An Integrative Conception of Micromobility: Its Technical Tendency, Its Appropriation, and the Role of Mobile Interfaces

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This article develops a heuristic framework for analyzing "micromobility" by integrating transportation and communication perspectives. Micromobility involves small electric vehicles, such as scooters and electric bicycles, and their digital user interfaces in the form of apps or embedded screens. We see the defining characteristic of micromobility not in the vehicles' weight, size, or even motorization but in their tendency to deploy motive power seamlessly in their users' everyday lives. Micromobility practices emerge through the appropriation of new vehicles as transportation and communication devices and the reappropriation and expansion of users' territories through these vehicles. By combining the characteristics of technical tendencies and social appropriation, our framework highlights critical issues in the evolution of micromobility, including users' autonomy and privacy, and the collective values of equal accessibility, urban cohesion, and sociability. It also indicates how mobile interfaces may intervene to orient micromobility in desired directions regarding these issues.

Keywords: micromobility, mobile communication, appropriation, territory, mobile interfaces

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Date submitted: 2022-03-17

[1] This work was supported by Région Bourgogne Franche-Comté, Grant Number 2019-Y-09065.

At the end of the previous decade, a new type of vehicle was rapidly rolled out in urban areas around the globe: Electric bicycles (e-bikes) and scooters were widely sold or dispersed throughout cities in entire fleets, sometimes overnight (Stiles & Schloss, 2019). The emergence of so-called "micromobility" vehicles was built on preceding light engines for individual transportation from mopeds to bikes to skateboards and on corresponding infrastructures, services, and practices. Its rapid uptake in recent years has been driven not only by advances in battery and motor technology but also by communicative innovations such as global positioning systems and broadband cellular networks to localize vehicles and coordinate supply and demand (Abduljabbar, Liyanage, & Dia, 2021) as well as new business models in the digital economy such as "mobility on demand" and "mobility as a service" (Cottrill, 2020). As suggested by theories of mobile communication and locative media (De Souza e Silva, 2006; Hildebrand, 2018), mobile interfaces have taken on various functions for users, from LCD screens indicating the speed and battery levels to smartphone apps and headsets, navigating riders and providing them with music and voice telephony. However, we are not aware of a general perspective on the potential of mobile interfaces to support and influence the further development of micromobility.

The use of micromobility vehicles has stirred much controversy. Some see them as part of a healthy, gentle, and smart solution to current transportation problems (Lang & Hermann, 2022). Others deplore them as accident-causing and polluting symbols of hyper-capitalism that are literally "moving fast and breaking people" (cf. Cocquempot, 2019; Lopatto, 2018). However, micromobility vehicles are rarely seen as emerging technologies whose form and role are yet to be determined through social negotiation and appropriation (Meng, Somenahalli, & Berry, 2020; Mora & Moran, 2020).

This article attempts to reframe micromobility by integrating its transportation and communicative aspects, its technological tendency, and the social dynamics that continue to shape it. It thus bets on the heuristic value of aligning communication and transportation with each other in the tradition of media ecology (Carey, 1983; Hildebrand, 2018; Innis, 1951). This perspective can guide scholars and practitioners in taking stock of existing features and practices of micromobility. It can sensitize them to the social and technological stakes of future evolutions and show them how mobile interfaces may influence the direction of these evolutions from the perspective of individual security and well-being, equal access to mobility, urban cohesion and sociability, and other principles.

We advance in three steps. First, we derive an integrative conception of micromobility that builds on its capability to *seamlessly deploy motive power* for the daily movements of people and goods and thereby reconciles the traditionally disruptive and cumbersome modes of transportation within the local contexts of users' everyday lives. We then examine the technology's social appropriation as a nested process regarding the *appropriation of the vehicles* (as the most tangible manifestations of the involved technologies) and the *appropriation of the territory* through these vehicles. At stake in both subprocesses of appropriation are not only the shapes of the technologies themselves but also the contexts of personal transportation and communication into which they are being appropriated in terms of the aforementioned individual and collective principles such as security and sociability. The third step addresses the potential of mobile interfaces to negotiate the technical and social forces that can orient the development of micromobility in specific directions, whether technologically or socially inspired. We summarize the resulting insights in an analytical grid, which crosses the two aspects of micromobility's *technical tendency*—

reconciling motive power and *seamlessness*—with the two processes of its *appropriation—appropriation of the vehicles* and of the *territory* through the vehicles.

A Media Ecological Conception of Micromobility

Common definitions of micromobility vehicles build on varying thresholds and ceilings for device weight and speed. Thus, the Society of Automotive Engineers (SAE International, 2019) includes vehicles with a maximum weight of 227 kg and a speed of up to 48 km/h. While these criteria meet their primary purposes of standardization and regulation, they are too attached to vehicle attributes and too arbitrary to accommodate a sustainable conception of micromobility. Even among the concepts that abstract from precise parameters of speed or weight, there is little consistency. Thus, some definitions attach the concept to the service model of shared vehicles (Shaheen & Cohen, 2019), while others link it to electric motorization (Maiti, Vinayaga-Sureshkanth, Jadliwala, Wijewickrama & Griffin, 2019), designating the other understanding of micromobility as the particular case of "powered micromobility" or, respectively, "shared micromobility" (for an overview of the factors taken into account in diverse conceptualizations, see Behrendt et al., 2022). Christoforou, De Bortoli, Gioldasis, and Seidowsky (2021) suggested a different path of conceptualization through a "mobility-oriented" definition, which "includes all transportation modes that allow their users to make a hybrid usage and behave either as a pedestrian or a vehicle at their convenience (e.g., to cross a road or board on a bus) or when necessary" (Christoforou et al., 2021, p. 3). We consider this vision of micromobility as a good starting point, but micromobility is not sufficiently characterized by just "hybrid use" and convenience. To determine its defining features, we count on the heuristic value of the abovementioned broad approach, which integrates communication and transportation perspectives.

Harold Innis famously investigated the "bias" of communication as a way of favoring a certain distribution of knowledge across time and space (Innis, 1951). It is from this basic assumption and subsequent analyses by Carey (1983) as well as more transport-oriented concepts that we derive our conceptualization of micromobility and the role that mobile communication technologies can play in its development. However, where Innis (1951) showed how the bias inherent in discrete media would transpire into culture and society to shift their balance, our understanding is less focused on specific technologies and less deterministic. We therefore speak of "technical tendencies," which mark specific technologies such as micromobility but unfold through what Simondon (2016) called an entire "evolving lineage"—in this case from mass mobility via automobility to micromobility. In addition, while we acknowledge their inherent dynamics, we conceive of their unfolding as an open socio-technical process of appropriation. While they may imperceptibly prejudice cultural and social dynamics as suggested by the term "bias," their tendency is primarily limited to the technical, so that their socio-technical unfolding is subject to a shaping by social and cultural forces in the many forms discussed among scholars of social appropriation (Jouët, 2000).

"Seamful" Expansion, Starting With the Railroad and Telegraph

The impulse that ultimately led to the emergence of micromobility came with the railroad and telegraph as technologies that carried the conveyance of objects and contents to an entirely new scale in terms of speed, capacity, and range, owing to industrially mined fossil fuels (e.g., coal) and resources (e.g., iron) and industrially produced components (e.g., wires, tracks, locomotives, batteries, generators). In his appraisal of the railroad and the telegraph, Carey (1983) emphasized another aspect of the rise of these technologies: The idea that the electronic transmission of messages at the speed of light permitted communication henceforth to coordinate transportation rather than depending on it through the transportation of physical messages. Oswald (2016) saw in the coordination of the railroad through the telegraph the first instance of "smart transportation as a set of tendencies working to integrate additional layers of information to achieve safer and more efficient management of flows" (p. 124). This coordination first occurred on the system level of railroad networks and did not support the individual coordination of specific users. The expansion later also applied to modes of transportation as industrially produced engines successively permitted travel on water, through the skies, and later through space. In parallel, electronic communication became available via audio (e.g., telephone, radio) and video (e.g., television).

The expansion was disruptive in the sense that the newly dominant means of transportation and communication were initially removed from most people's everyday lives. The networks of railways and telegraphs were too fragmented, and the train schedules were too scanty to fit into most peoples' regular patterns of communication and travel. We use the term "seamfulness," which has mostly been used to emphasize the positive aspects of friction and disruption, such as supporting social interaction (Chalmers & Galani, 2004). While our example here highlights its negative aspects for convenience, it is fundamentally neutral to us (as is seamlessness). While the force of transportation and communication technologies has since spectacularly continued toward more wide-ranging machines that handle more capacity faster (e.g., container ships, rockets, quantum computers), it is not that lineage that has spawned micromobility or mobile communication. The ongoing dynamic around scooters and smartphones is about consolidating the force of the new technologies into everyday life.

Consolidation Through Denser Networks

The consolidation started with the incremental progress of railroad and telegraph networks toward what transport scholars call *multinodality* networks (Schwartz, 2015), which are denser networks of discrete access points in the form of stations and telegraph devices. The second incremental progress occurred toward *multimodality*: The ability of the various modes of communication and transportation to interconnect with each other and become compatible with other user activities. Railroad networks were increasingly integrated with coaches, ships, bicycles, tram systems, and later automobiles by providing spaces to park those other vehicles or let them pick up and drop off passengers and by synchronizing timetables. Trains and railroad stations were furnished and equipped for sleeping, eating, reading, or working (Schivelbusch, 1986). Telegraph lines were also increasingly integrated with the services of messengers or auxiliary technologies such as call boxes and printing telegraphs to bridge the last mile (Sawhney & Wang, 2006).

Partial Continuity of Cars and Mobile Information and Communication Technologies

The second step in this consolidation arguably involved the use of automobiles and the first versions of mobile information and communication technologies, which have carried multimodality and multinodality from the state of dense networks to one of partial continuity. For example, in the United States of the 1950s, cars could turn the home or the workplace as well as almost any roadside spot between the two into a hub for entering or exiting automobility. Automobility also provided opportunities to engage with other modes of transportation without leaving the car behind (e.g., ferries, trains) and to engage in other activities from eating out to watching movies and dating without leaving the car (Urry, 2004). As Packer and Oswald (2010) emphasized, automobility also provided many first-use cases and frameworks for the first steps of information and communication technologies into mobility, such as the radio in the 1920s and personal navigation systems in the 1980s (Wilken & Thomas, 2019). Electronic information and communication technologies could thereby also play a coordinating role at the level of individual cars, though not at the user level.

However, the actual degree of multimodality and multinodality in automobility has remained limited. This is in part due to cars' own success, resulting in congestion and a lack of parking. To fit into everyday life, automobility also imposed substantial adjustments to urban environments (Urry, 2004). Finally, the integration of mobile phones into automobiles has proven dangerous.

The Unprecedented Seamlessness of Micromobility

Micromobility vehicles constitute a further advancement toward consolidation. The seamlessness with which motor power is integrated is unprecedented. This applies especially to scooters, which can be "free-floating," meaning that almost any spot in public space is a node to enter or leave motorized transportation, and are easily carried into other vehicles. From a communicative perspective, they are part of the Internet of things (IoT), offering what Ling (2018) called a "continuation of individual addressability [. . .] in the extension of communication into objects" (p. 16). This is illustrated by Lime (2018), the leader in micromobility services, in its mission statement "to provide on-demand transportation solutions that help people move seamlessly throughout their communities" (p. 2). The tracking systems, sensors, and applications that organize fleets of electric scooters and bicycles to provide them to users are crucial for enabling this seamlessness. As the context of smart transportation has thus shifted from the more logistically oriented system-level signals sent through the first telegraphs to location-based apps, the meaning of "smart" has also evolved. It includes what the former New York City traffic commissioner Schwartz (2015) called "street smart": Information that is savvy in the profane challenges of urban life, in step with its rhythms, accessible for a given user wherever needed. For micromobility to fulfill its promise of seamless integration into people's everyday lives, it must also be "street smart."

Before deriving our conceptualization of micromobility from this history, we need to put it into perspective. As in other media ecological accounts of change processes, our account is not comprehensive and does not do all cases justice. The successive evolution of transportation and communication technologies has played out differently across the world and even among cities in one country, such as the United States. It is modeled on cities that have been at the forefront of global technological innovation within their transportation and communication systems since the 19th century, such as London, New York, Tokyo, and Moscow. In other cities, it was the car (e.g., in Los Angeles) or bicycles and rickshaws (e.g., in Hanoi; cf. Arnold & DeWald, 2011) that marked transportation from the beginning.

Defining Micromobility

We define micromobility as a new stage of seamlessness in this consolidation of motive power in people's everyday lives, delivered through small vehicles, associated transportation and communication infrastructures, and corresponding practices and uses. Uses include interactions with interfaces of micromobility devices, such as the finding, reserving, unlocking, and locking of shared vehicles; the localization of points of interest and navigation to them; the management of vehicles' motor assistance and batteries; the reception of entertainment content; communication with others; and the measurement of trips and physical activities through devices. The corresponding practices include daily commutes to work, taking children to their activities, getting groceries, parcels, and food home (including the activities of professional delivery workers), as well as recreational trips and exercising, which can be performed with or without micromobility devices. The transportation infrastructure includes roads, bike lanes, sidewalks, areas to park, rent, and return vehicles, and transport via other means of transportation, and the communication structure includes the communicative layer of wireless networks and services for the coordination, management, and maintenance of vehicles by providers and individual users.

Our criterion for vehicles is that they are industrial engines that seamlessly deploy motive power for users and usually in their immediate environment due to their small size and weight, limited speed, and minimal noise and particle emissions. Although the concept of micromobility was popularized with electric vehicles, we extend it to those that are muscle-powered. It is not the motor that makes the difference but the industrial engine that delivers the motive power. We understand "industrial engine" in the older, broader sense of the term "engine" as "a compound machine or mechanical contrivance by which any physical power is applied to produce a given physical effect" (Webster, 1886a, p. 448), the effect being the users' motion. In contrast, the motor is "a source or originator of mechanical power" (Webster, 1886b, p. 862). The source from which the engine derives its power can be human muscular activity or the conversion of fossil, electric, or other energy into physical power. However, only industrial materials (e.g., steel, synthetic rubber, plastic), components (e.g., frame, crankset, chains, gear shift), and principles (e.g., interchangeable parts) permitted the bicycle to transform that power so efficiently into movement. For these reasons, the bicycle did not need a motor to be "at the cutting edge of technology, in the vanguard of the Second Industrial Revolution" (Smethurs, 2015, p. 3). Despite the plurality covered by this definition, we prefer to speak of micromobility in the singular. This approach is in line with other recent conceptualizations (Abduljabbar et al., 2021; Behrendt et al., 2022) and permits parallels with "mobile communication," which is also used in singular, although it contains diverse technologies and practices (von Pape, in press). Referring to the initially quoted "mobility-oriented" conceptualization of micromobility as transportation modes allowing their users to behave "either as a pedestrian or a vehicle at their convenience" (Christoforou et al., 2021, p. 3), it is not the hybridity or convenience of usage that we see at its bottom but the seamless integration of motive power that marks both.

The technical tendency of micromobility is thus to seamlessly integrate the additional motive power afforded by the Industrial Revolution into its users' daily lives. However, such tendencies do not automatically lead to that effect, as the history of the automobile shows: The promise of a continuous transportation experience that had made it so attractive to the masses ultimately failed due to its own success as urban traffic was blocked in congestion and parking spaces became increasingly scarce. Additionally, this tendency does not necessarily prevail over social, cultural, economic, or other factors that can drive technology in different directions. For technology to integrate into people's everyday lives sustainably, it needs to be appropriated.

A Nested Process of (Re)-Appropriation

Micromobility in itself is too abstract to be the subject of appropriation, and the infrastructures of transportation and communication that make it possible are too remote. Therefore, it is the new vehicles—scooters and e-bikes, among others, whose appropriation we will examine. We then consider a secondary process of appropriation, for which these vehicles only serve as tools: The appropriation of the territory. This idea of nested appropriation processes where the appropriation of the world through a tool is conditioned by the appropriation of a tool has been previously studied for communication technologies in the French research tradition of "sociology of technology usage" (e.g., Ben Affana, 2011). While this "conditioning" of the relation to the world echoes Innis' (1951) technological determinism, it is also countered by a double process of social appropriation, remaining true to the socio-technical approach of that research tradition (Granjon, 2014; Jouët, 2000). As the vehicles involved in micromobility often constitute more or less incremental innovations to current vehicles (bicycles, scooters, etc.), and the territory had been familiar to the users before as well, we can also consider both processes as *re*appropriation.

To account for the twofold tendency of micromobility as established in the previous section (motive power and seamlessness), we will consider the appropriation of the vehicles and the territory through two different angles. To account for the motive power, we compare the vehicles with conventional means of nonmotorized local transport, such as mechanical bicycles, scooters, or walking. To highlight the seamlessness, we compare them with conventional cars and motorcycles that have been motorized but are also too large, noisy, and polluting to seamlessly integrate into everyday life. To account for the contribution of digitalization to this seamlessness, we also compare Internet-connected micromobility vehicles with previously unconnected vehicles.

(Re-)Appropriation of Vehicles

We begin with the motive power that micromobility provides for short-range transportation. An obvious expectation is that this motive power has replaced the physical activity of walkers and cyclists. Although this hypothesis was partially confirmed for scooters (Glenn et al., 2020), the reality is more complex. Surveys indicate that e-bikes rather extend overall biking activities in terms of journeys (more frequent commuting with e-bikes) and distances traveled (which are longer for e-bikes; Rérat, 2021). Qualitative studies shed more light on the unique affordances appreciated in motive power (e.g., climbing steep hills, transporting heavy loads such as children, and arriving without sweating; Mayer, 2020). Furthermore, e-bikes' motor power can operate as activating energy, supplying users with just the necessary impulse to overcome barriers to velomobility. Thus, a biographical study (Marincek & Rérat, 2021) showed that older people who do not feel strong enough to propel their bicycle alone would (re)take up this activity gradually, increasing their own strength to the motor and going further and further. This ideally reinvigorates them in a virtuous circle from a health perspective. Nevertheless, the control of machines in urban traffic depends on complementary capacities (e.g., strength to handle heavy vehicles, sense of balance, and orientation) without which users, put in confidence by motive power, are at risk of accidents (Van Cauwenberg, De Bourdeaudhuij, Clarys, De Geus, & Deforche, 2019).

To highlight the contribution of *seamlessness*, we switch to the second perspective, starting from a comparison with conventional motorized vehicles such as cars and motorbikes. Here, again, we can expect a broadening in the range of users and uses. The barriers to becoming a user are mostly less restrictive for micromobility vehicles, especially in financial (cheaper purchase and leasing), cognitive, and administrative terms (no special training, license, or license plate required). That said, e-bikes, of course, have their own costs, and they suffer from other barriers, such as incomplete route networks.

It also seems likely that usage patterns will multiply with the further spread of micromobility vehicles. The use of conventional motorized vehicles was limited because they had to stop at parking lots, garages, and railway stations, which are often separated from everyday places by the "last mile" and in themselves sterile "non-places" for most users (Augé, 1992). On the other hand, micromobility vehicles can transport (or at least accompany) users to work, their homes and leisure activities, and other means of transport, such as trains and buses. This is reminiscent of how the smartphone brought the Internet from the sterile environments of personal computers (PCs) into the hands of users, accompanying them through the rich complexity of their daily lives and thus generating a multitude of new applications (Humphreys, Karnowski, & von Pape, 2018). These projections of fluid micromobility also depend on digitalization, which should relieve users of an increasing number of tedious tasks during journeys (in the form of automatic transmission systems, navigation systems) and between journeys (through automatic locking, monitoring of tire pressure, and battery status, etc.). This trend, which some see as the first step toward autonomous micromobility vehicles (Townsend, 2020), would allow users to allocate part of their attention to other activities during trips to complement the experience (listening to music, talking on the phone) or to increase it (by receiving information about the places they are passing through or successive connections). The users could delegate vehicle maintenance to self-diagnostics, remote updates, and professional interventions, as is already the case in the automotive field. However, we should weigh these gains in convenience against the risks of dependency on suppliers of products and services (e.g., navigation, repair), monitoring, and other common risks of digitalization (Royakkers, Timmer, Kool, & Van Est, 2018). Finally, the benefits of micromobility are unevenly distributed. The physical inequalities it promises to overcome, particularly for older people, may be replaced by new socioeconomic inequalities to the detriment of those who cannot afford the new technology. This phenomenon is similar to that of other assistive technologies (MacDonald & Clayton, 2013).

(Re-)Appropriation of the Territory Through Vehicles

In which ways could the emergence of micromobility play out in the (re-)appropriation of territories by the users through their vehicles? We rely on a broad interdisciplinary conception of territory as any socialized space appropriated by its inhabitants (Territoire, 2022). Although this notion admits that the territory is subject to natural conditions and transformations (e.g., tectonic, climatic), it emphasizes its social construction by many actors (e.g., political, economic). It focuses on the processes on the user side of this construction in the microcosm of individual inhabitants.

These elements allow us to question the role of micromobility vehicles in the appropriation of territory by considering motive power and then seamlessness. The boundaries of perceived neighborhoods depend in part on perceived proximity. They thus depend on kilometers, but also on more subjective measures such as time spent traveling or the physical and cognitive effort to do so (Solá & Vilhelmson, 2019). The *motive power of* micromobility vehicles—with the gains in range, acceleration, speed, and ease described above—could hence widen perceived neighborhoods. Vehicles could thereby activate the centrifugal forces of facilitated mobility. This is a phenomenon that Halleux (2004) observed for cars and that Townsend (2020) applied to micromobility: Whereas the car had led to a "sprawling" of cities through the birth of bedroom communities on the outskirts, micromobility vehicles could contribute to "micro-sprawling" (Townsend, 2020). The park 4 km away is then perceived as part of the neighborhood since it can effortlessly be reached in 10 minutes. However, for this expansion to become a lived reality, users must also be able to cognitively project themselves into the expanded area and appropriate it through daily practices and symbolic identification as its residents (Moreno, Allam, Chabaud, Gall, & Pratlong, 2021).

We now shift our perspective to the question of seamlessness and thus the affordance of micromobility to interlace transportation with other activities in daily life. Micromobility permits one to draw on motorized mobility almost anywhere and anytime. Just as the smartphone allows one to draw on digital communication, this overcoming of familiar restrictions can have a disorienting and paralyzing effect. As cell phone use demands some regulation by individuals (e.g., to turn attention away from the device) and among them (no phone at dinner), we must find the place for micromobility in the larger balance of individual and collective mobility. In the interest of their users' health, vehicles should not replace active walking or cycling, nor should they crowd pedestrians on sidewalks. In the words of the sociologist Rosa (2010), vehicles must be *synchronized* with individual and collective life to *resonate* with territories. If this succeeds, seamlessness could reinforce human interactions in enlarged neighborhoods and favor an economy of proximity over commuting among urban centers, bedroom communities, and shopping zones at the periphery, established by the automobile.

Again, these advantages and disadvantages may be unequally distributed. Thus, certain fleets of vehicles cover more economically privileged neighborhoods (Mora & Moran, 2020). Some providers even prevent their vehicles from leaving such neighborhoods through geofencing systems (Meng et al., 2020).

A Heuristic Framework for the Further Development of Micromobility

The third and final step toward our heuristic framework addresses the role of mobile informational and communicational interfaces in influencing the future evolution of micromobility, the general issues at stake in this evolution, and its outcomes. Poster (1995) defined the human–machine interface broadly as that which "stands between the human and the machinic, a kind of membrane dividing yet connecting two worlds that are alien to and also dependent on each other" (p. 20). We can thus understand graphical and auditory user interfaces and the respective hardware components of screens, microphones, and speakers as means to control devices. However, mobile communication devices also function in a secondary manner as interfaces for people to “filter, control, and manage their relationships with the spaces and people around them” (De Souza e Silva & Frith, 2012, p. 5), including other technological devices. In micromobility, onboard displays, rental terminals, smartphone applications, and vehicle touch surfaces likewise don’t only act as interfaces between users and their vehicles. Taken together with the vehicles, they also operate in a secondary manner as interfaces between users and the physical spaces through which they pass. This nested notion of interfaces corresponds to the nested processes of appropriation mentioned above.

Mobile information and communication interfaces are well positioned to manage the tensions between the technical tendency of micromobility and the existing social relationships by shaping these relationships in a direction that is desired by given interests and values. In our grid (Table 1), these fields of intervention are situated in the four central cells marking the intersection of technical tendency (columns A and B) and appropriation (lines 1 and 2). We will first construct these cells (A1, B1, A2, and B2) by stating the possibilities and constraints of mobile interfaces to guide the future development of micromobility. In the final step, we will complete the four marginal cells of the grid to identify the potential outcomes and stakes of the future development of micromobility for its technical tendency (Table 1, A3 and B3) and the relationships of the users to their vehicles and their territory (Table 1, C1 and C2). We will do so in an exemplary way with no claim to comprehensiveness.

Table 1. Grid for the Socio-Technical Analysis of the Interfaces of Micromobility.

	Technical Tendency		
	(A) Motive Power	**(B) Seamlessness**	**(C) Stakes (social)**
1. (Re-) appropriation of vehicles	**(A1) Fields of intervention:** Helping users to master the technology cognitively; encouraging active pedaling	**(B1) Fields of intervention:** Proposing diverse modes of cycling; multimodality; filtering local information; preventing risky uses; privacy regulation	(C1) Equal access to vehicles; diversity of uses; health effects of activity; respect for privacy and autonomy
2. (Re-) appropriation of territories	**(A2) Fields of intervention:** Indicating and locating meaningful destinations within the expanded perimeter and navigating there	**(B2) Fields of intervention:** Raising awareness for spots of personal interest and collective significance for the neighborhood	(C2) Equal access to the territory; maintain shared territory instead of isolation, individualistic mobility
3. Stakes (technical tendency)	(A3) Seamlessness as generative of uses and relationships to territories rather than neutralizing spatial structures	(B3) Seamlessness as generative of uses and relationships to territories rather than neutralizing spatial structures	

Fields of Intervention of Mobile Information and Communication Interfaces

Regarding the *appropriation of vehicles with respect to their motive power* (A1), we identified the need to accompany purely motor assistance with more comprehensive support, especially for fragile users, such as older adults. For overconfident users, the interfaces could warn them of risky behaviors (e.g., speeding, unsteady steering) through alerts. This could be done through tutorials integrated into onboard computers or smartphone applications (Ortet, Costa, & Veloso, 2019). Nevertheless, it would have to be accompanied by other solutions outside the interfaces, either technical (e.g., automatic stabilization systems), human (e.g., bicycle schools), or infrastructural (e.g., bicycle paths). Interfaces could also encourage users to engage in active pedaling despite the increasing capacity of motors and batteries to propel vehicles fully and over the entire duration of trips (Nikolaeva, Te Brömmelstroet, Raven, & Ranson, 2019).

Concerning the *seamlessness offered by micromobility vehicles* (B1), interfaces can guide users through the appropriation process by taking advantage of the diversity of possible uses. They could suggest different modes of cycling (e.g., for exercise, for exploration, for commuting) and adapt the level of motor assistance, the navigation, and the entertainment offered on the screen or smartphone (e.g., music, calls) accordingly. Depending on the traffic mode and situation, they could filter the signals to the users to send notifications (e.g., incoming calls), entertain them, or protect them from distractions. Interfaces could even discourage or inhibit problematic uses, such as texting (Dunand, 2017) or dangerous tinkering of the vehicle. They could also empower users to regulate privacy settings in meaningful ways that account for the varying contexts in which vehicles serve (e.g., private vs. professional, alone vs. accompanied).

Concerning the role played by *motive power in the appropriation of the territory* (A2), the interfaces could help users "conquer" their enlarged neighborhoods. This conquest depends in the first instance on the users' capacity to locate and identify significant destinations within their territories and project themselves there. While a good navigation system is crucial, other information could be integrated, such as a continuous visualization of the terrain that remains within the batteries' reach (for a round trip) as a concentric shape around the user, which narrows with the exhaustion of the batteries (Brethon, Jacques, Pinna, & Sadoine, 2020).

Finally, regarding the role of *seamlessness in the appropriation of the territory* (B2), interfaces can intervene by making users aware of new opportunities in the territory that they cross. Cars and smartphones are thought to isolate users from the public space they traverse and thereby affect the functions of the public space itself (Sheller & Urry, 2000). However, we also know that drivers establish meaningful associations between the music heard during a ride and the environment (Pink, Fors, & Glöss, 2019). Communicative interfaces can counter isolating effects and enhance connections with the environment. They can highlight environmental opportunities, such as the passage of a bus that could take the user of an e-scooter to her destination more quickly or the presence of a new market next to the road. They would then serve as what Ling (2019) called "meso-scopes"—operating between augmented reality, which highlights aspects of the immediate environment, and a telescope, which shows us what is very far away. The meso-scope shows us opportunities that are just beyond our field of vision, such as the bus passing behind a block. The potential of mobile interfaces to increase users' attachment to physical places and make them more meaningful to them has been richly theorized (De Souza e Silva & Frith, 2012) and empirically demonstrated by mobile communication scholars (Schwartz, 2014).

General Issues at Stake and Possible Outcomes

This brings us to the broader issues at stake and possible outcomes, which are marked in the third column (C) and third row (3) of Table 1. Regarding the appropriation of vehicles (C1), a basic goal would be to provide easy access, allowing a broad range of users to take full advantage of the vehicles' functionalities without endangering themselves or others. A more complex issue is user autonomy in interacting with vehicles. Monitoring users' behavior, processing the data, and transmitting it to other parties can make the users' experience more seamless, avoid theft and accidents, and ensure the fluidity of the entire transportation system. Even active interferences into user behavior can be of interest, such as asking for end-of-ride photos to favor responsible parking behavior, digitally capping maximal speeds, and obstructing tampering with technical components. However, they can also limit users' autonomy, conflicting with the deeply anchored "do-it-yourself" ethics of cycling as "a source of self-empowerment and pleasure, a pedagogical machine, a vehicle for community building" (Furness, 2010, p. 9). These conflicts echo the tensions that the arrival of "tethered appliances" and cloud computing has constituted for amateurs of "generative" computing (Zittrain, 2009). Micromobility providers can also collect user data, ranging from locative and financial data, possibly to gain insights into users' performance in handling vehicles (Cabalquinto & Hutchins, 2020; Cottrill, 2020). When household members share vehicles, vehicle tracing to avoid theft can also constitute a collateral form of electronic partner surveillance. While this surveillance is in principle symmetric for shared devices, we expect men to be in the surveilling role more often because of the gendered distribution of roles in the installation and maintenance of shared IoT technologies (Del Rio, Sovacool, & Martiskainen, 2021). As for the Internet in general, a challenge will be to reconcile convenience, simplicity, and security with autonomy and privacy.

Through the sociotechnical dynamics that allow the appropriation of a vehicle to influence the appropriation of space, the identified issues of vehicle-related self-determination and surveillance resurface in relation to their territories (C2). Behrendt and Sheller (2024) analyzed how issues of data justice can thus lead to issues of mobility justice. Whether micromobility can expand the personal territories of more groups than privileged older adults, whether this expansion is biased or segmented by issues of gender, status, or race is not predetermined by the technical tendencies of micromobility itself but may be mitigated by diverse entities, including interfaces.

We conclude with the general stakes of interfaces at the level of the technical tendency and its inherent values (cf. Table 1, row 3). The challenge regarding motive power (A3) is to turn it into activating energy, which invites users to mobilize their own forces and encourages them to actively appropriate the territory of their neighborhood. Otherwise, motive power could nudge users to spare physical effort and focus on the destinations of their trips, which could reduce their sensitivity to the neighborhood. Concerning the seamlessness of micromobility (B3), the challenge is to turn it into a constructive force that favors the emergence of new uses and new relationships with the territory, especially where the old "seams" had provided a certain structure to that territory. For example, car parks and railway stations near pedestrian zones used to operate as "landing sites" for visitors, starkly marking their arrival in the cities' inner sanctum and their transformation from drivers and passengers to pedestrians. This experience can be lost when visitors move directly to and from any place in the city center by a scooter or an e-bike, but it can be reestablished by interfaces emphasizing the special character of city centers. This may begin with the orange shading of areas of interest in Google Maps to orient individuals there and thereby possibly increase interest in the area in a self-fulfilling prophecy. Location-based social applications and games such as Pokémon Go have also permitted their users to make new use of their urban environment and discover new places within it (De Souza e Silva, Glover-Rijkse, Njathi, & De Cunto Bueno, 2021). To look beyond the individual users' perspective, a possible downside of seamlessness can also be that it comes at a price for other users of public roads, as the cautionary tale of the automobile tells us. Thus, the possibility of dropping off "free floating" scooters at any position has turned them into obstacles for pedestrians, so we need to ask for whom the technology is seamless. In this case, the abovementioned end-of-ride photos show how the interface can orient the appropriation of vehicles toward more socially responsible behavior.

Conclusion

The recent emergence of micromobility is of double interest for communication scholars. First, the contribution of e-bikes to transportation today strongly resembles the contribution of smartphones to communication in the early 2000s: E-bikes do not outperform existing vehicles in motor power, just as smartphones never exceeded the processing powers of existing PCs. The contribution of micromobility instead lies in seamlessly integrating those powers into everyday life. Second, its complex choreography of users and vehicles makes micromobility dependent on the coordinating power of communication technologies, turning them into an integral part of micromobility. This double interest places micromobility squarely within one of the founding issues of our discipline: The relationship between communication and transportation technologies, which is still an issue in the discussion about information-communication-transport-technologies (Hildebrand, 2018) and the dynamic field of mobile communication research.

What does this integrative conception add to our understanding of micromobility? On the most basic level, it conceives of micromobility independently of specific parameters and takes into account the social dynamics of its appropriation without denying its inherently technical tendencies. This balance is built into the very structure of our framework, placing any manifestation of micromobility at the intersection of technical tendency (columns in Table 1) and social appropriation (rows in Table 1). The framework further implements the balance in the concrete case of micromobility by specifying its technical tendency—reconciling power and seamlessness—and its appropriation—of the vehicle and the territory. While the technical tendency may undermine social and cultural processes such as an Innisian bias, seamlessness in itself—just like seamfulness—does not produce any specific social and cultural outcomes. It allows us to derive scenarios, which may, however, be quite the opposite, depending on the appropriation process: Activation versus sedentarism, and new sociability in urban space versus individuals obliviously gliding through it.

Our references to discussions and studies on micromobility illustrate how such questions as seamless access to vehicles in different parts of a city relate to deeper discussions of the accessibility and diversity of urban spaces. We see these illustrative references as the first steps toward a systematic literature review of research on micromobility and an empirical exploration through guided interviews with users. The heuristic value of our framework, as summarized in the analytical grid, lies in guiding such investigations toward initial questions (role of motive power, role of seamlessness, appropriation of the device, appropriation of the territory, intervening potential of mobile informational and communicational interfaces) and their stepwise integration with each other, ultimately leading to potential outcomes that may undergo normative evaluations.

For communication research, the immediate gain is a nuanced understanding of the role that mobile interfaces, with their intervening position, can play in shaping micromobility. This perspective can begin with a given interface such as an app tracking the rider's physical performance and question how this interface plays into the technical tendency and appropriation of micromobility, ensuring that designers keep in mind the stakes. It can also begin with a problem, such as the risk of seamlessness leading users to slip obliviously between neighborhoods. The framework then guides us to ways in which interfaces can, to the contrary, enhance awareness of the environment, acting as mediators of our relationship to the physical world (De Souza e Silva & Frith, 2012). Such mediators could be anything from embedded screens to haptic feedback in the handlebars and pedals to context-sensitive adjustments in the motor assistance itself. While placing attention on possible interventions through mobile interfaces, the framework does not preempt any research into the significance of these interfaces, as opposed to other interventions on the level of road design or new transportation offers or regulations.

This point brings us to the more fundamental potential of our framework to expand our understanding of mobile communication itself through links to micromobility, which we have laid bare. Thus, it highlights how users draw on the basic technical affordances of devices and how the degrees to which they integrate them into their ongoing activities can vary. As in the case of e-bikes switching from spending more muscular power to letting the motor do most of the work, this reliance on devices, in general, depends on how users want to experience their activity and their environment. Our framework shows how mobile media may interact with other technologies that assist humans technically and do so seamlessly in various ways so that we can consider their interplay with those other technologies. Music or multimodal transport apps can make any trip from home to work seamless, but so can good suspensions, adaptive motor assistance, and bike freeways. Thus, we provide one framework for considering how all of these elements can work together to establish the right constellation of seamlessness.

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