

Temporal Dynamics of Public Behavior

Keywords: Temporal, Mobility, Points of interest, Behavior, Geosocial

Extended Abstract

Despite variations in the population, climate, economics, politics, and culture, every country and city around the world shares the same time constraint: there are only 24 hours per day. Yet, the time-dependent activity patterns of when people interact with or move between public and commercial locations changes across geographies, spatial scales, and temporal scales. The temporal dynamics of places reveal unique behavioral patterns influenced by complex social and economic interactions.

What we do, and when we do it creates daily temporal patterns which can be split into aggregate sleep patterns and aggregate activity patterns, each influenced by their own set of complex factors. Aggregate sleep patterns are influenced by our social clock (when school or work begins and whether the following day is a workday/school day), the solar clock (the natural light-dark cycle), and our biological clock (circadian rhythms) [1, 2]. Aggregate activity patterns are the daily activities the population performs while awake. These are influenced by the places we live and the types of places such as Restaurants or Retail, we visit. These places are in turn influenced by a complex set of interacting social, economic, cultural, religious, and environmental factors [3-5]. However, unlike our understanding of how the solar, biological, and social clocks determine our aggregate sleep patterns, there is limited understanding associated with the precise determinants of our aggregate activity patterns, short of qualitative descriptions.

The scientific question that continues to motivate a growing study in temporal dynamics of places is: what are the determinants of temporal patterns of places, and how do the dynamics of places impact health, resilience, and economic outcomes? Figure 1 illustrates three bi-directional relationships that temporal dynamics of public behavior have with a place's (1) *Environmental Conditions and Mobility Disruptions*, its (2) *Built Environment*, and its (3) *Historical Context and Social Norms*. Each of these factors have influence over short, medium, and long-term time scales. We briefly discuss four case studies that provide insight on each of these factor's measurable impact on the temporal dynamics of places.

The data used to examine short-term *Environmental Conditions and Mobility Disruptions* were weekly activity patterns for POIs from 2019-2020 in the United States, provided by SafeGraph and made openly available to academic and research institutions. SafeGraph takes anonymous location information and determines the number of visits to a POI for each of the 168 hours of the week and aggregates these anonymous visits to create weekly POI activity patterns. The data used to examine medium-term *Built Environment* influences and long-term *Historical Context and Social Norms* were the hours of operation for POIs, collected globally from the Facebook graph API. The hours of operation data were processed to create weekly temporal signatures for multiple cities and place-types, where each hourly time interval represents the number of POIs open within a given city during a specific hour throughout the week.

Environmental Conditions & Mobility Disruptions (right side of Figure 1) operate on short time scales (weeks to years) and are representative of significant disruptions to aggregate behavior. The first example illustrates the influence of severe weather and natural disasters such as hurricanes. In August 2019 Hurricane Dorian hit the east coast of the United States. During the hurricane significant decreases in visitation to POIs, such as schools, were measured when comparing against historic baseline averages. The second example illustrates COVID's influence on global aggregate mobility behavior. In response to significant mobility reductions

starting March 2020, daily temporal patterns of human activity changed. Human mobility from 2019 to 2020 noticeably dropped as measured by cumulative decreases in weekly activity patterns for POIs. Coupled with net decreases in human mobility, daily temporal patterns of human activity changed nonuniformly. Morning activity started later, and evening activity started earlier in 2020 compared to 2019, and temporal behavioral patterns on weekdays began to look more similar to weekends [6].

The influence of the *Built Environment* (top/top-left of Figure 1) operate on medium time scales (decades) and are representative of slow-moving change to aggregate behavior at places. Place dynamics of a particular geographic region are influenced by the POI types and land use present in that region. The temporal dynamics of when people are active at grocery stores are generally distinct from when people are active at restaurants. Likewise, if a district in a city is largely single use, the activity patterns of that district will start and stop when the places in that district open and close for the day/week. In this example we focus on the comparison between Retail and Restaurant POI categories. For our city of interest, Retail POIs show a tendency to open approximately one hour earlier than their corresponding city Restaurant POIs, while Restaurant POIs stay open later by approximately two or more hours [5].

The influence of *Historical Context and Social Norms* (bottom/bottom-left of Figure 1) operate on long time scales (centuries) and reflect long standing place specific cultures and social norms across geographic regions. In this example, we identified global temporal patterns of cities generated by POI hours of operation [5]. We focus on modeling the general trends in temporal patterns for 135 cities around the world. The temporal patterns of cities change depending on the cultural region they're in. While temporal patterns of cities (and activity patterns in general) vary across space, the variation depends on the scale and scope of the space in consideration. While Paris and Amsterdam indeed have different temporal patterns, in a global context, they're much more similar when compared to cities outside of Western Europe. Whereas Tunis and Rome, being spatially near yet in different cultural regions, comparatively have much more different temporal patterns.

Time is a limited resource. No matter how rich or poor any person, any town, or any city, we all have 24 hours in a day and 168 hours in a week. How we as a collective choose to use that time tells us something about ourselves, our cities, our nations, and our businesses, that is not just an illustration of human behavior, but of economic processes, social processes, and the culture of places. By better understanding temporal dynamics of human behavior, we can begin to understand how the dynamics of places impact health, resilience, and economic outcomes.

References

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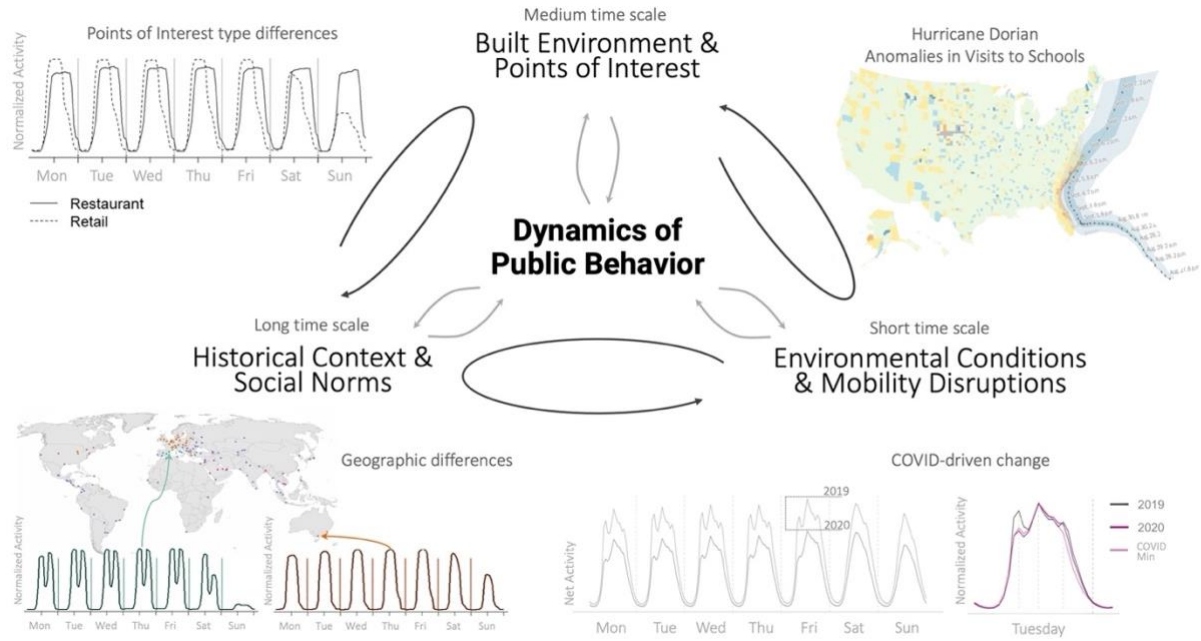


Figure 1. The influences and their relationships that determine the temporal dynamics of public behavior over short, medium, and long time scales. Environmental Conditions & Mobility Disruptions (right side of figure) operate at relatively short time scales and are exemplified through COVID’s influence on broad mobility disruptions as well as natural disasters (e.g., Hurricanes) influence on mobility disruptions. Built Environment & Points of Interest (top left) operate on relatively medium time scales and are exemplified through POI place type differences. Historical Contexts & Social Norms (bottom left) operate on relatively long time scales and are exemplified through changes in temporal patterns across cultural regions.