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Understanding the gender gaps in employment and mobility using large-scale behavioral data

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Extended Abstract

Women and men have significantly different daily travel habits [1, 2], and understanding the factors driving this gap is critical for creating inclusive and efficient transportation systems. A well-established hypothesis is that the observed gap is largely accounted for by the division of roles in the labor market [2], with women experiencing significantly lower employment rates than males.

The role played by an individual's employment status on travel behavior, however, has remained unclear, partly due to limitations in the data sources available. On the one hand, survey-based studies have been limited by response biases, as people may struggle to recall their movements over extended periods accurately. On the other hand, studies based on passively collected travel data are limited by the lack of individual socio-demographic information, focus on a specific country/city, or have been unable to pinpoint causal mechanisms.

In this work, we analyze the relationship between mobility, gender, and employment, using high-resolution traces describing the movements of 90,000 individuals from five European countries (United Kingdom, Germany, France, Spain, and Sweden) over two years (2017-2019) [1]. Individuals self-reported their age (between 25 and 64 years old) and gender. We estimated an individual's employment status using state-of-the-art time-space heuristics [4] that identify users as commuters or non-commuters. Given that our data set predates the COVID-19 pandemic, we consider commuting a proxy for employment.

Our contribution is twofold. First, we assess the correlation between employment, gender, and key aspects of mobility behavior on a large scale and across different contexts. Then, we test the central hypothesis that the effect of gender on mobility is, to a large extent, indirect because it is mediated by differences in labor responsibilities [2], using a quasi-experimental difference-in-difference approach [3].

Mapping the gender gap across countries and mobility dimensions. What are the differences in travel patterns between males and females? Here, we focused on three key aspects of mobility: (i) the typical distance traveled, captured by the radius of gyration, r_g; (ii) the distribution of time spent per location, captured by the time allocation entropy, $S(t)$; (iii) the predictability of user visitation patterns, captured by the visitation entropy, $S(n)$ [2]. Our findings confirm that women's daily travel is more limited and stationary than males'. On average, males' radius of gyration is $23.58 \pm 1.24\%$ larger than females, and their time allocation entropy $7.07 \pm 0.31\%$ is lower (Fig.1.e-f). Contrary to previous studies, however, we find that females present more complex visitation patterns, with females' visitation entropy being $3.23 \pm 0.17\%$ higher than males (Fig.1.g).

Unveiling employment-related factors driving the gender gap in mobility. Shifting our attention to the effect of employment on mobility, we observe that individuals' employment is strongly related to their mobility behavior (Fig.1.h-j). Unemployed individuals travel shorter distances ($r_g : -19.94 \pm 2.26\%$), distribute most of their time among a few locations ($S(t) : -42.56 \pm 1.19\%$), and their trips follow less regular patterns ($S(n) : 11.18 \pm 0.32\%$).

To test the hypothesis that the gap in employment is entirely responsible for the gender gap in mobility, we stratify our sample by employment status (Fig.1.k-m). We find that, even among employed individuals, males have a $19.69 \pm 1.17\%$ larger radius of gyration than females, a $5.30 \pm 0.30\%$ higher time allocation entropy, and a $3.67 \pm 0.17\%$ lower visitation entropy. So, contrary to the hypothesis that the gender differences in employment may fully explain the differences in mobility, we reveal that the gender gap persists between the employed, suggesting that other mechanisms may be at play.

Among unemployed individuals, males present a $66.89 \pm 5.51\%$ larger radius of gyration, a $29.15 \pm 1.92\%$ higher time allocation entropy than females, and a $6.63 \pm 0.64\%$ higher visitation entropy. These results reveal that the gender gap is significantly larger among the unemployed in all metrics, implying that the division of roles in the labor market is indeed partly responsible for the observed gap in mobility. Interestingly, focusing on the visitation entropy, we reveal an intriguing difference between employed and unemployed individuals. Unemployed females' trips are more regular than those of unemployed males, while the opposite is observed for employed individuals. This result aligns with the established notion that females and males play different roles within the household.

Importantly, we find that all our results are robust when controlling for age and level of urbanization. Finally, to ensure that our analysis is not confounded, we employ a within-individual design and study how a change in employment status influences individuals' mobility. We find that the behavior patterns observed across individuals persist within-individual. For instance, when users become unemployed, both males' and females' movement becomes more contained, stationary, and irregular.

Overall, our findings align with the hypothesis that employment status influences an individual's mobility. However, they reveal that the gender gap in employment does not entirely explain the gender gap in mobility. We identify a complex interrelation between socio-demographic features and various aspects of mobility behavior. Our results confirm that, beyond differences in employment, other elements, such as the division of household and familial responsibilities, could play a key role in human mobility.

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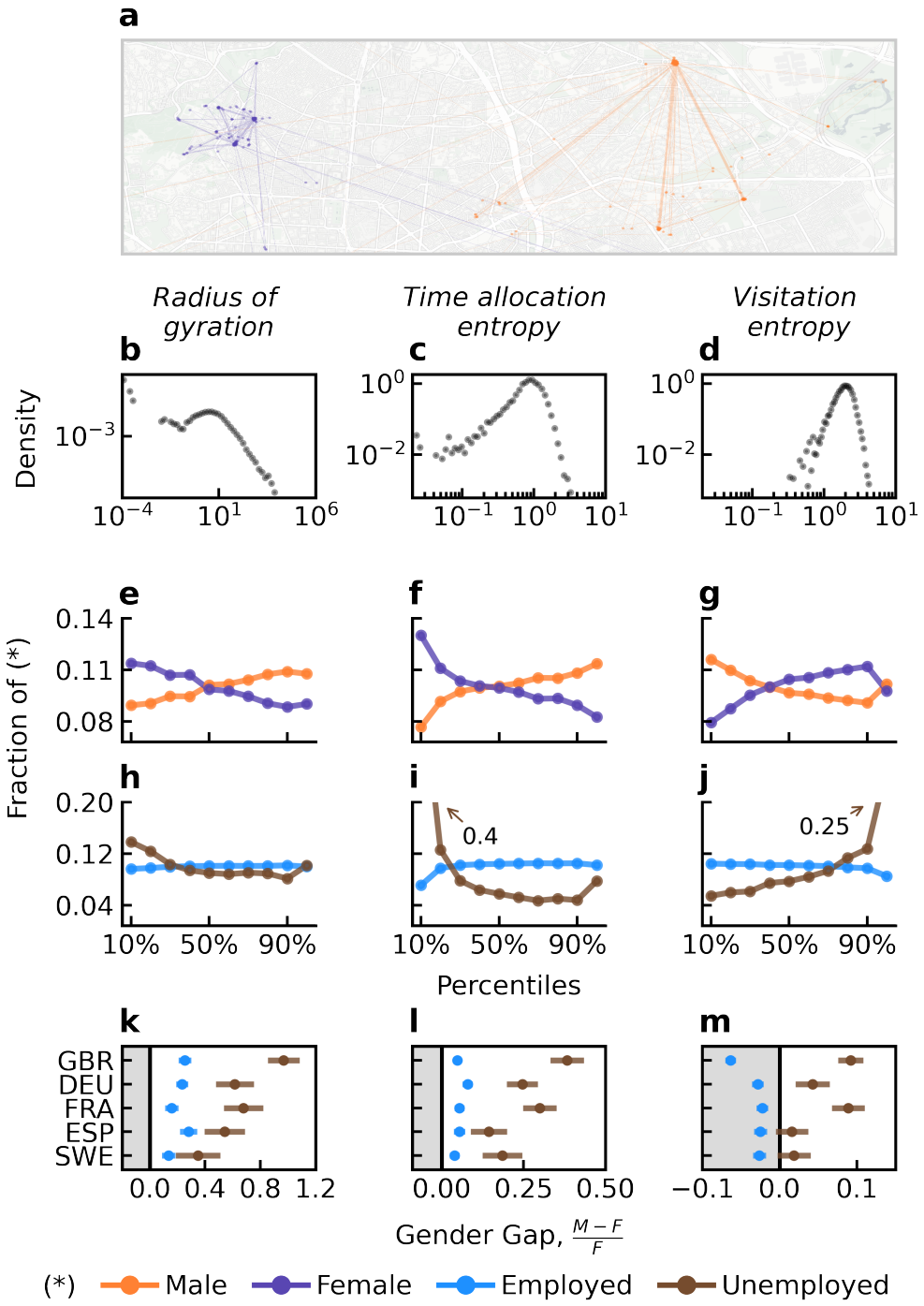

Figure 1: a. Network of locations for two sampled users, one male (orange) and one female (purple), displayed on an arbitrary map. b-d. The distributions of the radius of gyration r_g, time allocation entropy $S(t)$, and visitation entropy $S(n)$, respectively. e-g. The fraction of male (orange) and female (purple) users per percentile of the distribution and metric. h-j. The fraction of employed (blue) and unemployed (brown) users per percentile of the distribution. k-m. The gender gap as the relative difference between males (M) and females (F) by country, for the employed (blue) and the unemployed (brown).