Measuring and Boosting the Productivity of Disabled Workers: The Case of Food-Delivery Workers in China*

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Abstract

What do firms gain from hiring disabled versus non-disabled workers, and how is this affected by new technology? We shed light on this by examining the relative performance of hearing-impaired workers using administrative data from one of China's largest food-delivery platforms. While disabled workers are slightly slower than non-disabled workers and have worse customer ratings, they supply many more hours and orders per week to the platform and are much less likely to quit, and they earn more profit for the platform. Leveraging a policy change, we assess the impact of an intelligent outbound call system designed to improve communication for hearing-impaired workers. The new technology significantly enhances disabled workers' productivity, reduces negative customer reviews, and increases their work participation, thereby overturning most of the pre-technology gaps, and further enhancing the profitability of disabled workers. For gig work in China, a particular context but one covering many millions of workers, our results suggest that disabled workers face barriers but may still be quite valuable for firms, especially if disabled workers are supported with new information technology.

Keywords: Disability, Productivity, Information Technology.
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1 Introduction

Around the world, many disabled workers struggle to get decent paying work. Without it, disabled workers and their families may face a lower standard of living, and there are significant fiscal costs associated with the high and growing use of disability insurance (Autor and Duggan, 2003; Milligan, 2012). The challenges faced by disabled workers are especially acute in lower- and middle-income countries where government social insurance is often less developed (Banerjee et al., 2024). However, relatively little is known about "what works" in improving labor market outcomes for disabled workers.

A central policy to increase opportunity for disabled workers is civil rights legislation, a key example being the Americans with Disabilities Act (ADA) in the US. Passed in 1990, the ADA prohibits discrimination against disabled workers and mandates employers to provide reasonable accommodations. Unfortunately, research indicates that the ADA *decreased* the employment of disabled workers, potentially due to increased costs or legal risks for employers (Acemoglu and Angrist, 2001; DeLeire, 2000).[1] An alternative common policy approach pursued by some countries (e.g., Austria, Brazil, China) is quotas for disabled workers, often requiring that some percentage of employees at large firms be workers with disabilities. However, research suggests that firms comply with quotas by hiring disabled workers into lower-paid jobs (Szerman, 2022; Lalive et al., 2013). One reason civil rights laws and quotas may face limitations is that they may impose costs instead of addressing the underlying reasons firms hesitate to hire disabled workers. More generally, little is known about what firms gain or lose from hiring disabled workers.

Our study provides one of the first large-scale empirical analyses of disabled workers' productivity and how targeted technological accommodations can affect their performance. We answer two main questions: first, what do firms gain or lose by employing disabled workers relative to non-disabled workers, in terms of productivity, output, and ultimately profit? Second, can new information technology tools increase the value of disabled workers to firms by boosting their productivity or reducing any performance gaps?

To address these questions, we leverage a unique colloboration with a major food-delivery platform in China (hereafter, the Platform). The Platform offers an ideal setting for three reasons. First, the scale of the Platform is huge: it is one of the two dominant food-delivery apps in China, directly engaging millions of gig workers ($\approx$ 3 million active workers, completing hundreds of millions of deliveries per month). Second, and importantly, the platform has inclusive hiring: all applicants who meet basic criteria are accepted, with no higher bar

[1] Many countries have passed civil rights protections for disabled workers, such as the UK, EU, India, China, and Brazil.

or differential screening for disabled workers. Thus, disabled workers are employed under the same conditions as their non-disabled counterparts, allowing for a cleaner comparison of on-the-job performance (Pallais and Sands, 2016). Third, work on such platforms has become an essential source of employment for disabled individuals in China.

The majority of disabled workers on the Platform are people with hearing impairments. We focus on this group of hearing-impaired workers in our analysis.[2] Focusing on a single, relatively common disability allows us to clearly define the challenges involved and the specific technological solution introduced, while holding constant other factors–an approach that provides concrete insights into how to assist this group. Moreover, hearing impairment is a disability that gig economy platforms around the world are increasingly able to accommodate (e.g., through text-based communications), making our findings broadly relevant.

We use rich a administrative dataset from the Platform, which includes all newly registered disabled workers and a random sample of newly registered non-disabled workers over a three-year period (2021–2023). This dataset allows us to directly compare the job performance of hearing-impaired workers to a large sample of non-disabled workers on multiple dimensions. We examine key performance indicators such as delivery speed, customer satisfaction, number of orders completed, and labor supply (hours worked and attrition/retention). Crucially, in the middle of our observation period, the Platform introduced a novel "Intelligent Outbound Calling" feature designed specifically to help hearing-impaired workers communicate with customers. This feature—essentially a text-to-speech phone calling system with preset audio prompts—was rolled out suddenly in April 2022 to all hearing-impaired workers. We exploit this event as a natural experiment to evaluate how a targeted technology intervention can impact disabled workers' performance and the platform's outcomes.

Our findings show that prior to the new technology, disabled (hearing-impaired) workers were slightly less efficient on certain tasks (e.g. slower delivery times and slightly lower customer ratings) but contributed greater labor input (working more hours and exhibiting higher retention) than their non-disabled peers. The higher labor supply of disabled workers more than compensated for their small efficiency gap in terms of total output: disabled workers delivered more orders on average per week than non-disabled workers, making them valuable to the platform in the short run despite their limitations. After the introduction of the Intelligent Outbound Calling system, the performance of disabled workers improved substantially. The technology helped close efficiency gaps—for example, reducing the extra time disabled workers took in delivering orders and significantly lowering their rate of bad customer reviews—and further increased their output and retention. These improvements

[2]Hearing impairment is among the most prevalent disabilities, affecting approximately 7% of the Chinese population and 15% of the American population.

translate into a higher economic value of disabled workers for the firm, with preliminary evidence suggesting that the gains from the technology likely exceed its costs from the platform's perspective. In sum, this study highlights that disabled workers can be productive and reliable contributors in a gig economy setting, and that low-cost, targeted technological accommodations can markedly enhance both worker productivity and firm performance.

This paper contributes to several literatures, the first one being that on the economics of disability. Within this literature, a large body of work studies the determinants and consequences of disability insurance and other social safety programs for disabled workers (Bound and Burkhauser, 1999; Deshpande, 2016; Autor et al., 2019; Deshpande and Lockwood, 2022). As noted above, there is also work estimating the impact of civil rights laws and quotas for disabled workers, but relatively little is known about what works in improving labor outcomes for disabled workers.[3] An important exception is Bloom et al. (2025) who argue that the large rise in work from home has helped increase the employment of disabled workers. Much less emphasized in this literature has been the importance of understanding what firms gain from hiring disabled workers. We are not aware of prior work that has been able to compare disabled and non-disabled workers in terms of individual productivity data. Furthermore, we are not aware of prior work estimating the impact of new technologies on disabled workers.

Pre-technology, while disabled workers are less efficient than non-disabled workers, they still appear to be more profitable overall. This highlights the importance of comparing a broad range of outcome variables in evaluating the profitability of disabled workers for firms, raising the intriguing possibility that some firms could overlook the value of disabled workers if they are focused exclusively on some outcome variables. Further, our results indicate that a simple technology can be highly valuable in improving the efficiency and overall profitability of disabled workers. While wage subsidies need to be paid each time a disabled worker is hired, new technologies may be more scalable.

Second, it contributes to work in personnel and organizational economics on demand for disadvantaged workers. There is growing interest in these fields in worker selection (Oyer and Schaefer, 2011). However, as pointed out in the recent handbook chapter by Hoffman and Stanton (2025), there has been relatively little work on firm returns from disadvantaged workers. One recent exception is Benson et al. (2024), who analyze productivity differences between white workers and workers from under-represented groups in a large US retail firm. There is also work on policies and firm returns in regard to hiring workers with a criminal

[3]In recent work, Lise et al. (2023) find that the ADA had a negative effect on the employment of disabled workers with work limitations, but a positive effect on the employment of disabled workers with non-work limitations, such as mental illness.

record (Minor et al., 2018; Cullen et al., 2023). To our knowledge, ours is the first paper in personnel economics to measure what firms gain from hiring disabled workers.

Third, it contributes to work in the economics of technology, platforms, and digitization. Digitization economists are deeply interested in the impact of how new technologies, like information technology or artificial intelligence, affect worker productivity (Bloom et al., 2012; Brynjolfsson et al., 2023). Our paper provides an example of a paper of a technology focused specifically on a group of disadvantaged workers, namely, those with a disability, illustrating how new technologies can affect not only productivity overall, but also groups of workers where concerns about externalities are strong. It also illustrates how high-frequency administrative data from online platforms can illuminate the exact pathways by which technology affects productivity, including at many points over a worker's day and different activities.

The remainder of this paper is organized as follows. Section 2 proposes a theoretical model of worker behavior and firm profits. Section 3 describes the study setting, data, and outcome metrics used to measure productivity differences and the impact of the technology. Section 4 examines the productivity and efficiency of disabled and non-disabled workers prior to the technological intervention and identifies bottlenecks faced by disabled workers. Section 5 analyzes the effects of the Intelligent Outbound Calling intervention and explores their implications for labor economics, business strategy, and future research. Section 6 concludes with a summary of findings and final reflections on the role of technology in fostering labor market inclusivity.

2 Model of Disabled vs. Non-Disabled Labor Supply on the Platform

We present a model of labor supply on the Platform to ground our empirical analysis and to make predictions about differences between disabled and non-disabled workers, as well as how disabled worker productivity is affected by new technologies. The model builds on rich ethnographic observations of disabled riders on the platform.[4]

Workers have a productivity level, z, which may differ between disabled and non-disabled workers. The share of total work time allocated to platform work is denoted by h, while $1-h$ represents the share of time spent on other pursuits. Output on the platform is given by zh, and workers are compensated at a piece rate w based on their output. If workers choose not to work, they have outside options, the value of which is captured by the disutility of working, denoted as r.

[4]We detail our institutional setting in Section 3 and present our ethnographic observations, including interviews and fieldwork, in the Appendix.

Therefore, worker utility is given by:

$$U = w \cdot zh + \frac{1}{\theta} r \left(1 - h\right)^{\theta} \tag{1}$$

In our empirical analysis, we measure productivity broadly, incorporating speed at different points, customer reviews, and average total time per order.

Workers make a decision about the share of their work time to spend on the Platform, with our first order condition:

$$\frac{\partial U}{\partial h} = wz - r\left(1 - h\right)^{\theta - 1} = 0 \tag{2}$$

From equation (2), we can write the hours worked as:

$$h = 1 - r^{\beta} \left(wz\right)^{-\beta} \tag{3}$$

The parameter $\beta \equiv \frac{1}{1-\theta}$ governs how responsive the worker's labor supply is to changes in productivity or the outside option. In other words, β captures how sharply the worker substitutes between platform and non-platform work. A *larger* β, corresponding to θ approaching 1, indicates that a small increase in the wage or productivity results in a *large* shift in platform work hours. Since we assume $0 < \theta < 1$, it follows that $\beta \in (1, \infty)$.

From equation (3), taking the partial derivative of h with respect to r and z, we can get:

$$\frac{\partial h}{\partial r} = -\beta r^{\beta - 1} \left(wz\right)^{-\beta} < 0 \tag{4}$$

$$\frac{\partial h}{\partial z} = \beta r^{\beta} w \left(wz\right)^{-(1+\beta)} > 0 \tag{5}$$

Based on our ethnographic observations, we posit two main differences between disabled and non-disabled workers:

Assumption 1.

$$r_D < r_N$$

First, we assume that disabled workers have worse outside options than non-disabled workers (i.e., $r_D < r_N$). This is consistent with a large body of economic literature on the challenges and discrimination faced by disabled workers.

Assumption 2.

$$z_D < z_N$$

Second, in the absence of helpful technologies or other accommodations, we posit that disabled workers may have lower productivity than non-disabled workers.

There are three main ways to think about behavior on the platform: efficiency (z), labor supply (h), and total output (zh). Based on the implications of the partial derivatives of h with respect to the outside option r and productivity z in equations (4) and (5), we derive several predictions:

Claim 1. Before the new technology, differences in working time between disabled and non-disabled workers are ambiguous.

The nature of this ambiguity depends on the relative differences in r (outside options) and z (efficiency). If the difference in outside options is larger than the difference in efficiency, disabled workers will work more hours than non-disabled workers. Conversely, if the difference in outside options is smaller than the difference in efficiency, disabled workers will work fewer hours.

Claim 2. Before the new technology, the average differences in total output and profits between disabled and non-disabled workers are ambiguous.

If the difference in outside options is large, then disabled workers may have higher output and profit than non-disabled workers.

Claim 3. Suppose a new technology increases the efficiency of disabled workers. This will also increase their working time, total output, and profits on the platform, thereby closing the gaps between disabled and non-disabled workers.

Firm profits from a worker on the Platform are given by

$$\pi = -c\,\mathbb{1}_{\{\text{hired}\}} + (1-w)\,zh, \tag{6}$$

where $\mathbb{1}_{\{\text{hired}\}}$ is an indicator function that equals 1 if the worker is newly hired and 0 otherwise. The term $(1-w)\,zh$ represents the portion of total output (zh) that remains with the firm after paying the worker, whose compensation is $w\,zh$. The term $-c\,\mathbb{1}_{\{\text{hired}\}}$ captures the onboarding or hiring cost, which is incurred only when a new worker is hired. We allow the onboarding costs for disabled and non-disabled workers to differ.

3 Institutional Context and Data

We study a large Chinese food-delivery platform, one of the two leading companies in the country's massive online food-delivery market. This platform operates similarly to services like Uber Eats or DoorDash but on a much larger scale. Together, the two main platforms

in China engage approximately 10 million delivery workers, making this a labor force larger than that of some entire countries. Our focal platform alone employs around 3 million workers, completing hundreds of millions of deliveries per month.

Delivery workers on this platform use motorbikes or e-bikes to transport food, groceries, and other items from restaurants, convenience stores, and pharmacies to customers. The service is available nationwide, with a higher concentration of workers in urban and eastern regions where food delivery is most prevalent.

A key feature of this platform is its open hiring policy: anyone who meets the basic requirements—such as minimum age, possession of a valid driver's license, and no disqualifying criminal record—can register and begin working. Importantly, there are no separate or stricter hiring standards for disabled applicants. This ensures that our study captures a representative cross-section of disabled workers who have chosen to enter this form of employment, rather than a pre-selected elite subgroup.

Workers on the platform can choose between two work models: a team-based model, where workers are assigned to stations and may receive a structured wage scheme (with unit prices following a step function based on the number of monthly completed orders), or gig work, where workers operate independently and are paid per delivery. The two groups also differ in task assignment. Team workers receive pickup assignments from the platform's algorithm, while gig workers claim pickups on a first-come, first-served basis through the app. For team workers, order assignment is prioritized based on the number of past completed orders, but disability status is not considered. Approximately two-thirds of the workers are gig workers, as shown in Table 1. Both worker types are included in our analysis, and we control for these differences in our empirical models.

Assignment of Workers to Deliveries

Order assignment is determined by three key metrics: the service score, rider level, and order acceptance rate.

Assignment Score = Service Score + Rider Level + Acceptance Rate

The service score primarily depends on customer reviews (particularly negative reviews) and instances of late deliveries. The Rider Level is calculated based on tenure and the cumulative number of completed orders. Refusing system-assigned orders directly reduces a rider's Acceptance Rate. Workers report that this factor has the greatest impact on assignment score, so they usually do not reject system-assigned tasks. Notably, a rider's disability status does not affect their order assignment score.

The order assignment score influences two key operational aspects. First, order assignment priority is primarily determined by the assignment score, but the system also takes

logistical efficiency into account. Orders are assigned in a way that aligns with a rider's current route, optimizing for route consistency and operational effectiveness. Second, the assignment score affects the maximum number of concurrent orders a rider can handle. The maximum number of concurrent orders starts at a baseline of 3, with an upper limit of 13 for gig workers and 20 for team workers. A higher assignment score results in a greater allowable maximum. Typically, experienced workers handle an average of six concurrent orders, while high-performing workers can manage even more, often reaching around ten concurrent orders.[5]

Critically, disability status is not used in the assignment of workers to deliveries.

Data

Our dataset is a proprietary administrative panel provided by the platform, covering a three-year period from 2021 to 2023. The unit of observation is the worker-week—that is, for each worker in each week, we have detailed data on their activity and performance. The sample includes:

- $4,296$ hearing-impaired workers who registered and worked on the platform between 2021 and 2023.
- $40,000$ non-disabled workers, randomly selected from the pool of all workers who registered in the same period, to serve as a comparison group.
- In total, we have hundreds of thousands of worker-week observations.

This dataset allows us to track each worker from the start of their tenure on the platform and analyze how their performance evolves over time. Importantly, by focusing on newly registered workers, we can compare disabled and non-disabled workers from their point of entry, ensuring a fair and meaningful comparison.

The technological intervention was rolled out suddenly in April 2022 to all hearing-impaired workers. We have one year of pre-intervention data to compare the performance of disabled and non-disabled workers, and we tracked the workers for more than a year after the experiment to study its impact.

[5]Gig workers and team workers have distinct order allocation methods. Gig workers primarily rely on independently selecting orders from the order pool. While they do receive system-assigned orders, these are preferentially assigned to team workers under the same conditions. On average, 20% of gig workers' orders come from the system, while the remaining 80% are manually selected by the workers themselves. Gig workers operate across the entire city, often covering multiple commercial districts. In contrast, team workers almost entirely depend on system-assigned orders. The typical assignment range for team workers is within six kilometers of their designated station.

We examine a wide range of outcome variables capturing different aspects of worker performance, categorized into three main groups:

1. Total Output (zh in our model): Measures the number of orders completed per week and the coverage of serviced areas, including the total number of unique restaurants and customers served.

2. Efficiency (z in our model): Captures service quality and the average time spent per delivery, further broken down into time spent at each stage of the work process.

3. Labor Supply and Retention (h in our model): Includes total hours spent online per working day, the number of days worked per week, and the worker's retention rate.

We summarize all outcome variables below:

1. Total Output (zh)	2. Efficiency (z)	3. Labor Supply (h)
Total Orders Delivered	Order → Worker	Total Hours Online
Total Orders in Peak Hours	Worker → Store	Number of Working Days
Number of Restaurants Served	Store → Delivery	Working Days During Bad Weather
Number of Customers Served	Ratings (Number of Bad Reviews)	Survival Rate

There are three steps in the work process, and at each step, the worker must perform an action on the app, which provides a clear time stamp for when each step starts and finishes. We do not have this information at the order level, but we do have the average time spent per order at the worker-week level.

The three steps are as follows: First, once an order is initiated by the customer, it is assigned to a worker (Order → Worker). Second, once the worker receives the order, they pick it up from the restaurant (Worker → Store). The waiting time for food preparation is included in this step, which concludes when the worker actually receives the food from the restaurant. Lastly, the worker delivers the order to the customer (Store → Delivery).

Additionally, our dataset includes various control variables that account for worker characteristics and job conditions. These variables include worker demographics (e.g., age, gender), city of work, worker type (team-based vs. gig worker), registration cohort (year of entry), and order attributes (e.g., average customer-to-restaurant distance). By incorporating these controls, our empirical analysis ensures that comparisons between disabled and non-disabled workers are made under similar conditions.

Table 2 provides a detailed summary of key performance indicators for food-delivery workers, categorized into Total Output, Efficiency, and Labor Supply on the Platform.

On average, workers completed about 130 deliveries per week, with a median of 89. The standard deviation is quite large (about 140), indicating considerable variation in total deliveries. Peak-hour orders, which occur during high-demand times, account for about 77 deliveries per worker per week, suggesting that a substantial share of total orders happens during peak times. Team-based workers complete significantly more deliveries on average (103) compared to individual workers (25), reflecting the full-time nature of team-based work.

The time spent in different stages of the delivery process follows some notable patterns. The order-to-worker assignment time is relatively short, averaging 3.4 minutes, though the median is much lower at 2.4 minutes, indicating that most deliveries are assigned and accepted quickly, but a few take much longer. The worker-to-store travel time averages 11.6 minutes, with a median of 11.4 minutes, suggesting fairly consistent travel times. The store-to-delivery time is slightly longer at around 14 minutes, with a standard deviation of 5.6, implying variability due to delivery distances and potential communication delays with customers. Customer satisfaction, measured as bad ratings per 10,000 orders, averages 9.6, though the median is 0, indicating that most workers receive very few negative reviews, but a subset accumulates significantly more complaints.

Workers spend an average of about 1,520 minutes online per week, with a median of around 590 minutes. The high standard deviation (about 1,800) indicates wide variation in work intensity, with some workers putting in significantly more hours than others. The median number of workdays per week is 6, though the average is lower at 4.5, suggesting that while many workers work full weeks, others participate part-time or intermittently. The median tenure on the platform is 3 weeks, but the average is 11 weeks, with a high standard deviation, indicating that while many workers leave quickly, a significant portion remain active for longer durations.

In summary, the data reveal substantial variation in work intensity among workers—while some deliver a high volume of orders, many operate on a more part-time basis, as evidenced by the wide distribution in orders completed and hours worked. Team-based workers are notably more productive, handling nearly four times as many orders as gig workers, suggesting structural differences in work allocation and efficiency. Finally, while retention is high for some workers, a significant portion of workers do not stay on the platform for long periods.

Ethnographic Observations

In addition to analyzing quantitative data, our research team conducted qualitative fieldwork to better understand the experiences of disabled workers. This included:

1. Interviews with 10 hearing-impaired workers to learn about their daily routines, challenges, and communication methods.

2. On-the-ground field observations were conducted, during which researchers accompanied disabled workers and delivered orders full-time alongside them. In total, the researchers completed slightly more than 100 deliveries over multiple days. The purpose of these observations was to gain firsthand insight into the work environment of disabled workers, including their delivery process and customer interactions.

These qualitative insights helped us interpret patterns in the data and identify specific barriers faced by hearing-impaired workers—particularly in areas such as customer communication, navigation, and service speed. They also provided context for understanding labor supply differences, as many hearing-impaired workers expressed a strong attachment to their jobs due to limited alternative employment opportunities. Details of the interviews, photos, and fieldwork documents are provided in the Online Appendix A.

Together, the combination of high-frequency administrative data and direct ethnographic observation provides a rich and comprehensive view of the productivity, efficiency, and retention of disabled workers in the gig economy. This dataset and research approach form the foundation for our empirical analysis.

4 Measuring Productivity and Efficiency Differences

Our analysis proceeds in two stages. First, we measure the performance differences between disabled and non-disabled workers prior to the introduction of the new technology. Second, we evaluate the impact of the Intelligent Outbound Calling technology on the outcomes of disabled workers (versus a comparison group of non-disabled workers) using a difference-in-differences approach.

4.1 Empirical Strategy and Econometric Specifications

Using data from before the technological intervention in April 2022, we first compare the job performance of disabled (hearing-impaired) workers to that of their non-disabled counterparts. To estimate the average differences between these groups, we employ a regression framework. Essentially, we regress each outcome of interest on a disability indicator and a set of controls. The baseline specification is:

$$Y_{it} = \alpha + \beta\, Disability_i \;+\; \mathbf{X}'_{it}\gamma \;+\; \mu_t \;+\; \chi_i \;+\; \varepsilon_{it}, \tag{7}$$

where worker i works during week t, Y_{it} represents the outcome for worker i in week t. The term $Disability_i$ is a dummy variable indicating whether worker i is hearing-impaired (disabled) or not. To adjust for differences in the nature of work performed, we include a vector of time-varying controls, $\mathbf{X}_{it}$, such as the average customer-to-restaurant distance of orders that week. Additionally, we incorporate a set of worker characteristics, χ_i, including their city of work, team worker status, age, gender, and registration year. The term μ_t represents the time fixed effect. Standard errors are clustered at the individual level. We apply this analysis across multiple outcome categories, including efficiency metrics, output metrics, and labor supply metrics.

Next, we investigate the dynamics of worker productivity by estimating productivity-tenure curves separately for disabled and non-disabled workers. We employ a regression approach in which each parameter β_t captures the average productivity level of workers at tenure t months on the platform. Specifically, we estimate the following equation:

$$y_{it} = \sum_t \beta_t \times \mathbb{1}[\text{Tenure}_i = t] + \mathbf{X}'_{it}\delta + \epsilon_{it}, \tag{8}$$

where y_{it} denotes the productivity outcome for worker i in week t. The key explanatory variables are a set of tenure indicators ($\mathbb{1}[Tenure = t]$), allowing the estimation of productivity at each specific tenure level. We include a vector of time-varying controls ($\mathbf{X}_{it}$), such as the average customer-to-restaurant distance, to account for systematic differences in order characteristics that could influence worker productivity. Additionally, year-month fixed effects and city fixed effects are incorporated into the regression model to control for common temporal shocks, seasonal patterns, and location-specific factors that may influence productivity independently of worker tenure. Standard errors are clustered at the worker level to account for serial correlation within individual observations.

4.2 Results

Table 3 summarizes regression results for key outcome measures prior to the introduction of the new technology, where each coefficient represents the estimated difference associated with the Disability indicator (disabled = 1) from equation (7), controlling for various factors described earlier. For ease of exposition, these performance differences are illustrated in Figure 1. The bar plots depict effect sizes standardized by sample standard deviations, providing a clear visual comparison between disabled and non-disabled workers.

Total Output

Disabled workers deliver more orders per week on average than non-disabled workers. Specifically, being a disabled worker is associated with completing approximately 3 additional orders per week (2% more than non-disabled workers). They also complete about 2 more peak-hour orders per week (during high-demand periods). These differences are substantial, given that the median number of weekly orders in the sample is only a few dozen. The positive output differential is even larger within the subset of Team deliveries: disabled team workers handle approximately 10 more orders per week (4.7% more) than their non-disabled counterparts. Conversely, in the Gig (independent) segment, disabled workers complete about 5 fewer orders per week (9.6% less) than non-disabled gig workers.

This likely reflects a sorting or selection effect: the Team format provides more stable order assignments, and team workers can seek help from station managers, whereas purely gig-based workers are more independent and rely entirely on themselves. Nonetheless, aggregating across types, the total orders delivered per week is higher for disabled workers. Furthermore, disabled workers tend to serve a broader range of customers and merchants: they serve on average 4 more restaurants and 7 more unique customers (per week) than comparable non-disabled workers. These metrics reinforce the idea that disabled individuals are providing a high volume of service on the platform. The finding that disabled workers have higher total output aligns with our expectation that their greatly increased work time (to be discussed shortly) more than compensates for any per-order speed disadvantage. It also directly answers part of our first research question: in terms of sheer output, the firm gains somewhat more from an average disabled worker than from a non-disabled worker in the short run.

Efficiency (Speed and Quality)

Despite their higher output, disabled workers do exhibit some efficiency shortfalls on a per-order basis. In our data, disabled status is associated with slower delivery times in each segment of the order fulfillment process. For the stage from order initiation by the consumer to order assignment to the worker, disabled workers take about 0.16 minutes longer per order on average (approximately 5% slower than non-disabled workers). For the stage from confirming the order assignment to departure—which includes traveling to the restaurant, communicating with restaurant staff, and picking up the order—they are about 0.21 minutes slower (1.7% slower). The largest gap occurs in the final stage, from leaving the restaurant to delivering the order to the customer: disabled workers take about 1 minute longer (approximately 5.6% more) on average.

All these differences are statistically significant. While being less than a minute slower on average may seem minor for a single delivery, across many deliveries, the time adds up. This pattern aligns with insights from our interviews, which indicate that a major hurdle is communicating with customers upon arrival. Our fieldwork reveals that, in most cases, disabled workers are just as efficient as non-disabled workers. However, there are occasional situations where workers need to communicate extensively with customers, leading to significant delays.[6] In China, delivery workers are generally expected to call the customer upon arrival—for instance, to coordinate the handoff or confirm the delivery if the food is left in a delivery cabinet or at the front desk.

Prior to 2022, hearing-impaired workers who could not speak had to rely on app messaging or make a call, wait, and hope the customer noticed the message. This often led to delays – which likely explains why the Store → Delivery time segment (covering the travel to customer and the handoff) showed the largest delay. Additionally, disabled workers might drive slightly more cautiously or slower due to their hearing impairment (for safety), contributing to these time gaps. We also find that disabled workers receive lower customer ratings on average. Specifically, they receive about 5 more "bad" reviews per 10,000 orders delivered (33% more) compared to non-disabled workers.

In absolute terms, customer complaints are rare for both groups (the baseline bad review rate is low), but this difference is meaningful – it suggests that hearing-impaired workers were more likely to have instances of customer dissatisfaction. Customers might become frustrated if they cannot communicate easily with the worker (for example, if a worker cannot call to find them), or may misinterpret a lack of spoken communication as rudeness. Indeed, some hearing-impaired workers in interviews recounted instances where customers didn't realize the worker was hearing-impaired and left poor feedback about "not calling" or "not speaking clearly."

This gap in service quality is an important finding because it hints at a potential long-run risk: if customers are less satisfied, they might order less or the platform's reputation could be affected. The platform noted this concern, which is one reason they invested in the calling technology. In summary, before the intervention, disabled workers were slightly less efficient per order and had lower customer service ratings than their peers – confirming that $z_D < z_N$ in our model terms. However, these efficiency gaps did not stop disabled workers

[6]For example, during one delivery, when we were halfway to delivering the food, we received a phone call from the restaurant owner. She said she had forgotten to add fresh tomato to the package, as the customer had requested. She asked if we could return to the restaurant to pick it up. We had to explain that we were already halfway and couldn't go back without delaying the order. At the same time, we also needed to ask the restaurant owner to call the customer directly and explain the situation in case the customer blamed us and left a bad review.

from contributing strongly to the platform, thanks to their work effort, as we discuss next.

Labor Supply

Perhaps the most striking differences are in labor supply. Disabled workers tend to provide significantly more labor on the platform. Our regression results show that, controlling for other factors, disabled workers spend about 25 more minutes online per week (3.66% more). This finding is consistent with the notion that the disabled workers have fewer alternative opportunities and hence are willing to work more hours (i.e., their effective r is lower, driving a higher h^*). We also find disabled individuals work slightly more days per week: about 0.3 additional work days on average (5.18% more). It is not uncommon for hearing-impaired workers to work 6 or even 7 days a week, whereas some non-disabled workers might treat this as a secondary job and work only weekends or a few days. Furthermore, disabled workers are more likely to work during unpleasant conditions, with about 0.05 more days in bad weather (rain, etc.) per week than others.

This suggests a strong commitment – even when conditions are unfavorable, they tend to keep working (possibly because they really need the earnings). Finally, and importantly, disabled workers have substantially higher retention rates on the platform. We measure a "survival" metric indicating whether a new hire is still active after a certain period. The regression coefficient of 0.0628 can be interpreted as an approximate 12 percentage-point higher probability of remaining active at a given point (we observe them up to the end of 2023).

In practical terms, hearing-impaired workers are much less likely to quit. Many non-disabled workers treat the job as temporary—turnover is high—but disabled workers often remain on the platform longer, perhaps due to the scarcity of stable job opportunities for them. We confirmed this pattern by plotting Kaplan-Meier survival curves (Panel (a) of Figure 7): the curve for disabled workers lies significantly above that of non-disabled workers, indicating that a higher fraction of disabled workers continue working months after joining. We further explore onboarding and retention in the next subsection.

Onboarding and Retention

Figure 7 illustrates survival curves based on weeks worked. During the onboarding phase, defined as the period after individuals register as potential workers but before they deliver any orders, the exit rate for disabled workers is notably higher compared to their non-disabled counterparts. Specifically, 22% of non-disabled registrants never begin delivering orders, whereas this percentage increases for disabled workers (38%), indicating a significant

onboarding challenge among disabled individuals.

Qualitative insights from interviews identify key barriers faced by disabled workers during onboarding, primarily inadequate support and technological hurdles. Disabled workers frequently report difficulties such as unfamiliarity with restaurant locations, challenges in navigating apartment complexes, and significant mental stress related to potential communication issues with restaurant staff or customers in case of disputes.

However, Figure 7 also reveals a two-stage retention dynamic. After the initial challenging months, both disabled and non-disabled workers experience decreased attrition rates. Notably, disabled workers who surpass the initial onboarding period show a marked stabilization in employment, typically around eight months. This stabilization indicates that once initial barriers are overcome, disabled workers tend to achieve comparable or even superior long-term retention rates compared to non-disabled workers.

Interview data further corroborate this finding, suggesting that long-term retention among disabled workers is greatly facilitated by increased familiarity with their work environment, including neighborhoods, frequently visited restaurants, and common delivery destinations such as condominium complexes. Additionally, team workers emphasize the pivotal role of managerial support (from station managers) and peer support (from other disabled workers in the same team) in fostering job satisfaction and loyalty.

These findings underline a two-stage retention process: a critical initial phase marked by large attrition for disabled workers due to onboarding difficulties, followed by a stable employment period characterized by robust retention. Improving onboarding practices—such as providing targeted accommodations, promoting social inclusion, and offering strong managerial support from day one—could effectively reduce early attrition among disabled workers. Addressing these early challenges not only closes the initial retention gap but also harnesses the high potential for loyalty and long-term attachment that disabled workers frequently demonstrate once integrated into their roles.

4.3 Profits

We utilize the previously identified performance differences to estimate the profit disparity between disabled and non-disabled workers. Disabled workers tend to stay longer and complete more orders each month but are also more likely to receive negative reviews and experience late deliveries.

Using our definition of the profit function in equation (6), the profit difference between

disabled (D) and non-disabled (N) workers can be formally expressed as:

$$\Delta\pi = (1 - w) \cdot E(Y^D - Y^N) - c \cdot \Delta Pr(\text{hired} = 1), \tag{9}$$

where Y^D and Y^N represent the number of orders completed by disabled and non-disabled workers, respectively; w denotes the wage rate; c represents the onboarding cost; and $Pr(\text{hired} = 1)$ captures the differential probability of worker retention (i.e., survival probability).

Based on discussions with the platform, we assume a wage rate of approximately 80% and an average order revenue of 10 CNY. According to Table 3, disabled workers complete an average of 2.3 more orders per week than their non-disabled counterparts. On average, as shown in Table 2, a worker remains active on the platform for 11 weeks. Given these assumptions, the expected incremental weekly profit from disabled workers relative to non-disabled workers, considering order completion alone, is:

$$(1 - 0.8) \times 10 \text{ CNY} \times 2.3 \text{ orders/week} \times 11 \text{ weeks} = 51 \text{ CNY}.$$

Furthermore, disabled workers exhibit a higher retention rate. Table 3 shows that disabled workers have a 6.2 percentage point higher probability of continued employment (survival probability).

For the onboarding cost, we assume it is equivalent to two weeks' worth of wages, accounting for screening and onboarding expenses, as well as productivity differences between new and experienced workers (Blatter et al., 2012). This assumption aligns with insights from platform representatives, station managers, and workers. Given that the average weekly wage is approximately:

$$129 \text{ orders} \times 0.8 \times 10 \text{ CNY} = 1032 \text{ CNY},$$

the onboarding cost, c, is equal to two weeks' wages, or 2064 CNY (approximately USD 290). Thus, the incremental profit due to higher retention among disabled workers is:

$$c \cdot \Delta Pr(\text{hired} = 1) = 2064 \text{ CNY} \times 0.062 = 128 \text{ CNY}.$$

Combining both factors—higher weekly performance and increased retention—disabled workers generate approximately 179 CNY (about USD 25) more profit per worker than non-disabled workers. Given the platform's current workforce of approximately 10,000 disabled workers, this translates to a substantial benefit of over 1 million CNY.

5 Evaluating the Technological Intervention

The "Intelligent Outbound Call" is a feature on the app specifically designed to empower disabled delivery workers, particularly those with hearing and speech impairments, by enhancing their ability to communicate effectively with customers during delivery processes.

Prior to the introduction of this technology, disabled workers were restricted to communicating solely through text-based messages within the delivery platform's app. This posed significant challenges, as typed messages such as "Can you open the door for me?" or "I cannot find the place, please allow me an extra five minutes" often went unnoticed or unanswered by customers, resulting in delays, misunderstandings, and added stress for the workers.

In late April 2022, the platform introduced the "Intelligent Outbound Call" feature, which allows disabled workers to initiate automated voice calls to customers directly through the app. Each call begins with an introductory message clearly stating that the caller is a disabled worker using an automated system due to communication barriers, followed by a specific message conveying the worker's issue or request (for example, "Your food will be placed in a locker"). After selecting a prompt, the app initiates an automated voice call to the customer.

The system provides workers with a selection of default prompts (Panel (a) of Figure B.1) or the option to create and customize prompts tailored to specific situations. In Online Appendix B, we include a screenshot showing commonly used customized prompts by disabled workers (Panel (b) of Figure B.1). These prompts typically fall into one of the following categories: (1) difficulty locating the customer, such as when security denies the worker entry or when a buzzer code is needed; (2) notifying the customer that the order has been placed at a specific location, such as a food cabinet; or (3) politely requesting a positive review.

The advantages of the "Intelligent Outbound Call" technology include: first, enhanced customer responsiveness, as customers are significantly more responsive to phone calls compared to app notifications, ensuring prompt attention to critical communications; second, improved efficiency, since disabled workers can quickly address common issues through preset prompts without repeatedly typing messages, saving valuable time especially during peak delivery hours or adverse weather conditions; and third, personalization and flexibility, as workers can customize messages to clearly and effectively communicate unique situations.

To assess the impact of the Intelligent Outbound Calling feature, we employ a difference-in-differences (DiD) research design. The basic idea is to compare the changes in outcomes for the treated group (disabled workers, who benefited from the new feature) before vs. after the intervention, relative to the changes experienced by a control group (non-disabled

workers, who were not directly affected by the feature).

Let *Post* be an indicator variable that equals 1 in the period after the introduction of the new technology (Intelligent Outbound Calls, late April 2022 onwards) and 0 before. Our DiD regression can be specified as:

$$Y_{it} = \gamma \, \mathbb{1}[Disabled_i = 1] \times Post_t \; + \; \lambda_i \; + \; \xi_t \; + \; \varepsilon_{it}. \tag{10}$$

The interaction term $Disabled_i \times Post_t$ captures the DiD estimate of interest, and γ measures the differential impact of the technology on disabled workers relative to their non-disabled counterparts.

We include worker fixed effects λ_i and time fixed effects ξ_t. Worker fixed effects control for any time-invariant differences across individuals, while time fixed effects (weekly or monthly) capture trends affecting all workers. We estimate equation (10) using panel data at the worker-week level. Standard errors are clustered at the individual level to allow for correlation in errors within workers across time.

Figure 3 summarizes the treatment effects of the technology on all our outcomes. The bar plots depict effect sizes standardized by sample standard deviations, providing a clear visual comparison between disabled and non-disabled workers. The original regression results are reported in Table 4.

Total Output

The introduction of Intelligent Outbound Calling (IOC) led to a significant increase in the number of orders completed by disabled workers. Treated workers (hearing-impaired) delivered about 6 more orders per week because of the technology, representing a 4.7% increase compared to the average number of weekly orders for disabled workers prior to the intervention. This is an additional boost on top of their existing output advantage – effectively, the gap in weekly orders between disabled and non-disabled widened further post-intervention, in favor of disabled workers. The increase is particularly notable in the gig segment, where disabled workers delivered 9 more orders per week than they otherwise would have—an 18% increase compared to their pre-technology intervention average.

Interestingly, recall that pre-intervention, disabled gig workers were delivering fewer orders than non-disabled gig workers (a -5 gap). After IOC, not only did they catch up, they surpassed non-disabled gig workers by a considerable margin. In the team segment, there was a positive but smaller and only marginally significant effect of an additional 3 orders. This suggests that IOC particularly helped those hearing-impaired workers who were working in the more independent gig mode – possibly because team settings already had some

support or workarounds in place, whereas gig workers really benefited from the feature. In terms of other output metrics, disabled workers post-IOC served more restaurants (+4) and more customers (+6) than they would have without the technology. All these gains are statistically significant.

The bottom line is that the technology allowed disabled workers to handle an even larger volume of orders. This could be due to multiple reasons: faster turnover per order (if each order takes less time, they can fit more in a day), higher customer retention (if customers complain less, workers stay active and get more orders), or even the platform's algorithm giving them more orders if their metrics improved. Our analysis cannot pinpoint the exact mechanism, but the net effect is clearly a boost in output. For the platform, this means higher revenue per disabled worker after the intervention.

Efficiency and Service Quality

The IOC feature was aimed at improving communication, so we expect to see improvements in the efficiency metrics, particularly those related to the delivery handoff. Indeed, the data show that after IOC, the time spent in the final stage (store to delivery) by disabled workers decreased significantly relative to non-disabled: a reduction of 0.3 minutes per order on average. This indicates a substantial closing of the gap – recall the pre-IOC disabled lag in this stage was 0.82 minutes, so roughly one-third of that gap was eliminated immediately after introducing the call feature. Interestingly, for the earlier steps (Order $\rightarrow$ Worker dispatch time, and Worker $\rightarrow$ Store travel time), the coefficients are small and not statistically significant. This suggests those steps in the work prcess were not really affected by the calling feature, as expected (those stages don't involve customer interaction). Thus, IOC specifically tackled the delay at the delivery stage, which was indeed the main pain point.

Crucially, customer satisfaction for disabled workers improved markedly. The number of bad reviews per 10,000 orders for disabled workers dropped by about 2 relative to the control trend. This is a significant improvement, given that before IOC, disabled workers had around 5 more bad reviews per 10,000 orders than non-disabled workers. This reduction means that the gap in bad reviews between disabled and non-disabled workers shrank significantly. Customers presumably had fewer reasons to complain once they started receiving the normal phone call alerts (albeit automated) from disabled workers. The communication friction was alleviated, leading to smoother delivery completions and happier customers. Qualitatively, our interviews with workers after IOC indicated they felt more confident and had fewer incidents of misunderstanding. Some customers even left positive feedback, appreciating the effort when they realized that the worker was hearing-impaired and was using an assistive calling system.

Labor Supply and Retention Post-Intervention

Our diff-in-diff results show no significant change in total hours online for disabled workers attributable to the IOC introduction. The coefficient on online duration is negative (roughly -1.4 hours per week if averaged, but with a very large standard error) and not statistically different from zero. Thus, we cannot reject that disabled workers kept their heavy work hours roughly the same after getting the new tool. They did slightly increase the number of days worked per week, by about 0.14 days. This could mean a few more disabled workers decided to work a 7th day occasionally when they might not have before, perhaps feeling more empowered. Notably, however, disabled workers significantly increased their bad-weather working days by 0.05 (a 7.7% increase compared to the pre-IOC mean), indicating greater willingness to work in tough conditions. Typically, during bad weather (heavy rain or heavy snow), there is a higher likelihood of food preparation delays, increased order volume, and more unexpected situations, requiring workers to communicate more frequently with customers.

Importantly, the retention of disabled workers improved further. The survival probability of disabled workers rose by an additional 6.2 percentage points post-IOC relative to non-disabled. This is a striking effect on top of an already higher baseline retention. It implies that the technology not only helped in performing the job but may have increased job satisfaction or viability for disabled workers, leading them to stay longer. In essence, IOC made the platform an even more attractive and sustainable workplace for disabled workers, which is a positive outcome both socially and for the firm (as it reduces hiring and training costs through lower turnover).

In conclusion, the Intelligent Outbound Calling feature had a positive and significant impact on the productivity, efficiency, and retention of disabled delivery workers. It effectively boosted the productivity of disabled workers, substantially closing the performance gap between disabled and non-disabled, and in some aspects even giving disabled workers an edge. This provides an affirmative answer to our second research question: yes, a new IT tool can increase the value of disabled workers to the firm, as evidenced by improvements in their output and service quality metrics post-intervention.

6 Conclusion

We examine the productivity of hearing-impaired food-delivery workers in China and evaluated a technological intervention designed to boost their performance. Using detailed data from a major delivery platform, we address two key questions: What do firms gain from

disabled vs. non-disabled workers? and Can new technology increase the value of disabled workers to firms?

First, we document that even in the absence of special accommodations, hearing-impaired (disabled) workers generate as much if not more total output than their non-disabled peers, despite facing efficiency challenges on a per-order basis. Disabled workers achieved this through greater labor supply — they spent more time online and were significantly less likely to quit, indicating remarkable commitment and attachment to the job. This result challenges any prior assumption that disabled workers are less productive; on the contrary, in a supportive platform setting, they can be high-output workers.

Second, we found that a targeted IT solution — the Intelligent Outbound Calling feature in our context — substantially improved disabled workers' productivity and service quality. After the introduction of this text-to-voice calling system, disabled workers' delivery speeds improved (especially in the previously problematic last-mile stage), their customer complaint rates dropped sharply, and their weekly order completions increased further. The efficiency gap between disabled and non-disabled workers narrowed dramatically as a result, and disabled workers' already high retention got even better. These improvements illustrate the power of a relatively low-cost, focused technological intervention to enhance both worker outcomes and firm performance. Notably, our evidence suggests that the gains from the technology likely exceeded its costs, implying a net private benefit to the firm in addition to the social benefits.

Overall, our study underscores the economic value that disabled workers can bring when they are inclusively employed, and it demonstrates a practical way to unlock that value. The combination of granular productivity data and a natural experiment allowed us to isolate the effect of inclusion efforts in a real-world setting. The findings carry encouraging implications: they show that with the right tools, equity and efficiency can go hand in hand. A firm does not have to sacrifice performance to hire disabled workers — if anything, it stands to gain loyal and hardworking employees. For policymakers, the lesson is that facilitating such investments (through incentives or support for assistive tech) may be more fruitful than purely relying on mandates or anti-discrimination enforcement.

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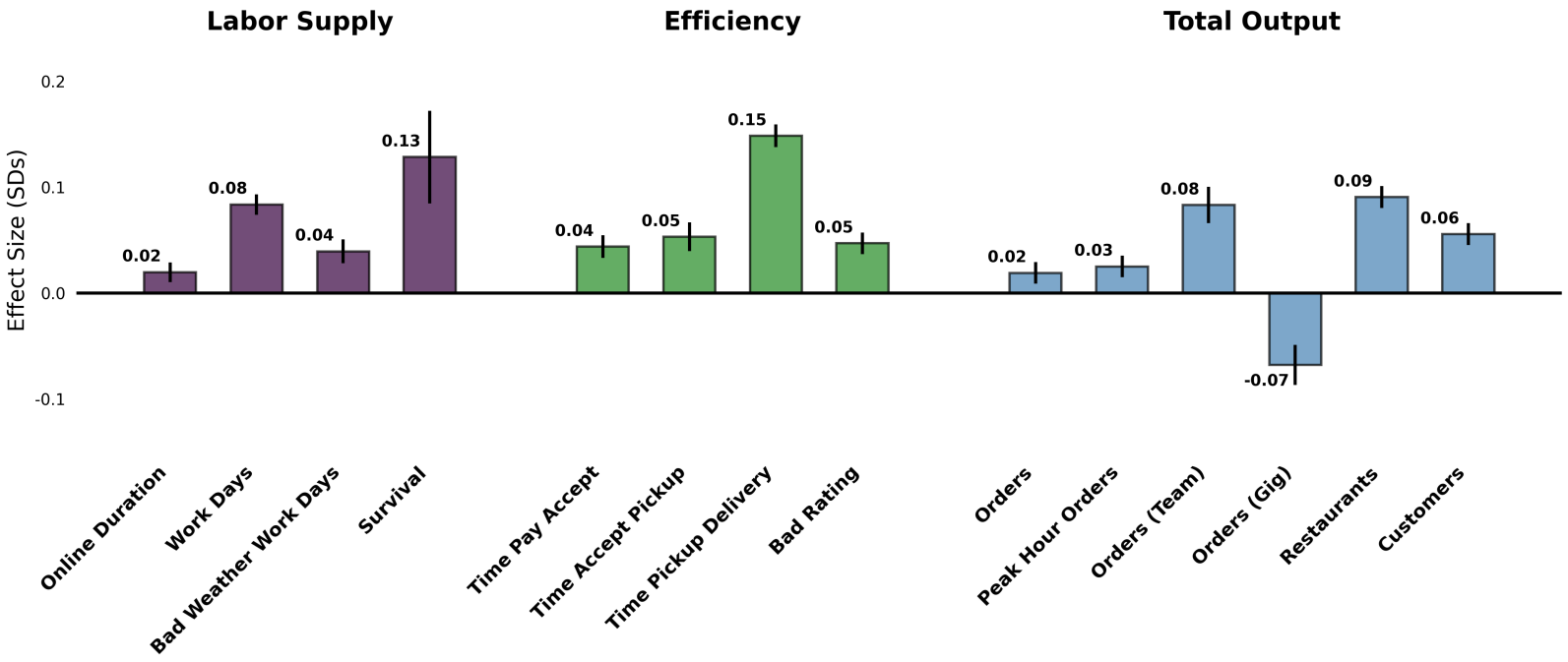
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Figure 1: Effect Sizes of Disabled vs. Non-Disabled Performance Differences (Pre-Treatment)



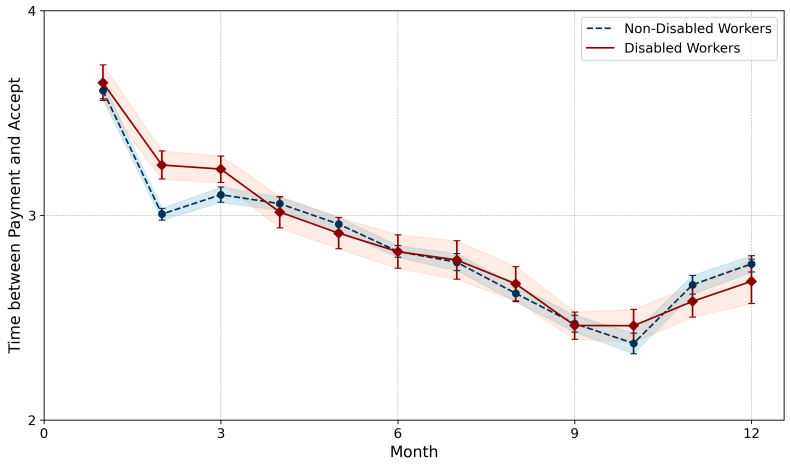
Notes: This Figure visually summarizes the performance gaps between disabled and non-disabled workers across key metrics before the intervention, based on regression results from Table 3. Each bar represents a standardized difference associated with being a disabled worker for a given outcome (e.g., weekly orders, delivery time). "Standardized" means the differences are measured in units of the variable's standard deviation, allowing direct comparison across different metrics. A bar above zero indicates that disabled workers score higher on that metric, while a bar below zero indicates they score lower relative to non-disabled workers. Error bars represent 95% confidence intervals, providing an estimate of precision. If an error bar crosses zero, the difference is not statistically significant, whereas bars entirely above or below zero indicate significant differences, as confirmed by Table 3.

Labor Supply covers weekly work effort: *Online Duration* (total time the worker was online and available for orders, measured in minutes per week), *Work Days* (number of days the worker was active in that week, out of 7), *Bad Weather Work Days* (days the worker worked in bad weather conditions like rain or snow that week), and *Number of Weeks Worked* which is the total number of weeks the worker has been active on the platform up to that point or in total. The last variable essentially reflects each worker's tenure or longevity on the platform.

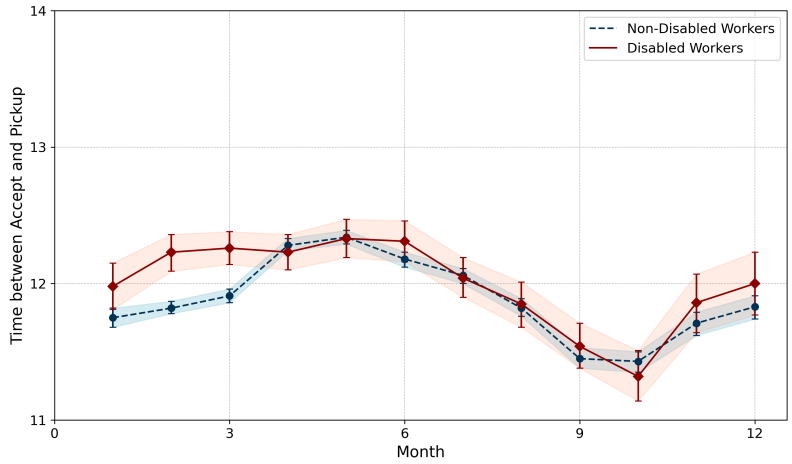
Efficiency records average time durations for each delivery stage: *Order* $\rightarrow$ *Worker* is the dispatch time from order placement to a worker accepting it, *Worker* $\rightarrow$ *Store* is the travel time from accepting the order to arriving at the restaurant, *Store* $\rightarrow$ *Delivery* is the travel time from pickup to delivering to the customer. These times are measured in minutes per order (averaged over the week for each worker). *Bad Rating* is the number of negative customer ratings received, normalized per 10,000 orders.

Total Output includes: *Orders* (the total number of delivery orders completed by a worker in a week), *Peak Hour Orders* (the subset of those orders delivered during peak demand hours), *Orders (Team)* and *Orders (Gig)* (weekly orders completed by workers in each registration category – effectively the average weekly orders if the worker is a team worker vs. if they are a gig worker), and the number of unique *Restaurants* and *Customers* served per week.

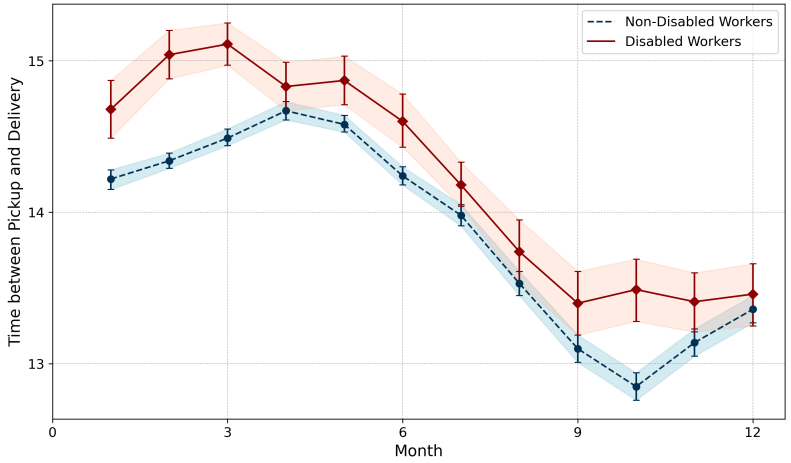
Figure 2: Tenure Curves for Time Spent per Order (Months of Experience)



(a) Time Spent Between Order → Worker (Per Order)



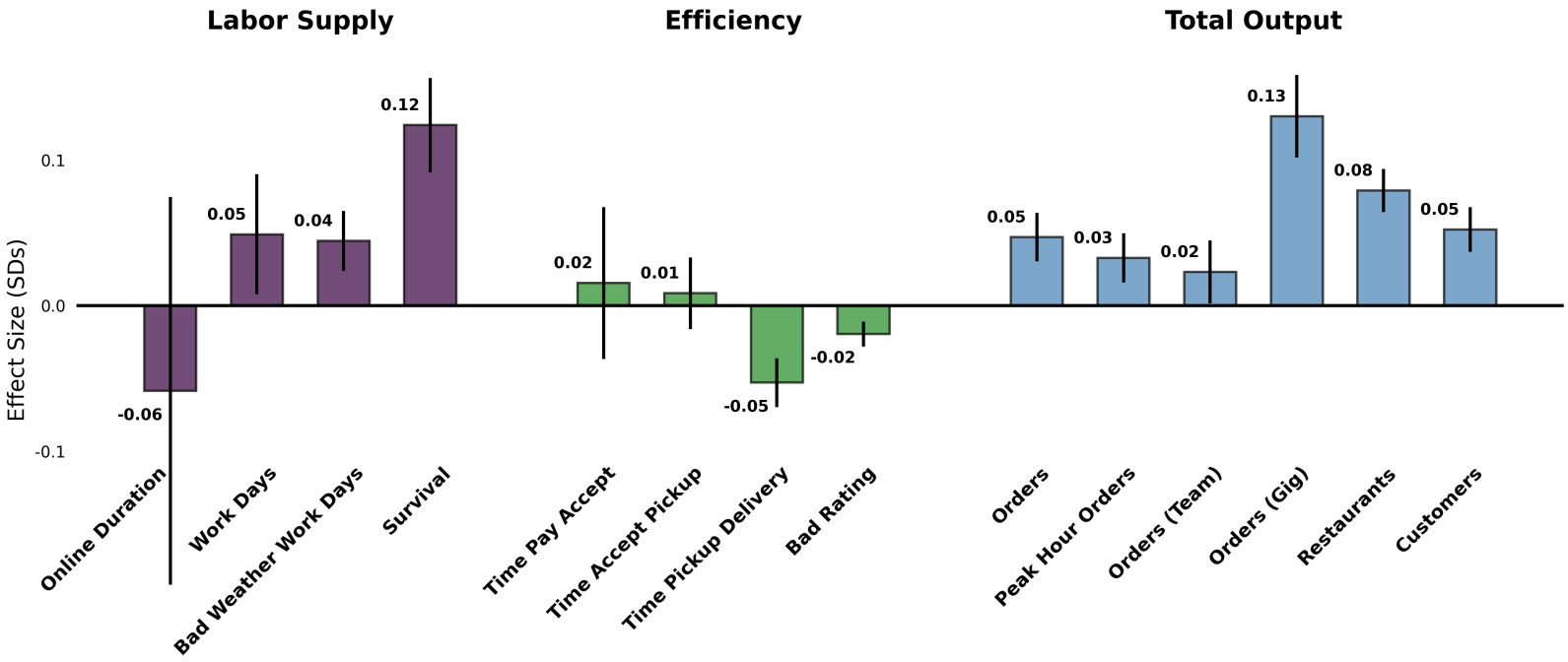
(b) Time Spent Between Worker → Store (Per Order)



(c) Time Spent Between Store → Delivery (Per Order)

Notes: Figure 2 examines how worker efficiency (speed) changes with experience (*tenure*) on the platform. It plots the average time spent per order at each month of a new worker's tenure for both disabled and non-disabled groups across three panels: **Panel (a) Order → Worker**: Average dispatch time (minutes per order) from customer order to rider assignment, tracked by tenure month. **Panel (b) Worker → Store**: Average time (minutes per order) from assignment to arrival at the restaurant. **Panel (c) Store → Delivery**: Average time (minutes per order) from food pickup to customer delivery. Each point on a curve represents the mean time for that stage among workers with a given tenure month. For example, at "Month 1," the figure shows the average per-order time for all workers in their first month, while at "Month 6," it represents the average for those with six months of experience. Error bars represent the 5th to 95th percentile confidence interval. The red solid line is for disabled workers and the blue dashed line is for non-disabled workers.

Figure 3: Main Treatment Effects



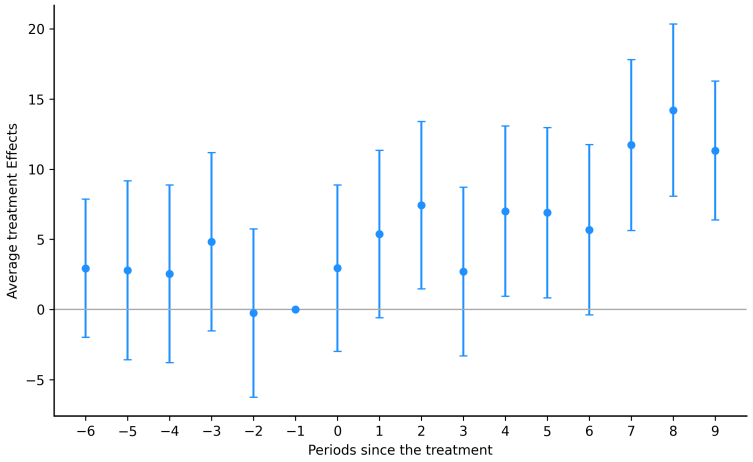
Notes: Figure 3 is analogous to Figure 1 but focuses on the impact of the Intelligent Outbound Call intervention. This visualization is based on the difference-in-differences regression results (Table 4). Each bar represents the shift in the disabled vs. non-disabled gap due to the intervention, expressed in standard deviation terms. Positive bars indicate an improvement from the disabled workers' perspective, such as an increase in orders (beneficial) or potentially longer working hours. Negative bars suggest a decline in the metric for disabled workers relative to non-disabled workers. However, for time-related or bad review metrics, a negative bar actually signifies improvement, as it reflects a reduction in time spent or complaints received. Error bars represent confidence intervals; if they cross zero, the effect may not be statistically significant.

Labor Supply covers weekly work effort: *Online Duration* (total time the worker was online and available for orders, measured in minutes per week), *Work Days*, *Bad Weather Work Days* (days the worker worked in bad weather conditions like rain or snow that week), and *Number of Weeks Worked* which is the total number of weeks the worker has been active on the platform up to that point or in total.

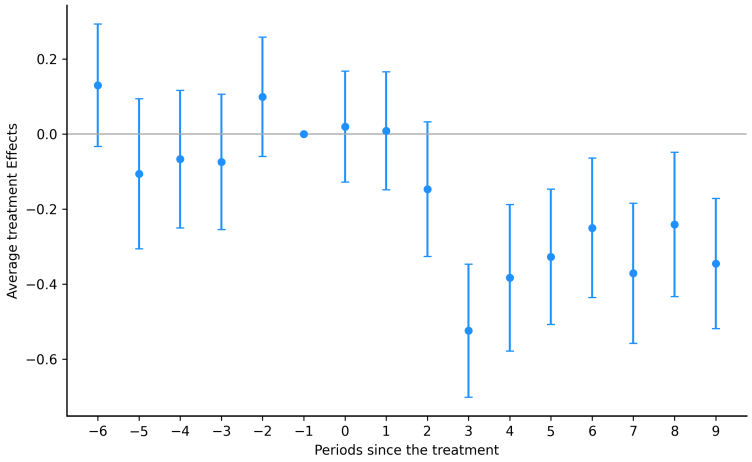
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Figure 4: Event Study Analysis of Technology's Impact



(a) Number of Orders Completed



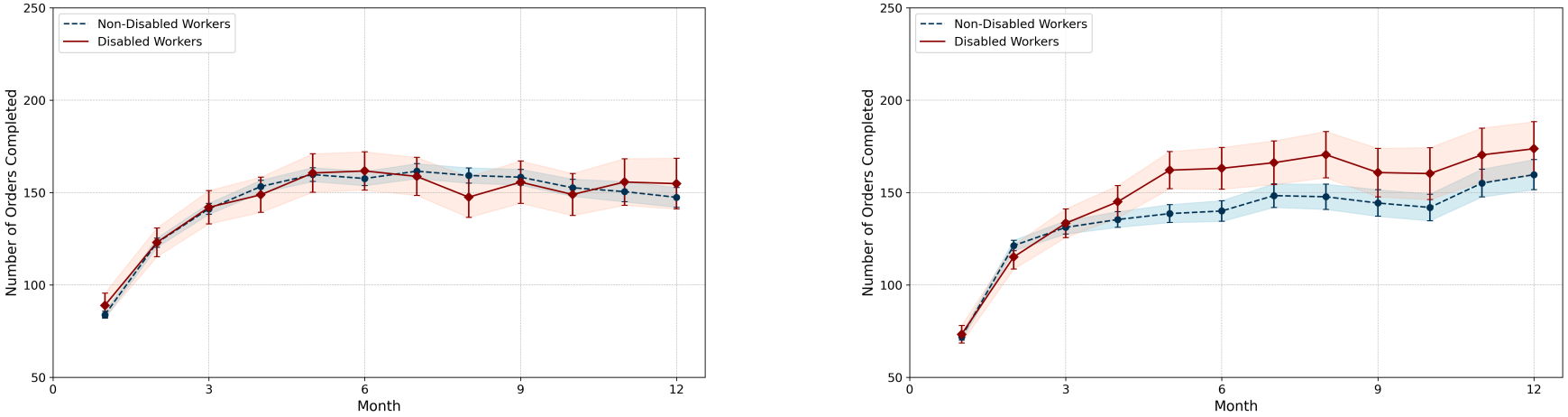
(b) Time Spent Between Store → Delivery (Per Order)

Notes: Figure 4 presents an event study analysis of the introduction of the Intelligent Outbound Call (IOC) system, examining trends before and after the intervention.

Panel (a) plots the difference in weekly orders between disabled and non-disabled workers for each time period relative to the IOC implementation. The x-axis represents the number of months relative to the intervention, with 0 indicating the implementation week, while the y-axis shows the estimated difference in orders between disabled and non-disabled workers.

Panel (b) illustrates the difference in time spent in the final delivery stage between disabled and non-disabled workers over time, relative to the IOC implementation.

Figure 5: Tenure Curves: Number of Orders Completed



(a) Pre-Periods

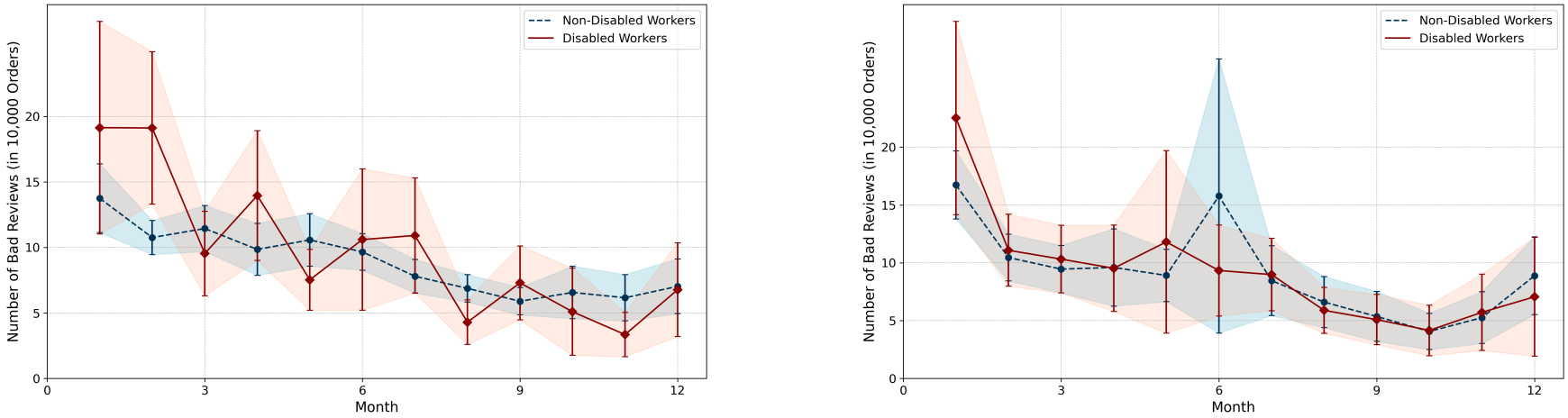
(b) Post-Periods

Notes: Figure 5 examines how the productivity trajectory of new workers over their first year differs before and after the introduction of the Intelligent Outbound Call (IOC) technology. It focuses on the number of orders completed per month of tenure. Error bars represent the 5th to 95th percentile confidence interval. The red solid line represents disabled workers, while the blue dashed line represents non-disabled workers. The tenure curves follow a similar approach to Figure 2 (cohort analysis or regression by tenure month) but are split based on whether workers had access to IOC from the start. The IOC system was implemented in April 2022, with the pre-period covering January 2021 to early 2022, and the post-period starting in April 2022 and extending 12 months onward.

Panel (a) Pre-Period: Displays the tenure curve of monthly order counts for disabled and non-disabled workers who started before IOC was implemented (i.e., cohorts from the pre-IOC era). For each tenure month (1–12), it plots the average number of orders completed by workers of that tenure.

Panel (b) Post-Period: Shows the corresponding tenure curves for workers who started after IOC was introduced (the post-IOC era). It tracks the monthly deliveries of disabled and non-disabled workers from month 1 to 12.

Figure 6: Tenure Curves: Bad Reviews (in 10,000 Orders)



(a) Pre-Periods

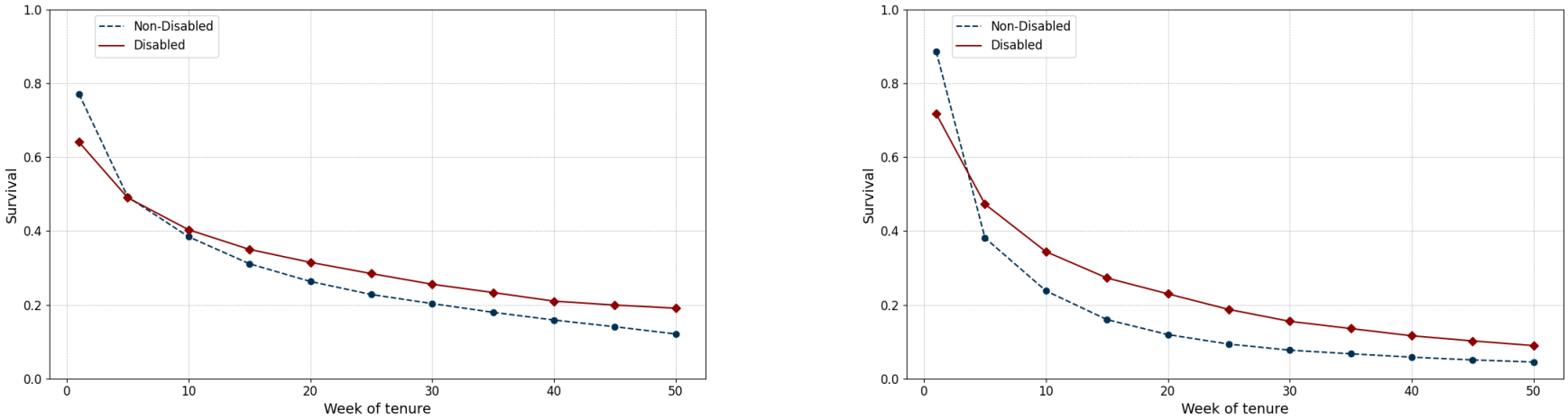
(b) Post-Periods

Notes: Figure 6 is analogous to Figure 5, but focuses on service quality, measured by negative customer reviews. It illustrates how the rate of bad reviews changes as workers gain experience and how this trajectory differed before and after the introduction of IOC. The metric used is the number of bad reviews per 10,000 orders for each month of tenure. Error bars represent the 5th to 95th percentile confidence interval. The red solid line represents disabled workers, while the blue dashed line represents non-disabled workers. The IOC system was implemented in April 2022, with the pre-period covering January 2021 to early 2022, and the post-period beginning in April 2022 and extending 12 months onward.

Panel (a) Pre-Period: Displays the tenure curve of bad review rates for new disabled and non-disabled workers who joined before IOC was introduced. For each month of experience (1–12), it plots the average negative review rate per 10,000 orders for those workers.

Panel (b) Post-Period: Shows the corresponding tenure curves for cohorts who started after IOC.

Figure 7: Survival Curves: Before and After Comparison



(a) Pre-Periods

(b) Post-Periods

Notes: Figure 7 compares the retention (survival) of workers on the platform for cohorts before and after the introduction of the Intelligent Outbound Call (IOC) system, highlighting differences between disabled and non-disabled workers. The y-axis represents the fraction of workers still active (i.e., those who have not quit), while the x-axis shows the number of weeks since a worker started. The red solid line represents disabled workers, while the blue dashed line represents non-disabled workers. The IOC system was implemented in April 2022. The pre-period covers January 2021 to early 2022, while the post-period begins in April 2022 and extends 12 months onward. The starting point at week 0 (or week 1) is 100% by definition, as all workers are initially registered as potential workers. As weeks progress, the curves decline as workers leave the platform.

Panel (a) presents the survival curves for disabled and non-disabled workers who joined before the IOC system was introduced. It illustrates the percentage of workers remaining active over time (week 1, week 2, etc.). The week 1 result shows the number of workers who registered and delivered at least one order in their first week: approximately 22% of non-disabled registrants never actually begin the job (i.e., they sign up but never complete their first order), while for disabled workers, this figure is much higher at 38%. This gap suggests that disabled workers are more likely to drop out at the very beginning, possibly due to concerns about communication barriers or a lack of onboarding support. However, among those who do start working, disabled workers tend to have higher ongoing retention than non-disabled workers. Their survival curve declines more gradually, indicating that they remain active for longer.

Panel (b) displays the corresponding survival curves for workers who started after IOC was implemented. The results show that the initial onboarding drop is still present even after the technology change, since IOC mainly helps once workers start delivering. It might not affect someone's decision to start in the first place, as that decision could depend on other factors like confidence or training. However, except for this initial drop, more disabled workers remain active at each subsequent point compared to Panel (a). The gap between disabled and non-disabled survival widened in the post-IOC cohort, meaning that the technology not only improved performance but also encouraged disabled couriers to remain on the job longer.

Table 1

Summary Statistics and Tests of Differences Between Non-Disabled and Disabled Workers in the Data Sample

	Non-Disabled Workers	Disabled Workers	Full Sample	P-Value of Disabled vs. Non-Disabled Difference
	Mean	Mean	Mean	
	(1)	(2)	(3)	(4)
A. Demographics				
Age	30.29	32.82	30.54	0.00***
% Male Workers	90.81	92.57	90.98	0.00***
B. Registration Type				
% Gig Worker	63.62	64.69	63.72	0.17
% Team Worker	36.38	35.31	36.28	0.17
	N	N	N	
	4,296	39,354	43,650	

Notes: The table is based on a sample of 43,650 food-delivery workers observed between early 2021 and the end of 2023. This includes 4,296 hearing-impaired ("disabled") workers and about 40,000 non-disabled workers, randomly selected by the platform for comparison. Column (1) shows non-disabled worker averages; (2) shows disabled worker averages; (3) is the full sample average. The unit of observation is worker-level for demographics (each worker contributes once). Age is the worker's age in years (average values shown), and % Male Workers is the percentage of workers who are male. % Gig Worker and % Team Worker indicate the worker's registration type on the platform. Gig workers work flexibly on their own schedule, paid per order independently of monthly totals, while Team workers are affiliated with a local station and often receive coordinated dispatches and monthly pay with bonuses for higher order counts. These two categories sum to 100% and reflect different work arrangements on the platform. Column (4) reports the p-value for the difference in means between disabled and non-disabled groups. Asterisks indicate significance levels (*** $p<0.01$, ** $p<0.05$, * $p<0.1$). Disabled workers in this sample tend to be slightly older (mean age 32.8 vs. 30.3) and more likely to be male (92.6% vs. 90.8%) than non-disabled workers – both differences are highly significant. In terms of work type, disabled and non-disabled workers have similar distributions between gig and team roles (around 64% gig vs 36% team for both, with no significant difference). This suggests that the disabled workers are demographically distinct (older, predominantly male) but participate in the platform's work arrangements at similar rates as their non-disabled counterparts. In other words, being hearing-impaired did not substantially affect whether a worker joined as a gig worker or through a team station. Any performance differences between the groups, therefore, are less likely to be driven by role distribution and more by other factors, given that their roles are proportionately comparable.

Table 2

Descriptive Statistics for Key Outcome Variables (Worker-Week Level)

A. Total Output	Mean	Median	Std. Dev.	**B. Efficiency**	Mean	Median	Std. Dev.	**C. Labor Supply on the Platform**	Mean	Median	Std. Dev.
Orders	128.75	89	141.30	Order → Worker	3.35	2.41	12.35	Online Duration	1519.69	592.51	1807.71
Peak Hour Orders	76.82	52	87.69	Worker → Store	11.59	11.35	7.07	Work Days	4.49	6.00	2.74
Orders (Team)	198.46	194	150.75	Store → Delivery	13.82	13.34	5.59	Bad Weather Work Days	0.63	0.00	1.10
Orders (Gig)	55.01	21	80.40	Bad Rating	9.62	0.00	94.14	Number of Weeks Worked	11.00	3.00	20.00
Restaurants	55.79	47	51.28								
Customers	116.15	75	127.22								

Notes: This table summarizes weekly work outcomes for the delivery workers (with the unit of observation being a worker-week). These statistics are computed from a panel of 568,218 worker-week observations, which comes from tracking 43,650 unique workers over up to 157 weeks (early 2021 through end of 2023). Because many workers did not work every single week (and many left after a short time), the total observed weeks (568k) is less than the theoretical maximum (which would be $43{,}650 \times 157 \approx 6.8$ million).

Panel A: Total Output includes: *Orders* (the total number of delivery orders completed by a worker in a week), *Peak Hour Orders* (the subset of those orders delivered during peak demand hours), *Orders (Team)* and *Orders (Gig)* (weekly orders completed by workers in each registration category – effectively the average weekly orders if the worker is a team worker vs. if they are a gig worker), and the number of unique *Restaurants* and *Customers* served per week.

Panel B: Efficiency records average time durations for each delivery stage: *Order → Worker* is the dispatch time from order placement to a worker accepting it, *Worker → Store* is the travel time from accepting the order to arriving at the restaurant, *Store → Delivery* is the travel time from pickup to delivering to the customer. These times are measured in minutes per order (averaged over the week for each worker). *Bad Rating* is the number of negative customer ratings received, normalized per 10,000 orders (to standardize the measure).

Panel C: Labor Supply on the Platform covers weekly work effort: *Online Duration* (total time the worker was online and available for orders, measured in minutes per week; 1,520 minutes ≈ 25.3 hours), *Work Days* (number of days the worker was active in that week, out of 7), *Bad Weather Work Days* (days the worker worked in bad weather conditions like rain or snow that week), and *Number of Weeks Worked* which is the total number of weeks the worker has been active on the platform up to that point or in total. (The last variable essentially reflects each worker's tenure or longevity on the platform, with median 3 weeks and mean 11 weeks, indicating high turnover.)

Table 3

Performance Differences Between Disabled and Non-Disabled Workers: Pre-Intervention Regression Results

A. Total Output	Estimate	Observations	R-squared	**B. Efficiency**	Estimate	Observations	R-squared	**C. Labor Supply**	Estimate	Observations	R-squared
Orders	2.336***	206,966	0.341	Order → Worker	0.155***	181,539	0.197	Online Duration	24.62***	206,966	0.306
	(0.761)				(0.0232)				(7.070)		
Peak Hour Orders	1.909***	206,966	0.332	Worker → Store	0.205***	181,539	0.093	Work Days	0.235***	206,966	0.253
	(0.472)				(0.0319)				(0.0165)		
Orders (Team)	9.786***	116,370	0.108	Store → Delivery	0.820***	181,539	0.326	Bad Weather Work Days	0.0432***	206,966	0.168
	(1.225)				(0.0360)				(0.00753)		
Orders (Gig)	-4.810***	90,596	0.043	OverTime Rate	3.432***	181,539	0.134	Survival	0.0628***	15,710	0.108
	(0.816)				(0.693)				(0.0130)		
Restaurants	4.320***	206,966	0.243	Bad Rating	5.183***	181,539	0.006				
	(0.303)				(0.684)						
Customers	6.484***	206,966	0.304								
	(0.730)										

Notes: This table presents regression results comparing the performance of disabled and non-disabled workers before the introduction of the communication tool. Each row represents an outcome variable, with the reported coefficient indicating the estimated difference associated with the disabled worker indicator. The regressions use data from January 2021 to mid-April 2022 (pre-policy period). The regression includes various controls: worker role (team vs. gig), age, and gender, along with fixed effects for registration year, week of observation, and city of operation. We also include the time fixed effect. Standard errors, clustered at the individual level, are reported in parentheses. Asterisks denote statistical significance: (*** $p < 0.01$).

Panel A: Total Output – Weekly Orders completed, Peak Hour Orders, and the breakdown by type (*Orders (Team)* and *Orders (Gig)*), as well as unique *Restaurants* and *Customers* served per week. These are the same definitions as in Table 2, but here we focus on the difference for disabled workers. For example, the coefficient for "Orders" (2.336***) means disabled workers complete about 2.336 more orders per week than similar non-disabled workers on average.

Panel B: Efficiency – Average time per order in minutes for each stage: *Order → Worker* (order dispatch time), *Worker → Store* (travel time to the restaurant), *Store → Delivery* (travel time to the customer), and *Bad Rating* (the number of bad customer reviews per 10,000 orders). A positive coefficient for a time means disabled workers take longer (which is less efficient), while a positive coefficient for *Bad Rating* means disabled workers receive more negative reviews than non-disabled workers.

Panel C: Labor Supply & Retention – *Online Duration* (total weekly time online, in minutes), *Work Days* (days worked per week), *Bad Weather Work Days* (days worked in weeks with bad weather), and *Survival*. Here, "Survival" is a measure of retention: it indicates the difference in the probability of remaining active on the platform for disabled vs. non-disabled workers. In this context, the survival coefficient (0.0628***) can be interpreted as disabled workers being 0.0628 higher in the survival metric – roughly a 6.3 percentage point higher chance of staying on the platform at any given time compared to non-disabled workers.

Table 4

Treatment Effects of the Intelligent Outbound Call (Difference-in-Differences Results)

A. Total Output	Estimate	Observations	R-squared	**B. Efficiency**	Estimate	Observations	R-squared	**C. Labor Supply**	Estimate	Observations	R-squared
Orders	5.800***	559,888	0.638	Order → Worker	0.0551	480,070	0.007	Online Duration	-73.22	559,888	0.678
	(1.545)				(0.112)				(101.3)		
Peak Hour Orders	2.500***	559,888	0.634	Worker → Store	0.0331	480,070	0.000	Work Days	0.138*	559,888	0.530
	(0.780)				(0.0576)				(0.0704)		
Orders (Team)	2.735*	289,786	0.502	Store → Delivery	-0.291***	480,070	0.001	Bad Weather Work Days	0.0489***	559,888	0.294
	(1.221)				(0.0565)				(0.0137)		
Orders (Gig)	9.216***	270,102	0.568	Bad Rating	-2.128***	73,159,231	0.251	Survival	0.062***	43,650	0.109
	(1.221)				(0.569)				(0.00986)		
Restaurants	3.771***	559,888	0.675								
	(0.429)										
Customers	6.108***	559,888	0.663								
	(1.085)										

Notes: This analysis uses the full panel from 2021 to 2023 (156 weeks), covering both pre- and post-intervention periods. The IOC technology was introduced in late April 2022 (week 17 of 2022); "Pre-Periods" refer to weeks before this date, and "Post-Periods" to those after. The regression is at the worker-week level, including both disabled and non-disabled workers. All regression analyses account for the fixed effects of the week and worker. Robust standard errors are clustered at worker level are and reported in parentheses. *** p<0.01. The table reports the impact of the new assistive technology on these outcomes. Each coefficient represents the estimated additional change for disabled workers following the IOC feature's introduction, relative to any changes among non-disabled workers. This difference-in-differences estimate captures how the disabled–non-disabled gap evolved post-intervention.

The structure remains consistent as in Table 3:

Panel A: Total Output (weekly orders, peak-hour orders, orders by team/gig type, and unique restaurants and customers served).

Panel B: Efficiency (order processing times and bad review rate).

Panel C: Labor Supply & Retention (online hours, workdays, bad-weather days, and retention/survival metrics).

For example, a coefficient of 5.800*** on "Orders" indicates that after the communication tool was introduced, disabled workers completed about 5.8 more orders per week than they would have otherwise, accounting for trends in the control group. A negative coefficient, such as -0.291*** for "Store → Delivery" time, suggests that disabled workers' delivery time per order decreased by 0.291 minutes relative to the control group, indicating an efficiency improvement due to the tool.

Online Appendices (Not for Publication)

Measuring and Boosting the Productivity of Disabled Workers: The Case of Food-Delivery Workers in China

by Yanyou Chen, Mitchell Hoffman, Huilan Xu, and Zhe Yuan

A Ethnographic Observations

Interviews

After conducting a preliminary analysis of the data on measuring the productivity of disabled workers, we sought to better understand their daily routines, how they work, and the challenges they encounter. Therefore, we conducted interviews with several disabled workers.

Figure A.1: Interviews with Disabled Workers



During these interviews, we spoke with seven disabled workers. To facilitate communication with hearing-impaired workers, we hired a translator proficient in sign language (She is seated at the bottom right of the picture, wearing a black shirt.).

Below, we summarize the demographics of our interviewees as well as the questions asked and the responses received.

Q: During pickup, do you encounter communication barriers?

A: Workers reported experiencing occasional communication barriers during pickups. Four respondents described needing to repeatedly remind restaurant staff—often two to

Table A.1: Summary of Interviewee Demographics

Age	Hometown	Years of experience	Marital Status	Gender
22	Fujian Province	1+ years	Single	Male
26	Chongqing Municipality	3 years	Single	Male
27	Chongqing Municipality	4 years	Single	Male
24	Henan Province	3 months	Single	Male
25	Henan Province	3+ months	Single	Male
24	Henan Province	1+ years	Single	Male
23	Henan Province	1+ years	Single	Male

three times—due to communication difficulties, while non-disabled riders typically resolve issues swiftly by shouting a single instruction that kitchen staff immediately understand. Consequently, non-disabled riders tend to receive meals faster because their vocal presence exerts greater urgency on kitchen staff.

Q: What specific challenges have you encountered during deliveries?
A: Workers highlighted several challenges:

1. One rider described an incident where a customer interaction required mediation by the station manager due to communication barriers. Despite the manager's assistance, the rider received a negative review, significantly affecting his morale and leading him to consider leaving the job.

2. Another rider expressed frustration with having multiple deliveries labeled as "T3" within one month, indicating these deliveries exceeded the app's allowed time window by at least three minutes. Such labels negatively impacted his performance record.

    - **Note on T3 classification:** A delivery is categorized as "T3" if it surpasses the app's specified time window. Although minor delays within a designated buffer period typically do not incur immediate penalties, significant delays adversely affect riders' service scores, potentially leading to reduced order allocations or other penalties. The expected delivery timeframe is calculated based on factors like the rider's speed, distance to the customer, and restaurant preparation time.

3. A rider mentioned taking proactive measures during deliveries to reduce confusion, such as sending a pre-written explanatory message to customers with the station's

contact information to address issues caused by delays or miscommunications.

Q: Have you experienced forced stops during deliveries?

A: Four workers reported that switching between apps, such as moving from navigation to the order interface, frequently results in forced stops. One rider specifically noted that managing two phones simultaneously—one dedicated to navigation and another to orders—necessitated frequent stops, causing significant disruptions.

Q: Do you receive advance notifications about potentially overdue orders?

A: All workers acknowledged receiving in-app reminders, but due to the nature and pace of their work, they rarely had sufficient time to read or react to these notifications.

Q: Do you have access to rest facilities or water during work?

A: Workers reported using specialized restroom-locating maps to find nearby public facilities for quick rest and water. They seldom return to the station for breaks.

Fieldworks

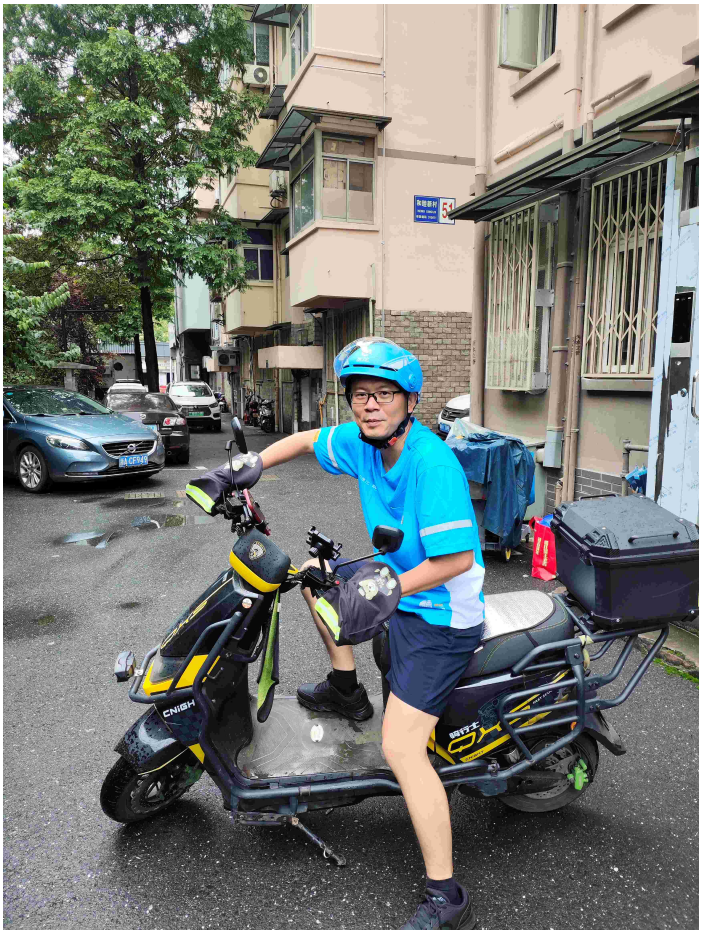
To deepen our understanding of the working conditions and everyday challenges faced by disabled delivery workers, we undertook immersive fieldwork alongside them. Specifically, we conducted two practical explorations: First, one author simulated the experience of a newly registered worker by delivering multiple orders while wearing earplugs to mimic hearing impairment (see Panel (a) of Figure A.2). This allowed us to better understand the initial challenges faced by novice workers. Second, another author spent several days directly observing disabled workers by accompanying them full-time, seated on the back seat of an electric motorcycle during their delivery shifts (see Panel (b) of Figure A.2). This hands-on approach enabled us to closely observe and document the workers' daily routines and the specific difficulties they encounter.

Fieldwork Records, July 2, 2024

Location: Hangzhou
Subject: Male, 27 years old, 3 years of employment
Duration: 10 hours 50 minutes (10:00 AM – 8:50 PM), 33 orders delivered
Observations:

1. Delivery workers tend to gather at a common meeting point after completing their orders. For instance, we were near Hangzhou 303 Life Plaza, where many workers

Figure A.2: Immersive Fieldwork with Delivery Workers



(a) Author delivering orders with earplugs to simulate hearing impairment



(b) Author observing a disabled worker during deliveries

frequently returned. Workers tend to avoid orders exceeding 4 kilometers, and after delivering such "distant orders," they usually navigate back to common gathering points.

2. A common tactic I noticed was workers pressing multiple elevator buttons when making deliveries. For instance, if a worker had to deliver to the 20th floor, he would also press buttons for the 21st and 22nd floors. This strategy allows them to reduce waiting time on the way down.

3. Over the course of a day, I noticed that many of the deliveries were from the same restaurants or to the same apartment complexes. The worker often made repeated trips to the same locations throughout the day.

4. During the lunchtime peak hours, the worker was handling six orders simultaneously, which led to a delay in one of the deliveries. After this delay, the number of orders assigned to them decreased significantly. One reason for the delay was that the second order was held up due to the restaurant's slow preparation and packaging process. The authors confirmed with the platform that no additional time is granted for subsequent orders the worker is simultaneously carrying in such situations. Another cause was the worker's decision to wait for the delayed order instead of collecting food for the other orders from nearby restaurants in the same mall. The worker could have optimized their pickup sequence to avoid unnecessary waiting.

5. The worker mentioned that if a delayed order is transferred to another worker, the worker who accepts the transferred order is not penalized for the lateness of the delivery. Workers are allowed to transfer up to two orders on the platform every 24 hours.

6. While having lunch together, I noticed that many restaurants offer discounts to the food-delivery workers, often around 20% off. After resuming work at 2 PM, the majority of the afternoon orders were for milk tea.

7. At 3:50 PM, the worker received a grocery order, after which he stopped to change the battery of his electric motorcycle. A fully charged battery allows for approximately 100 kilometers of travel. These batteries can be swapped at dedicated charging stations, which function like lockers, where you insert your empty battery and exchange it for a fully charged one.

8. At 4:30 PM, we returned to the gathering point in front of Plaza 303 to wait for more orders to be assigned. During this time, other workers at the site shared their

progress: one had completed 31 orders, another had finished 25, and a newer worker had completed only 7.

9. The top-performing worker at this station managed to complete approximately 2,823 orders in a month, earning around 20,000 CNY ($2,800 USD). However, this required working over 16 hours a day. At times, the worker would fall asleep on their electric motorcycle between orders, waking up only when the next one was assigned. Occasionally, they would even fall asleep while waiting at traffic lights.

Fieldwork Records, July 7, 2024

Location: Hangzhou
Subject: Male, 24 years old, 1 year of employment
Duration: 12 hours 20 minutes (7:45AM – 8:05PM), 75 orders delivered
Observations:

1. At 7:45 AM, we started the day. The worker provided me with a full set of sun protection gear, including a sun-protection suit and a neck gaiter. The temperature that day ranged from 38 to 40 degrees Celsius (over 100 degrees Fahrenheit). Figure A.4 shows the equipment required for working outdoors.

2. By 9:00 AM, we had completed eight orders. A fellow worker, mentioned in the previous report as the station's top performer, had already completed 21 orders. The worker informed me that the top performer starts his day at 6:30 AM and finishes at 2:00 AM.

3. Around 9 AM, we received an order for a large watermelon. However, the mall where the order was placed didn't open until 10:00 AM, so we had to pick it up from a locker in the underground parking lot. The security guard wouldn't allow us to ride the motorcycle down to the parking lot, so we had to run from the garage entrance to the basement, grab the watermelon, and run back up to avoid a late delivery.

4. Later in the morning, we received an order for McDonald's. The platform indicated that the food should be picked up from a collection locker. When we entered the store, a staff member in the kitchen shouted, 'The food is on the counter,' but the worker didn't hear and went straight to the locker. After unsuccessfully entering the pick-up code several times, the worker finally went to the counter to communicate with the staff and retrieve the meal.

5. The intelligent outbound call is frequently used when workers request customers to open doors, and it is generally very effective. However, there was one exception during

our deliveries. In this case, when we arrived at the destination, the worker followed the customer's instructions to contact the apartment complex management via the intercom. After the system connected, no one spoke on the other side. Although I heard the door unlocking sound, the door did not automatically pop open, and there was no visible indication that it had unlocked. The worker continued waiting by the intercom until I eventually walked over and pulled the door open.

6. One order was delivered to an urban village, but the address was inaccurate. Upon arriving, the worker used the intelligent outbound call to contact the customer, who said, 'I'm upstairs.' However, it was unclear what the customer meant by 'upstairs.' I then heard the customer shouting from inside a factory behind us, but by that time, the worker had already started riding in the opposite direction. I stopped the worker, informing him that the customer was inside the factory, and we managed to find the customer. In such situations, a worker with a hearing disability could waste significant time locating the exact address. Later that afternoon, we encountered a similar issue with an order delivered to a construction site.

7. There was another incident where a restaurant incorrectly packed an order. The customer had ordered noodles and fresh tomatoes, but the restaurant forgot to include the tomatoes. The restaurant called the worker during delivery and asked them to return to pick up the missing tomatoes. However, we were already halfway to the destination, and returning would have delayed the delivery. Communication between the restaurant and the worker was challenging, even with the intelligent outbound calls. I had to step in to explain to the restaurant that we were near the destination and couldn't return. I suggested the restaurant to contact the customer directly to explain the situation.

8. In general, when a situation requires in-depth communication with restaurants or customers, a worker with a hearing disability still faces difficulties and takes significantly more time to resolve the issue compared to a non-disabled worker. While these types of problems are difficult to address, they occur rarely. In most cases, the intelligent outbound calls are sufficient to assist workers.

9. For long-distance deliveries, the worker drove at high speeds (40-60 km/h). Sitting in the back seat, the wind was so strong that it caused my eyes to tear up, and I could barely keep them open despite wearing glasses. I couldn't imagine how the worker managed to see clearly without any protective eyewear.

10. There were many heartwarming moments throughout the day. For example, building janitors and restaurant staff were noticeably warmer toward me (as I wore the food-

delivery worker uniform) compared to when I was a customer in my everyday life. They were more inclined to chat with us. During a short break inside a building in the afternoon to escape the heat, a janitor approached us, commented on how hot it was, and reminded us to stay hydrated. Later, during dinner, a restaurant staff member came over and spoke with us for a long time, discussing strategies to encourage restaurants to offer discounts to delivery workers.

11. It was clear that pedestrians, motor vehicles, and bikers were cautious—if not outright afraid—of us on the road, often stepping aside as soon as they saw our electric motorcycle approaching.

12. One moment that left a strong impression on me was when I asked the worker, "Are you happy working as a food-delivery worker? How do you feel?" The worker responded, "I have no emotions; I'm just here to deliver orders." He explained, "If you get emotional while delivering, you won't last long. Whether it's riding on the road, picking up orders, or delivering them— dealing with restaurant delays in preparing the food, climbing six or seven floors on foot, late deliveries, or carrying overweight packages—there's no room for emotions." Doesn't "having no emotions" mean there are many tough moments to endure? If everything were pleasant, would there be a need to become so desensitized? After a day of running deliveries, I felt the same — under the scorching sun, with temperatures over 38 degrees (100°F), sprinting with two boxes of milk and four bottles of water, climbing four flights of stairs, and racing from the 20th floor to the first in three minutes when an order was nearly late. In those moments, the feeling of happiness seems irrelevant. All you can do is toughen up and adapt to this lifestyle.

13. By evening, I was too exhausted to run. Many of the late-night orders required entering residential complexes on foot (because the security guard wouldn't allow us to ride the motorcycle inside) and climbing stairs, all of which the worker handled alone. After a full day of work, my fingers had pruned from being soaked in sweat for so long. All of this made me feel awkward, as the worker is much younger than I am but clearly much tougher, both physically (evidently) and perhaps mentally as well.

14. In the afternoon (before dinner), there were fewer orders, mostly for milk tea or desserts. One incident stood out that I want to note: we went to a dessert shop where only one young woman was preparing the orders, and it was clear she was overwhelmed by the number of orders. As three or four more workers arrived and waited for their orders, they began pressuring her to speed up. One worker was noticeably

impatient and even rude, saying, "If there's only one of you, what kind of restaurant do you think you can run? You're making us wait too long."

15. The worker I worked with mentioned, "I typically start running orders at 7:00 AM and take a break around 3:00 PM. Then I go back online from 4:00 PM until 8:00 or 9:00 PM." My observations and experiences working alongside different full-time workers were similar. According to them, to earn a decent income, they need to work between 10 and 13 hours a day.

16. Below is a summary of orders that I found particularly difficult for the workers to deliver:

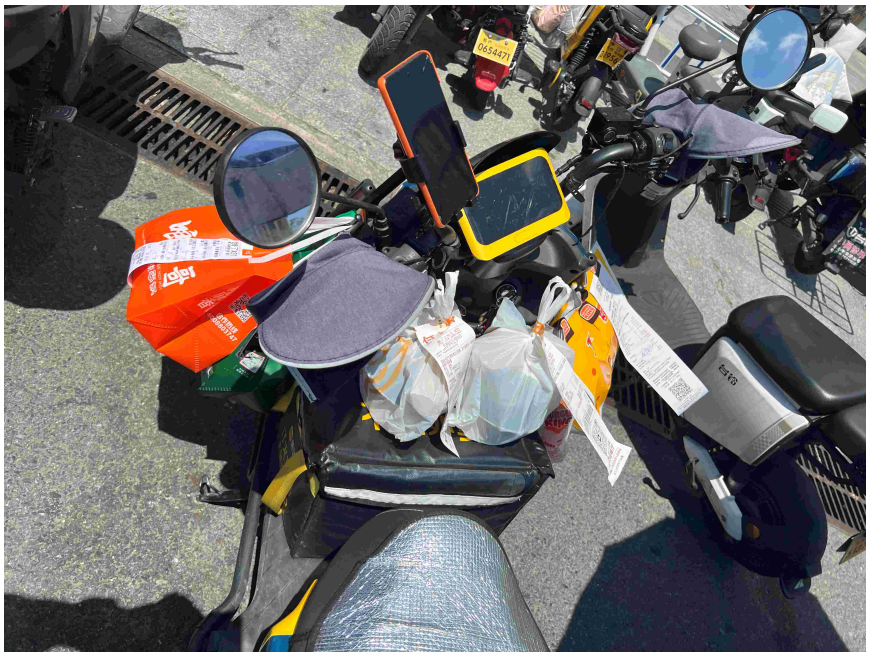
    - Some residential complexes have very slow elevators (there are many residents, but very few elevators).
    - Some older complexes do not have elevators.
    - Security guards at certain complexes do not allow workers to enter with electric motorcycles.
    - Apartments in large residential complexes can be difficult to navigate.
    - Delivering to urban villages is particularly challenging, as the locations are difficult to find and often require climbing stairs without elevators.

17. Below is a summary of some observations on how workers interact with the platform's algorithms:

    - Workers must perform three actions during the delivery process: 'confirm arrival at the store,' 'confirm food pickup,' and 'confirm delivery.' The app only allows workers to confirm arrival at store within a certain range of the store. However, if the restaurant has not prepared the food within three minutes after confirming arrival, the worker can report the delay, and the platform will grant an additional five minutes for delivery. To avoid potential delays when handling multiple orders, workers will sometimes confirm arrival at the store for order A, pick up order B from another restaurant, and then report a delay in food preparation for order A to gain more time. The risk is that false reports of delays can result in penalties, such as a lower service score (which affects priority in order assignment). I noticed that the worker I was paired with had multiple score deductions in his history due to false reports, though none occurred on the day I worked with him.

- To avoid being assigned too many unwanted orders by the station manager or platform, workers may delay clicking 'confirm delivery.' For example, when we delivered to Westlake University in the afternoon, the worker didn't want to take any more distant orders, so he delayed confirming the delivery.
- To return to a specific commercial area, such as Plaza 303, workers can accept orders in that direction from the order-grabbing page, and the algorithm will then assign more orders headed that way. There are two ways workers receive orders: they either get them through direct assignment (80% of orders are assigned this way), or if they want to take on more, they can choose orders from the order-grabbing page.
- Compared to the other workers I worked with, this worker was clearly more skilled at route planning and time management, as he avoided any late deliveries. He prioritized deliveries based on estimated times, rather than strictly following the algorithm's sequence, which helped him stay on time.

Figure A.3: Concurrent Orders During Peak Hours



Notes: Figure A.3 illustrates multiple orders being simultaneously handled by a delivery worker during peak hours. Experienced workers typically manage between 6 and 10 concurrent orders during peak hours. The maximum number of orders a rider can handle simultaneously is set by the platform's algorithm, considering factors like tenure and past performance. Further details on the assignment algorithm are discussed in Section 3.

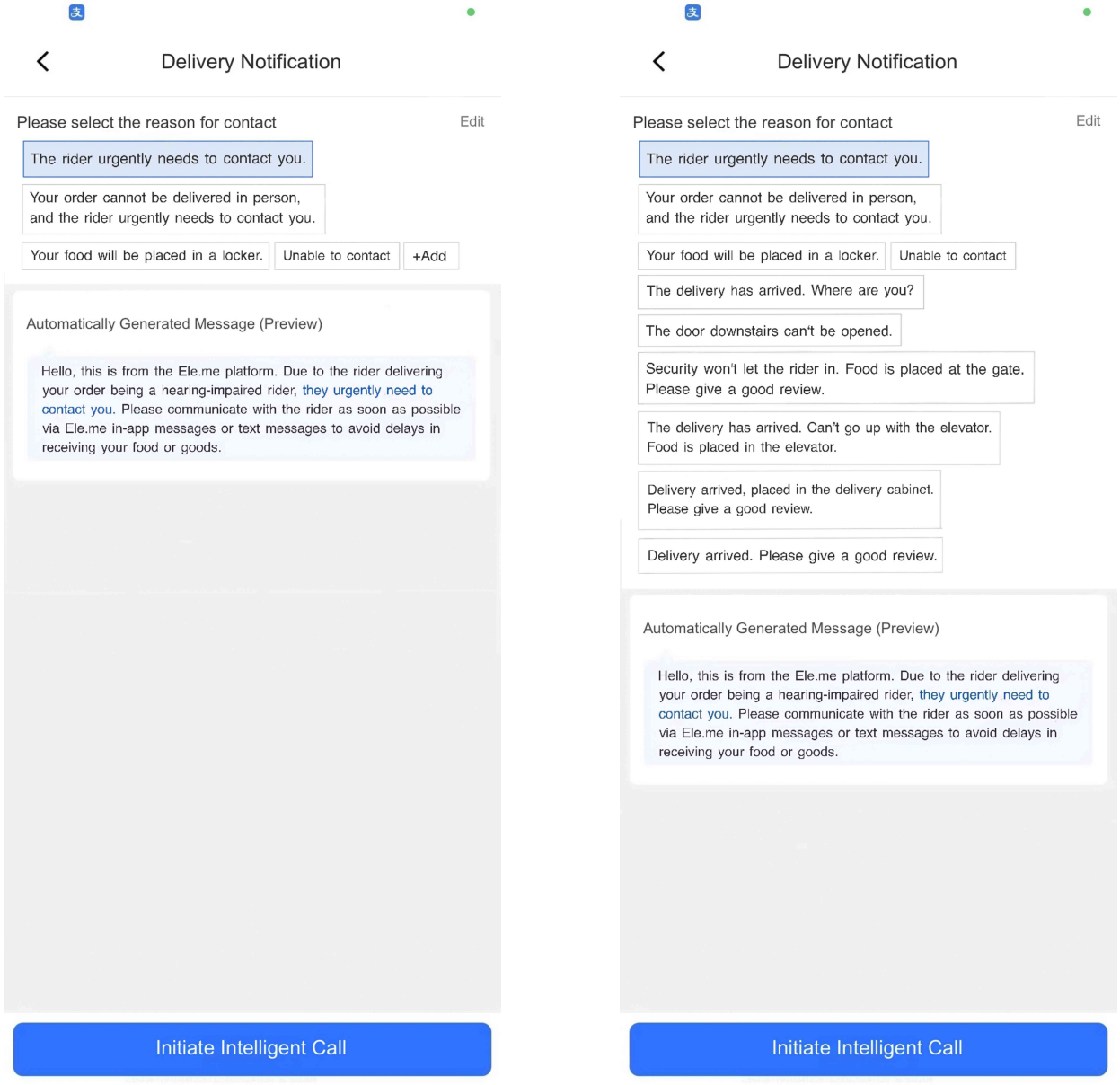
Figure A.4: Essential Equipment for Outdoor Work



Notes: Figure 7 illustrates the necessary protective gear for outdoor delivery work, including a sun-protection suit, helmet, and neck gaiter. Typical summer temperatures in the focal city range from 38 to 40 degrees Celsius (over 100 degrees Fahrenheit). Consequently, complete sun-protection equipment is essential, and workers must remain well-hydrated to avoid heat-related illnesses such as heat radiation sickness.

B Intelligent Outbound Call

Figure B.1: Screenshot of the Intelligent Outbound Call Feature



(a) Default Prompts

(b) Customized Prompts

Notes: Figure 7 shows the default prompts for Intelligent Outbound Call in Panel (a). Panel (b) presents a screenshot of one of the disabled workers we worked with, demonstrating the common prompts they use.

The Intelligent Outbound Call feature is an in-app tool designed to empower delivery workers with hearing or speech impairments by facilitating effective communication with customers through automated voice calls. Previously, these workers relied solely on text

messaging within the app, which customers often overlooked, leading to misunderstandings and delays. This technology bridges a critical communication gap by converting selected text prompts into automated voice calls.

The Intelligent Outbound Call feature is integrated into the delivery app. Workers can select from predefined default prompts or input customized prompts relevant to specific situations. These text messages are converted into audio through an advanced text-to-speech system and sent to the customer via a cellphone call directly from the worker's phone number.

Panel (a) of Figure B.1 displays default prompts provided by the app, addressing common scenarios such as urgent contact needs, inaccessible delivery locations, or delivery placement instructions. Workers can quickly select an appropriate option, preview the automatically generated message, and initiate the automated call instantly.

For situations beyond standard prompts, workers have the flexibility to create and store personalized messages. Panel (b) of Figure B.1 illustrates common customized messages tailored to real-world delivery challenges, such as access restrictions, security issues, or polite customer engagement.

The Intelligent Outbound Call feature significantly enhances the delivery experience in three key ways:

- Improved Customer Responsiveness — Customers are more likely to notice and respond to automated voice calls compared to in-app text notifications, leading to faster resolutions and fewer misunderstandings.

- Enhanced Efficiency — By addressing communication bottlenecks through automated messages, workers with disabilities can complete more deliveries with fewer delays, significantly improving productivity.

- Flexible and Personalized Communication — Workers can easily adapt their messages to specific circumstances, clearly communicate unique instructions, or politely request customer assistance or feedback, thereby enhancing the overall delivery service quality.

In essence, Intelligent Outbound Call technology represents a significant advancement in inclusive communication practices within delivery services. It empowers workers with disabilities to operate efficiently and confidently while ensuring high-quality service for customers.