each bucket representing a day of the week and hour of the day combination), and compute the entropy of App usage and location visits for each bucket. This results in two 168-length vectors for each user. Then, we compute the correlation coefficient between the two vectors and observe the extent of similarity/dissimilarity. We repeat this computation for

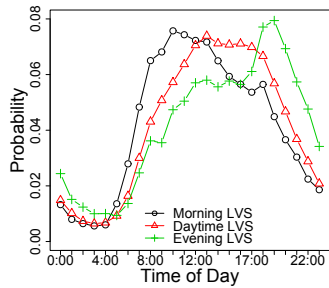


Figure 3: Probability distribution of morning/day/evening variety seekers visiting new places across different hours of the day. LVS - Location Variety Seekers.

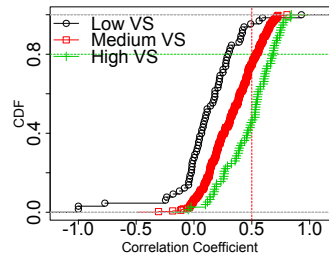


Figure 4: CDF of hourly correlation between App and location variety for low, medium and high variety seekers.

low, medium and high variety seekers, separately. Figure 4 shows the CDF of the resulting correlation values. We see that the hourly correlation between App and location variety is highest for high variety seekers; in fact, more than 55% of high variety seekers show positive correlation higher than 0.5. Overall, only a minor proportion of the users show negative or no correlation; less than 10% of the low variety seekers, and negligible percent of the medium/high variety seekers. The results suggest that *VST is strongly correlated across online and physical world behavior*—when users show greater diversity in locations (e.g., they are commuting), they are also likely to utilize a wider variety of Apps.

Evolutionary Behavior of VST

Next, we investigate the divergence in users' App and location VST, as measured over successive weeks. We list the set of Apps A_w and locations L_w for each user, for every week $w \in W$ during the collection period, where W is the set of all weeks. Then we compute the Jaccard distance between every pair of A_w and A_{w+1} (similarly L_w and L_{w+1} for location) to compute the *weekly divergence* over consecutive weeks. We hypothesize that when the Jaccard distance of physical world locations is high (e.g., a person visiting a new place), the online distance measure would be high as well (i.e., the user would use more novel Apps, such as travel and transport Apps when visiting a new country, or using bus/train Apps when going to a new restaurant). We compute the correlation between these distances for every user, plotting the CDF of these correlation values in Figure 5 (the blue, green and red lines represent all users, high variety seekers and medium variety seekers, respectively). We observe that, for at least 40% of all users, the correlation between the divergence measures is at least 0.5. At least 90% of all users show positive correlation, indicating that *users*

visiting new places do indeed show a tendency to utilize novel Apps.

Discussion

We now briefly discuss the limitations of our current study and possible inclusions for future work.

Limitations: The application usage information is only available for 10% of the screen ON sessions leading to data sparsity; the usage intensity of users could in fact be much higher. We overcome this by considering longitudinal data over six months. We have also limited ourselves to deliberate launches of foreground Apps, and have thus ignored Apps (e.g., music players) that could be actively running in the background.

Extensions and future work: Although the data currently suggests possible tendency of users to seek variety, there is no ground truth available as at yet to confirm the validity of the results. As a next step, we plan to actively experiment on participants in the LiveLabs testbed [12], by (1) issuing coupons and observing their conversion rate across low/medium/high variety seekers, and (2) recommending “new Apps” during periods when our algorithms indicate high VST values. This work also opens up possibilities for understanding other personality traits such as *Boredom Proneness*: e.g., the tendency of a user to switch back and forth between the same Apps within the same screen ON session.

Conclusion

Variety seeking is a personality trait that is of importance to varied audiences; advertisers and marketers find people with high VST as a high target value consumer group. By analyzing App usage and location visit patterns of users at different times, we demonstrated that users'

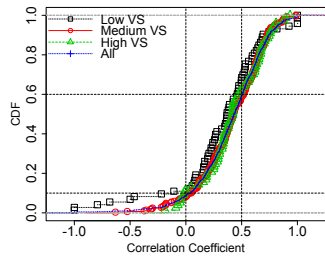


Figure 5: CDF of correlation between weekly divergence of App usage and location visits. VS - Variety Seekers.

online and offline choices for variety *are often* correlated, across different time-scales. Our work thus suggests that smartphone traces may be a potential source for understanding not just VST, but other personality or behavioral traits of individuals.

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