Beyond ‘mobility’: A new understanding of moving with technology

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Abstract
We report a surprising experience with mobile technology: the lead author found herself seeing and acting differently while running over part of her usual running track with the exercise-tracking application ‘Strava’ on her phone, even without focal attention to the app. We apply the method of problematization to a detailed empirical account of this experience, in conjunction with a literature analysis of taken-for-granted assumptions underpinning research on ‘mobile technology use’. This reveals that, while the relationship of attention, perception, movement and technology was a key element of the surprise, these themes are not well accounted for in current IS literature. In response, we employ William Gibson’s ecological theory of visual perception to reinterpret the empirical account and thereby build a new understanding of the human plus mobile technology that we term moving-with-technology. We introduce to IS: moving-with-technology as a new analytical perspective; the new phenomena of digital sub-species, digital-niches and asynchronous co-location; and stimulus for new ecologically oriented ‘mobile methods’. Moving-with-technology also has practical implications for urban planners who are using data from digital trace-making tools such as Strava in their decision-making, thereby generating what we call ecological feedback loops.

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1 INTRODUCTION

As I neared the lake my pace began to quicken. iPhone in hand, headphones in ears, I weaved oblivious past walkers and their dogs. The surrounding parkland a blur, my only focus was on the path ahead, until the lake disappeared again. Then I returned to a plodding pace, slower than usual. This new and unintended shift in pace and perception as I moved around the lake returned on subsequent runs. What was behind it...

It is no longer remarkable to use previously fixed technologies, such as computers or phones, across a variety of locations. Mobile technology has become a normal part of everyday life. Yet this mundane ‘everydayness’ of such technology (Bødker, Gimpel, & Hedman, 2014; Yoo, 2010) presents Information Systems (IS) researchers with the conceptual challenge of describing what is now novel or distinct about mobile technologies. While research attention was initially directed towards the mobility of mobile technology when this was a new technological achievement, it is now increasingly unclear what ‘difference’ mobility makes to the understanding of this kind of technology. Consequently, it has been pointed out that what is actually different about mobile technologies remains under-theorised (Kakihara & Sørensen, 2002; Wilken & Goggin, 2012).

This research takes up the challenge. It makes use of a surprising observation in everyday life: as related in the opening descriptive fragment, the lead author found herself moving differently through a particular section of her normal path after starting to carry the exercise-tracking application Strava while running. She began inspecting the ‘results’ of her runs at their conclusion, but never consciously ‘decided’ to compete with others while running this section. Yet over time, she came to move differently along this particular part of her running track and came to perceive it differently – as a place where speed mattered. This was surprising because mobile technology was not being ‘used’ in an attentive way while running. Upon later reflection, it became clear that this unexpected experience was quite at odds with conventional wisdoms about what role a mobile technology might play in perception and action because the phone was out of sight and not attended to, yet was still consequential for how the runner ‘saw’ and moved through her environment.

In this article, we use this surprising observation – that mobile technology can be consequential for perception and movement even without focal attention – as an opportunity to ‘problematize’ and challenge certain taken-for-granted assumptions that seem to organize our academic and everyday understanding of ‘mobility’ and ‘mobile technology use’. Specifically, we pose three research questions: (a) What assumptions underpinning the field of mobile technology research are revealed by the surprising observation? (b) What theoretical resources can be used to make new sense of the phenomenon? and (c) What are the broader implications of such a new understanding of the phenomenon for the field of mobile technology research?

To address these questions, we employ the dialectical process of ‘problematization’ proposed by Alvesson and Kärreman (2007), outlined in Section 2 and followed throughout. Section 3 presents a detailed account of the surprising observation we wish to problematize, which embraces storytelling (Davison, 2016) as a way to communicate the lead researcher’s first-hand experience and subsequent reflections. Section 4 examines the literature on mobile technology use with the specific aim of uncovering dominant background assumptions about the nature of ‘mobility’ and ‘mobile technology use’. In Section 5, we outline Gibson’s (1979) ecological theory of visual perception and argue that it provides a suitable theoretical resource to illuminate the surprising element of the empirical story because it...
highlights the role of movement in attention, perception and action. Four concepts are taken up as particularly relevant: direct perception, the education of attention, trace-making tools and niches. In Section 6, we reinterpret the empirical account using these conceptual tools to show how they resolve the surprise. Finally, in Section 7 we build on this reinterpretation to propose and discuss the implications of a novel ecological understanding of what we term moving-with-technology as an alternative to the usual conceptions of mobile technology use.

Moving-with-technology has implications on an individual, social, and ecological level: it implies changes in how we see and act in the world; it illuminates how our actions and ways of living in the environment become bifurcated as we are socialised into particular technological practices and it draws attention to ecological feedback loops whereby the environment is deliberately designed and shaped in response to the data traces and digital niches that result from collectively moving-with-technology. Rather than treating mobility simply as the defining property of a certain class of technologies, our ecological approach emphasises the role these technologies can play in how people see and act differently as they move about the world.

2 | RESEARCH PROCESS: PROBLEMATIZING THE SURPRISE

Our research objective is to surface assumptions underpinning the accepted narratives in IS concerning what is new about mobile technology and to challenge these as a way of advancing understanding in the area. Under the rubric ‘problematization’, Alvesson and co-authors (Alvesson & Kärreman, 2007; Alvesson & Sköldberg, 2017; Alvesson & Sandberg, 2011) have explicitly developed an approach for uncovering the normally unstated assumptions that give rise to ‘problematic’ or ‘mysterious’ phenomena. Surprises are known to arise from a disjunction between expectation (informed by implicit assumptions) and actuality (empirical experience) (Casati & Pasquinelli, 2007; Maguire, Maguire, & Keane, 2011). Therefore, surprising observations are a candidate trigger for problematization, to surface those tacit assumptions that rendered this experience surprising in the first place, and identify why these assumptions were inadequate to explain what occurred. We applied this approach using the method detailed in Alvesson and Kärreman’s (2007) paper1 as follows.

We took the runner’s observation that she perceived her path and acted on it differently while running with an exercise-tracking app – even without focal attention to the app – as the revelatory surprise. Literature was then sought out with the specific aim to identify assumptions widely held in the mobile technology research field that might be challenged by the surprising observation. A detailed account of the first author’s experiences of running with the exercise-tracking app Strava was prepared to make the phenomenon more explicit and to reflect on the nature of the disjunction between tacit expectation and actual experience revealed by the surprise. We identified the relationship between attention, perception, movement and technology as the core issue at stake. Consequently, Gibson’s (1979) ecological theory of perception was identified as appropriate to interrogate the empirical material anew, because it emphasises the pivotal role of movement in attention, perception and action, and for its account of direct (unmediated) perception, which appeared to be decisive elements of the surprise. Through an extended and iterated dialectical reinterpretation of the empirical account using key elements of Gibson’s theory, we arrived at a new ecological understanding of moving-with-technology as an alternative to the dominant conceptions of ‘using’ mobile technology revealed through the literature analysis. We then explored the implications of this ecological understanding beyond accounting for the initial observation, in order to demonstrate that it has the potential to generate new lines of inquiry in IS, in keeping with the overall objective of the problematization method (Alvesson & Kärreman, 2007).

1Problematization has been advocated in Information Systems and Organisational Studies for several purposes: challenging existing assumptions and developing interesting new theory (Alvesson & Kärreman, 2007; Riemer & Johnston, 2019), formulating new research questions (Alvesson & Sandberg, 2013), thinking outside the box (Alvesson & Sandberg, 2011), and as a way to tell a research story. Here, we draw primarily on the first application using guidelines from Alvesson and Kärreman (2007). Where we use the later work of Alvesson and Sandberg (2011), Alvesson and Sandberg (2014), and Alvesson and Sandberg (2013) we reference it explicitly.
These research design choices, reflected in our article structure, were informed by the nature of the focal phenomenon of surprise. First, the theory-laden nature of supposed ‘facts’ lies at the heart of the phenomenon of surprise (Alvesson & Kärreman, 2007, p. 1287). Therefore, problematizing our surprise required us to engage in an iterated, dialectical interrogation (Alvesson & Sandberg, 2011, p. 252) of data with theory and theory with data, to question accepted ‘facts’ of the field. Consequently, empirical and theoretical materials were used in a more symmetrical way (Alvesson & Kärreman, 2007) than either of the usual choices of theory building or theory testing (e.g., Eisenhardt, 1989). Second, the selection both of empirical and of theoretical materials was driven by the nature of the surprise: the empirical materials were assembled to contextualize a particular instance of the surprising phenomenon in detail; the theoretical materials were chosen for their ability to provide deeper access to the nature of what was surprising about the phenomenon than those commonly used in IS, and therefore to undercut crucial unreflective ‘wisdoms’ of the field (Alvesson & Kärreman, 2007). Finally, surprises are perspectival: what is ‘surprising’ to an observer or a reader depends on their background assumptions and their openness to challenging them. Consequently, it was necessary to actively ‘construct’ and narrate the surprise to a reader by drawing on first-hand observation (Eslambolchilar, Bødker, & Chamberlain, 2016; Prasopoulou, 2017) and story-telling (Davison, 2016) approaches. However, this does not pose a threat to validity because the new understanding reached through the problematization process stands on its own conceptual coherence, rather than on the initiating surprising observation. Ultimately problematization should be judged against its own claim (Alvesson & Sandberg, 2013) of providing a new ‘way of seeing’\textsuperscript{3} that opens up “interesting” (Davis, 1971; Alvesson and Sandberg, 2014) new research directions.

3 | EMPIRICAL MATERIAL: THE SURPRISE NARRATED

The following first-person narrative places the ‘revelatory surprise’ within the broader events and context in which it was experienced by the first author while using Strava.\textsuperscript{4} It provides the empirical material for our problematization process. It was synthesised from reflections, notes and discussions with co-authors.

3.1 | Running with Strava

Being a regular but by no means competitive runner I was curious about the mobile application ‘Strava’ for two reasons – first, I wanted to track my runs and performance, and second, I wanted to see whether the capacity to record my progress would motivate me to run more regularly. Over 12 months, Strava became an integral part of my running routine.

I downloaded Strava on a friend’s recommendation. My iPhone was already a part of my runs – I carried it in my hand, with headphones attached so that I could listen to streamed music. This already required the use of 4G services so loading Strava at the start of my run was straightforward. It was just one more app to activate and it did not require me to look at my phone while running.

Figure 1 shows the dashboard information that was displayed on the conclusion of one of my first runs with Strava. The red line on the map represents the path I took. This line does not join up because I started and stopped

\textsuperscript{2}For clarity, the iterated dialectical approach has been linearized into a single dialectic episode in the report.

\textsuperscript{3}Essentially, the aim of problematization is to encourage the kind of ‘gestalt’ change in worldview characteristic of a paradigm shift (Kuhn, 1962; Riemer & Johnston, 2019).

\textsuperscript{4}The interlocutor used the exercise-tracking app Strava and details of its specific functionality are woven into this narrative. In our later analysis, we will use the terms ‘exercise-tracking app’ or ‘trace-making technology’ to indicate where conclusions would apply more generally to technologies with related functionality.
**FIGURE 1** Summary of run [Colour figure can be viewed at wileyonlinelibrary.com]

**FIGURE 2** Summary of performance [Colour figure can be viewed at wileyonlinelibrary.com]

**FIGURE 3** Sydney Park Lake [Colour figure can be viewed at wileyonlinelibrary.com]

**FIGURE 4** Leaderboard [Colour figure can be viewed at wileyonlinelibrary.com]
using the application some distance from my house. The reason for this was privacy and security. Given the regularity of my runs, I did not want publicly available information to reveal my home location through the mapping feature.

To further protect my privacy, at first I rejected the Social Media aspect of the application by using a pseudonym as my username (‘nimmersatt’) and not ‘following’ other users (Ellison, 2007) or allowing other users to ‘follow’ my activities. Thus, my activity ‘feed’ only showed my own activities and personal performance statistics; I could not see anyone else’s runs or data. The application was thus not, for me, a social tool but rather a tracking and record-keeping device with a competitive game element that was inward facing. The aim was to make running more “gameful” (Deterding, Dixon, Khaled, & Nacke, 2011) on a personal level, not to compete with others.

After finishing one of my first runs and inspecting the app, I noticed that I had won ‘x 4’ trophies – displayed as a symbol on the activity home screen (Figure 1). By investigating further (by scrolling down – Figure 2), I could see I had beaten my previous times over certain standard distances (e.g. 400 m/1 km). This self-competition was at first motivating, until after a few weeks had passed, when I stopped beating my previous records and no longer received the trophy icon. As I ran less, I knew I would be less competitive against my past self and lost interest – both in the application and to some extent in my running. Some weeks later however my curiosity was renewed through discussion with friends who used Strava for cycling. I activated the app once again.

Soon after re-activating Strava, I won a new trophy. I discovered it during my usual post-run inspection of the app. On arrival at home, I tapped on the trophy icon and saw that on this run I had received a ‘place’ for a ‘segment’ called ‘Sydney Park Lake’ (Figure 3). Down the bottom of the screen, I saw that I had been added to a ‘leaderboard’. I followed this prompt and found the names and performance times of other (female) runners who had at some stage run around this same lake (Figure 4; first names and images are blurred to protect privacy). I had, without knowing it, run the fifth-fastest time around a lake that had been in my route for some time. This revelation was confusing as I had not intended to make my activities public and I felt irritated at being made visible to other users of Strava.

The concept of a ‘segment’, I learned, is a crucial element of Strava use. A segment is a stretch of path that has been nominated by a Strava user as a place for competition. Through this process of nominating and traversing segments, a section of a road or trail becomes specific and available to those who use the app, as a place of private significance to Strava users, where they can compete amongst themselves while passers-by remain oblivious to their competition. The path around Sydney Park Lake had at some point been submitted to Strava as a segment, which then became discoverable as a competitive stretch of path. Even while rejecting the competitive social interaction that Strava promotes I had stumbled onto the Sydney Park Lake segment that had been defined and reified by other users.

3.2 | The Lake is transformed

The next time I ran, my routine was just as before, running with Strava activated but out of sight with my phone in hand. But when I reached the lake, the path appeared somewhat altered – there was an ‘intensity’ associated with this place now. I saw less of my surroundings – the path ahead drew me forward. I did not register this change in a deliberate or reflective way at the time, but upon returning home my sense that something was different was confirmed when I inspected my Strava results. Unknowingly, I had sped up while running around the lake – and I had run more slowly for the parts of my run that were not a part of the Sydney Park Lake segment. This was not something I had planned. I had, after all, dismissed the competition that Strava revealed was taking place in this ‘segment’ as a distraction. Yet the path around the lake seemed to have transformed somehow, and my pace had followed suit.

Over time I gave more and more emphasis to this stretch of my run, checking my results along this segment and adjusting my efforts accordingly. I had thus unwittingly entered into a competitive relationship with unknown others who shared a similar mode of engaging with this place, albeit at different times. The path around the lake had become distinctive to me as a ‘segment’ that was significant to a social group, tied together by the practice of competition, with my status and rank displayed in the leaderboard (Figure 4).
3.3 | The making of a surprise

This experience surprised me because it involved several changes to how I attended to, perceived, and acted on the path around the lake, despite my explicit rejection of the notion that the ‘segment’ was of any relevance to my running. I had run more quickly in this location, directing my energy towards this stretch of path, and this also impacted what I did not see or do: I did not look around at the trees and sunset as I had previously done. I registered other people as mere obstacles to be dodged, anticipating and avoiding dogs and strollers, always looking straight ahead. Even though I did not look at my mobile phone screen to check Strava while running through this place, the app was very much implicated in how I saw and acted while in motion through the environment – the lake appeared differently to me even though Strava’s displays were not, I would have thought, playing any direct role in my perception of the lake path. Over time, this change was reinforced through further running and competing against other Strava users, until I could no longer ‘see’ the path around the lake the way I had before it became a ‘segment’.

I later started to reflect analytically on how my use of the exercise-tracking app over time changed how I perceived and moved along the path around the lake, in that it became altered and differentiated in terms of competition. This insight was gradually constructed through discussion with my colleagues as grounds for problematizing dominant understandings of mobile technology use: what part had this exercise-tracking app played in altering my attention to, perception of, and movement through my environment, even when I was not looking at my mobile while running?

4 | LITERATURE: SURFACING TACIT ASSUMPTIONS ABOUT ‘MOBILITY’

The surprising observation recounted above prompts us to examine assumptions that underpin how mobile technology use is currently understood in the literature. In keeping with the problematization approach (Alvesson & Kärreman, 2007) and the nature of surprise (Casati & Pasquinelli, 2007; Maguire et al., 2011) we anticipate that the surprise arises from certain widely held preconceptions about how we expect mobile technology use to affect perception and action while moving through the environment. Consequently, we proceed with a selective review of the literature that is aimed specifically at surfacing core ‘accepted wisdoms’ about mobile technology use, rather than providing a comprehensive review of its content. Finally, we examine the assumptions thus uncovered against our surprising empirical observation.

4.1 | The nature of ‘mobility’ and mobile technology ‘use’

Guided by what presented to the interlocutor as surprising in the above account of running with an exercise-tracking app, we here concentrate on examining core assumptions about: (a) the nature of ‘mobility’ and its relation to movement; (b) the kind of ‘use’ that is relevant to mobile devices and (c) the role that mobile technologies play in how users perceive and act in their environment. We identified the following three key implicit assumptions.

‘Mobility’ is commonly understood as device portability: We begin with the observation that IS and neighbouring disciplines have come to understand mobility largely in terms of portability. ‘Mobile devices’ can be carried around and are therefore universally available to the user regardless of location, thus enabling computing across varying contexts. The IS field has historically been focused on this novelty, which was introduced when previously static technologies became portable. For example, Junglas and Watson (2006) in their review article identify portability as the most basic characteristic of mobile computing from which other characteristics, such as reachability, accessibility, localization and identification are derived.

It is this portability of mobile technologies, the availability of devices across a range of contexts, that has been treated as transformative and worthy of research attention. For example, Lyytinen and Yoo (2002) coined the term...
'nomadic computing' to refer to a new wave of mobile technologies that arrived in the early 2000s and made it possible to access information and remain connected across contexts. According to Junglas and Watson (2006), portable computing with mobile devices differs markedly from traditional computing as it enables both accessibility: access to a mobile network anywhere and everywhere, and reachability: the ability to stay 'in touch with and [be] reached by other people 24 hours per day, 7 days per week' (p. 573).

It has since been shown that these technologies have played a role in transforming a range of work practices, such as in knowledge work (Dery, Kolb, & MacCormick, 2014), management practices (Mazmanian, Orlikowski, & Yates, 2013), police work (Karanasios & Allen, 2014) and nursing (Tang & Carpendale, 2008). In knowledge work mobile technologies allow workers to stay connected with one another as they conduct work from a range of different locations, and this connectivity has led to a certain 'context collapse' as arenas of life become available across contexts that would not ordinarily intersect (Middleton, Scheepers, & Tuunainen, 2014). Moreover, the ubiquitous accessibility of online networks brings private social interactions (e.g. via social media) into work contexts (e.g. Sergeeva, Huysman, Soekijad, & van den Hooff, 2017). Conversely, knowledge work entering private contexts via mobile technology blurs the boundary between work and leisure time (e.g. Mazmanian, Orlikowski, & Yates, 2005, Prasopoulou, Pouloudi, & Panteli, 2006).

Junglas and Watson (2006) further show how portability generates localization, the ability to establish the location of a portable device, and identification, the capacity to associate such a device uniquely with one person (see also Nickerson, 2008). These two characteristics are at the heart of mobile e-commerce, also known as m-commerce. For example, Varshney (2003) explores how location-based information can be sent to a user's device in personalized advertising relevant to the user's current location. Other studies have outlined the possibilities of tailoring information delivery to the contextual needs of individual users, be they in end-consumer or business-to-business contexts (Zhang, 2003).

Use of mobile devices is understood to require attention to information on a screen: Mobile devices are generally screen-based, be they mobile computers, tablets, smartphones or smart watches. It follows from the discussion of portability as enabling 'computing' in different contexts that, while devices might have changed in form in the push for portability, the actual use of these mobile devices is most commonly, if implicitly, understood as the manipulation of software (or apps) on a screen requiring focused user attention. For instance, early research on the use of emerging smartphone technology discussed at length the design of user interfaces for mobile devices to replicate known computing experiences on what was seen to be a severely limited 'screen real estate' (Billus, Brunk, Evans, Gladish, & Pazzani, 2002; MacKay, Dearman, Inkpen, & Watters, 2005; Nickerson, 2008; Pande & Gomes, 2015). Specifically in the literature on the adoption of m-commerce, studies (Keith, Babb, Lowry, Furner, & Abdullah, 2015; Ngai & Gunasekaran, 2007; Wakefield & Whitten, 2006; Wang, Lin, & Luarn, 2006) have drawn on the Technology Acceptance Model (TAM) framework and have assessed (among other variables) the ease with which users can manipulate a mobile device's screen interface to navigate the screen's menu and read and compose messages (Hoehle & Venkatesh, 2015; Keith et al., 2015; Sarker & Wells, 2003).

The central role of the screen in demanding user attention is also at the heart of the discussion concerning pedestrian (e.g. Schabrun, van den Hooorn, Moorcroft, Greenland, & Hodges, 2014) and driver (e.g. Steelman, Soror, Limayem, & Worrell, 2012) safety risks from mobile phone use, as well as developments for alternative modes of interaction via voice command, such as for in-car virtual assistant systems, intended to mitigate distraction from screens while driving (Strohmann, Höper, & Robra-Bissantz, 2019). Furthermore, observational data collection methods prevalent in mobile technology research frequently necessitate investigating situations where the device/screen commands a user's focused attention (Eslambolchilar et al., 2016; Ghose, Goldfarb, & Han, 2013), thereby reinforcing the assumption that mobile technology use occurs by directly 'looking at' a screen that sits between device and user.

Mobile devices mediate between users and their environment: The influence of mobile technologies on a user's experience of their environment is most often conceived as one of mediation. The device either provides on-screen information about the user's context or overlays that information directly onto an image of the environment, such as
through augmented reality technology. In either case, the mobile device is treated as mediating the user’s perception and action by interposing between the user and their environment. As such, the user views and processes information offered by the device that is location-specific, either by ‘looking with’ or ‘looking through’ the device at the environment.

For example, Noguera et al. (2012, p. 37) discuss how map-based interfaces and location-sensitive information can be utilized ‘for assisting on-the-move tourists to choose points of interest to visit according to their physical location’ (Noguera et al., 2012, p. 37). Similarly, Zhang, Adipat, and Mowafi (2009) outline how mobile applications can be designed to be ‘context-aware’ in order to provide users with more relevant information and services about their current environment and location. Using such context-aware or location-based services, the user is thus able to receive information for decision-making and recognition of relevant features in the environment that would otherwise go unnoticed, a form of looking with the mobile device at the environment.

The most advanced and explicit stream of research investigating the mediating role of mobile technology is the emerging field of augmented reality, featuring devices such as Google Glass and Microsoft’s Hololens and their associated applications (Walton, Thomas, Steed, & Sugimoto, 2017) such as in health (McNaney et al., 2014), gaming (Li & Fang, 2018), or sales (Xu, Liu, & Lee, 2018). This stream of research highlights how mobile technology acts as a medium that sits quite literally between the user and the environment and provides location-specific information overlayed directly onto (a representation of) the physical surroundings so that the user is essentially ‘looking through’ the device at the environment.

In sum, we find three implicit assumptions underpinning existing mobile technology research that are relevant to our surprise: (a) that the novelty and significance of ‘mobile’ computing technologies stems from their portability and thus their availability in a wider range of locations than previously possible; (b) that mobile technology use still typically involves looking at and manipulating screens, thus requiring user attention and (3) that mobile devices are a medium that sits between the user and their environment, either providing information about the environment (looking with) or enabling the environment to be marked up and viewed through the device (looking through). We note that these characteristics will appear self-evident to researchers and practitioners in the field: this is why they are rarely explicitly spelled out in research papers, but also why problematization of our surprise is needed to surface and question them.

4.2 Evaluating the literature in relation to the surprise

In keeping with the problematization approach, we now examine these broad assumptions against our surprising empirical observation to determine whether there is a need to look outside the current literature to make sense of the surprising observation.

We begin by seeking the implicit attitude to mobile technology that lies behind these assumptions. First, understanding the ‘mobile’ in ‘mobile technologies’ as portability reflects a certain separation of the device from movement. It emphasises a user carrying technology along with their existing motion within an environment and draws attention away from how the device might become an integral part of that motion and perception itself. Second, emphasis on a user’s focal attention to the display of the device suggests that information provided by looking at and manipulating screens, thus requiring user attention and (3) that mobile devices are a medium that sits between the user and their environment, either providing information about the environment (looking with) or enabling the environment to be marked up and viewed through the device (looking through). We note that these characteristics will appear self-evident to researchers and practitioners in the field: this is why they are rarely explicitly spelled out in research papers, but also why problematization of our surprise is needed to surface and question them.

Next, we examine whether the runner’s experience narrated in the previous section has an ‘obvious’ explanation on the basis of this conventional way of understanding the possible role of mobile technologies in attention, perception and action. Recall that after being made aware by the exercise-tracking app Strava that the lake segment figured
in others’ competitive behaviour, in subsequent runs the runner’s perception of, and running over, this section of track was changed even though the app was not attended to during running. We can rule out a direct influence because, while the mobile with an exercise-tracking app was carried while running, it was not attended to: consequently, the app was not mediating the real-time relation between the runner and her environment. A more indirect explanation might be that information obtained from the runner’s earlier viewing of the exercise-tracking app display changed her goals and subsequently her running behaviour. On this reading, the app’s display acted like management ‘dashboards’ act on business performance: ‘what gets measured gets improved’. This kind of conventional mentalistic reasoning about the efficacy of information displays could possibly explain why the runner subsequently sped up over the lake segment and slowed down elsewhere. Although it is not possible to rule out this kind of mentalistic explanation completely, it is inadequate to explain the surprising observation in two respects.

First, it is not consistent with how the phenomenon was experienced at the time. The runner explicitly rejected the collective competitive orientation to running that the tracking app display was depicting, and had no experience of consciously deciding to change running objectives or behaviour. It therefore seems implausible that the connection between the app display and subsequent running times occurred via a change in the mental state of the runner, at least not of readily accessible mental states such as intentions and objectives.

Second, a key element of the surprise was that after being made aware by the exercise-tracking app that the lake segment figured in others’ competitive behaviour, the lake segment was perceived differently – as a place for competition – on subsequent runs. While information displayed by the app and looked at by the runner might affect later action via changes of mental state, according to conventional wisdom, mobile technologies should not affect the real-time perception of the environment except by directly mediating interaction with the environment. This would require that the mobile was in use in the conventional sense of holding focal attention during subsequent runs. However, this was not the case, nor was its representational capacity being used in real-time while running.

This kind of disjunction between experience as narrated in our account, and tacit expectations about the role of mobile devices in perception and action as reflected in existing literature, is what qualifies our observation as a ‘revelatory surprise’ and invites the use of problematization to make new sense of the phenomenon.

5 | ALTERNATE THEORETICAL MATERIALS: FOUR CONCEPTS FROM GIBSON

In keeping with the aims and method of problematization, this disjunction between observation and accepted wisdom suggests we should turn to alternate theoretical materials that are not commonly deployed in the discipline. We propose Gibson’s ecological theory of visual perception (1979) for this purpose. Gibson’s work is predominantly known in IS through his concept of ‘affordances’ (which is treated quite briefly in his 1979 book), but his central thesis on direct perception and its relationship to movement and attention has been largely overlooked. This alternate, non-mainstream theoretical perspective is suggested by the nature of our
'revelatory surprise', namely, that it hinges on the relation between attention, perception, motion and technology, which is also the concern of Gibson's theory. However, the choice will ultimately be justified by showing (in Section 6) that using this perspective to reinterpret our empirical account makes sense of the surprise.

In this preparatory section, we introduce four key concepts from Gibson that have been underutilized in IS research. They are direct perception, the education of attention, trace-making tools and niches. In the next section, we demonstrate how Gibson's alternate account of the relationship between attention, movement, perception and technology can be used to resolve the surprise. Then in Section 7, we draw more broadly upon these insights to bring forth in a new way what is novel about mobile technology.

5.1 | Direct perception and its relation to movement

We first introduce the crucial (and in his time quite radical) premise of Gibson's ecological theory of visual perception: that perception depends on movement. Studies of perception in Gibson's time were often premised on the metaphor of the eye as a stationary camera (Gibson, 1979). Theories that built on this underlying assumption were reinforced through laboratory experiments that forced the subject to remain still, using 'the headrest, the bite-board...the darkroom' (Gibson, 1979, p. 3). Such laboratory setups mimicked static, 'snapshot' vision, which relied on 'the subject's being willing to hold his eye fixed like a camera' (Gibson, 1979, p. 4). Gibson (1979) responded critically to this approach, pointing out that such a scenario is artificial. In the course of everyday life, animals do not hold still – they are constantly on the move, whether walking, running, or just glancing around their environment (an observation also made by Merleau-Ponty, 1962).

Gibson (1979) therefore built his theory on the ambulatory vision of a moving animal. He argued that an animal's constant motion is fundamental to systems of perception and that perception should therefore not be characterised as a passive, intermittent reception of raw sense data, but instead as an ongoing, active and adaptive process (Gibson, 1979). The difference is significant – aperture vision, associated with the camera metaphor, would offer the perceiver a sequence of still snapshots that need to be integrated before sense can be made of them, while ambulatory vision offers to the animal a continuously changing but patterned 'flux' of optical experience of its surroundings (Gibson, 1979, pp. 1–4) from which already-relevant information is 'picked up' directly.

Ambulatory vision is based on such 'direct perception' (Gibson, 1979; Michaels & Carello, 1981), which is 'the activity of getting information from the ambient array of light' through the process of 'information pickup' involving 'the exploratory activity of looking around, getting around, and looking at things' (Gibson, 1979, p. 147). Through direct perception during getting around and looking around, the animal is able to extract what are known as 'invariants' in the optic array (Gibson, 1979, p. 2). The word invariant is used by Gibson not in the usual sense of 'unchanging' but in the mathematical sense of a pattern that remains fixed across changing contexts. Invariants in the optic array include 'ratios, gradients, discontinuities, and other relations in the ambient light that owe their existence to the persisting features of the environment' (Gibson, 1979, p. 308).

As animals move about the environment, over time they learn to associate such invariants with what these environment structures allow the animal to do. For instance, the ubiquitous occurrence of alternating vertical and horizontal planes (steps) in both ambient and built environments is both useful to a bipedal walking animal (e.g. a human) for climbing and also produces a characteristic and recurring optical pattern (horizontal stripes) that can be detected in the moving animal's optical array. As a result of this process, the opportunity to climb can be perceived directly.

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8Gibson's work is focused on organisms generally (called animals) and their environment, and he often does not distinguish between human and non-human animals. We adopt and adapt such ecological vocabulary for our purposes.
In sum, optical invariants and their relation to useful environment structures provide the information that makes direct perception possible and this information is picked up directly, in the form of what are sometimes described as 'action-possibilities' (Markus & Silver, 2008, p. 622), during ambulatory vision involving a constant scanning of the environment. This, however, highlights a paradox for researchers interested in Gibson’s theory of direct perception: when discussing an ‘action-possibility’ as such, we have already analytically split action from perception. While it may be useful to do this for analytical purposes, this split is antithetical to the notion of direct perception.

Direct perception is instead possible because an active, moving animal lives in an environment to which it is already adapted and to which it is already perceptually attuned. In an attempt to summarise this fundamental link between an animal’s perception and its actions, where we see in terms of what we do, Gibson (1979) coined the term ‘affordance’. Affordance is a nominalisation of the verb ‘afford’ (Bloomfield, Latham, & Vurdubakis, 2010). Gibson (1979) coined it to refer to how we directly perceive our environment in terms of actions performed as we move about. An easily overlooked but crucial point here is that an affordance cannot exist independently of a specific perceiver moving about her environment. In the strict (Gibsonian) sense, affordances thus do not reside in technologies, nor in structures, but rather in the attunement of a moving perceiver to the environment. Some of this attunement is innate but for humans, in built environments, it is overwhelmingly learned (Gibson, 1979, p. 130).

5.2 Learning as an ‘education of attention’

Attunement to the environment is an ongoing process of adaptation, and so a theory of learning that is compatible with direct perception is needed. Traditional learning theories take content filling (see Freire, 2000; Ingold, 2018 for a critical discussion) or transmission metaphors (Gibson, 1979) as their basis. These traditional notions are insufficient for understanding changes in direct perception because they rely on a model of mediated information processing that Gibson eschews. From his ecological perspective, learning involves becoming attuned to different kinds of information as we move through the environment. Attunement and learning are thus intertwined. Gibson (1979) therefore posits that learning should instead be understood as an education of attention. Such a theory of learning is compatible with his notion of direct perception and even helps us to explain how direct perception can change.

On this view, learning denotes the adjustment of what we pick-up as distinct and important from the environment (Michaels & Carello, 1981). Conversely, learning impacts on what we do not attend to (Gibson, 1979). When moving about, we cannot attend to everything so we filter what is picked up from our environment in an economical way (Gibson, 1979, p. 135). An ‘education of attention’ occurs when perception becomes ‘attuned to information of a certain sort’ (Gibson, 1979, p. 254). For Gibson, it is this refinement or re-tuning of what information we pick up from the invariants available in the optical array that is primarily constitutive of learning. Learning thus results in a narrowing rather than an opening up of attention; it is a situated process of informational refinement that transforms and steers how we directly see/act in the world.

5.3 Trace-making tools

Gibson (1979, pp. 40–41) wrote only briefly about tools, but his treatment of them is illuminating. He emphasises that when they are in use tools cease to be a part of the environment and instead become, in effect, a part of the person:

When in use, a tool is a sort of extension of the hand, almost an attachment to it or a part of the user’s own body, and thus is no longer a part of the environment of the user. (Gibson, 1979, p. 41)
This point invites us to consider first that movement, not just the property of ‘portability’, is important to the operation of many tools, and second that when in use, tools play a role in how and what we directly perceive as we move about. Rather than being something that is perceived, tools can join a human actor in movement and play an active role in how her environment is perceived.

In this regard, Gibson highlights a special kind of tool that he calls a trace-making tool, ‘that, when applied to a surface, records traces and thus affords trace-making’ (1979, p. 134). According to Gibson (1979, p. 134) such trace-making tools (e.g. a pencil or pen) are of ‘enormous importance’ to humans because they have in many ways been fundamental to social life. Their traces have made it possible, since early cave paintings, for humans to inscribe and communicate information that is relevant to other members of the species across temporal and spatial boundaries. When trace-making tools are used to convey way finding, for example through the marking up of directions, we can say that such tools are both dependent on and can inform human movement and perception.

5.4 | Niches

Gibson (1979) is better known for his work on individual perception than his account of social life. Yet in his foundational text, he uses the term niche to clearly link how we perceive our environment individually with how groups (which he refers to from an ecological standpoint as ‘species’) live in the world.9

Gibson (1979, p. 128) asserted that while there is only one environment, this environment ‘offers many ways of life’. Where an animal lives is its habitat but how it lives is what Gibson calls the animal’s ‘niche’, which he defines as a species-specific ‘set of affordances’ (Gibson, 1979, pp. 128–30). This means that one habitat may cater to many kinds of animal but within that habitat, each kind of animal occupies a different niche according to the activities that this habitat makes possible. The concept of the niche is so important to Gibson’s collective level theorising that he states that ‘the niche implies a kind of animal and the animal implies a kind of niche’ (Gibson, 1979, p. 128). For example, a lake is a duck’s habitat (where it lives) but the affordances of ‘dive-into-able’, ‘swim-on-able’, ‘and nest-near-able’ together comprise the duck’s niche (how it lives).

Furthermore, as the specific way that an animal sees and acts in its environment comprises how it lives, this is also what makes that animal distinctively connected to other members of its species: place, perception, action and belonging are inherently linked. Consequently, different species of animal perceive the same environment differently. A waterbird would directly perceive a lake differently from a human, but this does not just mean that each animal would see a different ‘image’ of the lake in the manner of differently composed snapshots taken by distinctive models of camera: rather, the information directly available to each kind of animal and its significance to the animal while moving about that environment are different.

The invariants of the optical flow that provide information to each animal will differ because the underlying structures that they are attuned to and that are useful to them differ. In part, this has to do with physiology but more importantly, it is because each kind of animal depends on different kinds of activity. As an example, the invariant structure that to an adult human appears directly as climb-up-able would not appear as such to a bird that neither has the necessary physiological equipment for step-climbing nor is concerned with step-climbing (it is not something this animal needs to do).

While Gibson is referring to a ‘kind of animal’ in the conventional sense of a zoological sub-species or variety, we adapt this concept to propose that groups of people that perceive and act in their environment in a common way that is distinct from other groups may be thought of as sub-species that occupy different niches.

9The concept of ‘niche’ has had some prior use in IS, particularly in design research (Bergman, Lyytinen, & Mark, 2007). Jung and Lyytinen (2014) refer to a user’s surroundings as a ‘niche’, while Mettler, Sprenger, and Winter (2017) cite Gibson (1979) when studying how service robots in hospitals are variously understood and adopted. However, in contrast to our ecological use of the term, existing use of this term in IS focuses on a technological device and what it can do for the user in a reasonably static use context (e.g. Leonardi, 2013, Tim, Pan, Bahri, & Fauzi, 2017).
6 | EMPIRICAL MATERIAL RE-INTERPRETED WITH GIBSON: MOVING-WITH-TECHNOLOGY

In this section, progressing with our problematization method, we use these four concepts from Gibson to give an alternate interpretation of our empirical account; an interpretation from an ecological perspective foreign to current 'mobile technology use' literature in IS.

The task for this reinterpretation will be to give a different account of how viewing Strava's displays of competition at the lake during the post-run inspection, could change the runner's subsequent perception and motion over this 'segment'. The key conceptual move of our reinterpretation – motivated by Gibson's approach – is to propose that the effect of Strava's displays was not primarily through providing additional information, but instead through directing the runner's attention to her environment in a new way. Furthermore, this education of attention accounts for the subsequent change in both perception of, and moving over, the lake path. In the following sections, we explore this alternate ecological mode of explanation and the new understanding of the role of mobile technology it provides.

6.1 | Running with Strava interpreted as direct perception

Running, as a practiced routine activity with a high degree of automaticity in its execution, provides a good example of 'getting around and looking around' in a manner highly coordinated with an unfolding environment. The runner must plant her feet safely on variable ground with little premeditation; she must avoid stationary obstacles and others who are also using the park; she must quickly assess the danger of approaching animals and adjust her stride accordingly; she must navigate the twists and turns of the track and the overall route of the run; and she will take in and savour the overall ambience of the outdoor scene, all while dissecting the events of the day and planning the evening. All this highly coordinated action makes heavy demands on attention and perception with insufficient time to explicitly analyse the environment and plan the interleaved movements required. Gibson's account of direct perception, with its emphasis on the role of movement in the detection and use of invariant structure, and of learned selective attention to such structure, provides a compelling account of such coordinated real-time performances.

Gibson emphasises the role of attention in such action performances. Attention manages what information is picked up from the environment directly and so what is perceived. But for Gibson perception and action are not distinct. Thus, attention is also directly linked to movement. Prior to using Strava (and when using the app only in a marginal way early on), the runner interleaved attention to obstacles, unexpected events, the path and the broader scene, as required and with varying degrees of focality. However, no particular section of the path itself stood out as particularly worthy of special attention during running, and running style over the whole of the track was rather homogeneous.

However, after Strava had revealed that a particular stretch of the path around the lake was significant for competition as a 'segment' within the Strava community, the runner 'saw' that section of path differently and moved differently through it. Drawing on Gibson, we can interpret this change ecologically as a change in direct perception that occurred through a narrowing of attention to the environment. During these runs, the section of the path around the lake was perceived as 'more focal', while other features of the environment in this place were perceived as more peripheral. Once the runner passed the lake, however, her attention to the environment was less upon the path and returned to taking in other features of the environment in the usual way. This shift in attention occurred on the runs that followed looking at the app while stationary. Inspecting its depictions of the section of lake as a 'segment' of a 'competition' had given significance to a formerly undifferentiated part of the environment. In the following, we interpret this change, and its subsequent reinforcement, as an education of attention.
6.2 | Strava’s role interpreted as educating the runner’s attention

According to our account, initially, the runner consciously rejected Strava's invocation to run competitively over the ‘segment’. Yet its representation of the distinctiveness of the lake section of path nevertheless had an effect on how the path around the lake was attended to subsequently. We can interpret this aspect of the account using Gibson’s notion of educating attention. The significance of the path around the lake was reinforced every time the runner inspected her performance over this segment via the Strava dashboard at the conclusion of each run until the path around the lake itself was perceived as a segment. It came to be ‘seen’ as a place for competition that invited running at a greater pace and with increased attention on the path ahead, while the ‘dimming’ of focus on other sections of the run was accompanied by a relaxation of pace.

To understand this change we draw on Gibson’s view that learning is not an addition of information, but rather a refinement of attention regarding what information we are attuned to in our environment. Accordingly, we contend that while the runner was informed about the competition at the lake, the effect that viewing the exercise-tracking app had on her subsequent running need not be directly attributed to information transmitted to the user, leading to a decision to act differently. Rather, drawing on Gibson, the role the app played can be interpreted as educating the runner’s attention to a newly discriminated part of the environment, so that her direct perception of the environment, in terms of what it offered her, was altered. This helps us to understand how, as narrated in our account, an application that was not itself looked at while running, nevertheless could play a role in what information was picked up directly from the environment by the perceiver as she moved with the app. Conversely, running with an exercise-tracking app also impacted what was not attended to while running, which we will argue is significant when we consider the ubiquity of such technologies in everyday life.

6.3 | Strava interpreted as a ‘digital trace-making tool’

We now consider how Gibson’s concepts can be used to reinterpret the role of Strava as a technology in a way that is consistent with the events of our narrative. We show that conceiving Strava (combined with the mobile device executing the application) as a trace-making tool allows us to understand its role in changing the runner’s direct perception of her environment through an education of attention, and at the same time provides an alternate to the traditional assumptions about how mobile technologies can influence attention, perception and action.

The ‘traces’ that Strava creates when carried were displayed as red trail lines that were visible on the runner’s mobile phone display at the conclusion of her run (shown in Figures 1 and 3). The data that generated these traces were gathered automatically as the ‘runner-with-Strava’ ran with the app activated in her hand. These traces were viewed in post-run evaluation when traces generated by other runners’ activities showed our runner that she had passed over a distinct section of path – a segment – and that this act of moving through a particular stretch of the environment had placed her in competition with other users (Figures 3 and 4). The segment then began to take on significance to the runner because she became trained to see the lake path directly in terms of this trace.

Furthermore, these traces of the segment were replicated in subsequent runs by the runner-with-Strava and by other users similarly attuned to the Sydney Park Lake segment, thereby reinforcing the distinctiveness of the segment and the competitive activity that it invited. This act of ‘trace replication’ was essentially a ‘tracing over’ of existing traces, similar to how a child learns to draw by following marks on a page that are rendered significant in the act of faithful replication:

A child can ‘trace over’ an existing trace, or he can ‘trace’ an existing pattern on a transparent or semi-transparent overlay so as to replicate it. He can thus perceive the congruence of the two patterns. He learns how to match traces and to see the match, or the mismatch, of separated traces. (Gibson, 1979, p. 277)
However, digital trace-making also differs from what is done with a pencil or pen: a pen makes visible its trace simultaneously with the act of tracing, whereas Strava’s traces were collected synchronously with the runner’s motion but were accessed visually by our runner asynchronously, only once the activity has passed. This has two important implications for digital trace-making.

First, it demonstrates that both the carrier’s movements and the technology itself were equally important in the act of digital trace-making. While the runner came to emphasise in her movement traces that the technology rendered as potentially meaningful as human paths, the technology could only do this because the data it collected derived from an actual human carrying it while moving on what they directly, and unreflectively, perceived as a path.

Second, the digital traces produced did not directly mediate between the user’s perception and action while running as the user did not look at the device or its output or use it to control action synchronously with running. Strava was switched on and carried with the user, so the app was ‘doing something’ synchronously with running – automatically providing data for subsequent tracing – but it was not mediating perception or action. Its role in altering perception occurred asynchronously, through subsequently educating attention and revealing social significance. Thus, Strava’s influence on perception had both synchronous and asynchronous elements, which depended on, and subsequently informed, both perception and movement.

We thus interpret the exercise-tracking app’s involvement in the runner’s changed direct perception of the park while running in three ways, derived from the technology’s automation of tracing: first, inspecting Strava’s display at the conclusion of her run educated the runner to see a particular section of path (the Sydney Park Lake segment) as distinct while running through the park. Second, inspecting Strava’s display of her own and others’ traces (and derived performance data) revealed the running of the segment as having a new kind of worth, deriving from proximity and competition. Finally, this perception of distinctiveness and worth was reinforced through the app’s subsequent automated tracing of the runner’s later motions through the segment. Thus, both attention to the segment as a distinct part of the running track, and the social worth of acting differently (competitively) over this part were learned through tracing and retracing the segment by running with Strava.

More generally, we argue that certain portable information technologies can be productively understood as ‘trace-making tools’ when joined in movement with a perceiving human ‘mover’. Trace-making tools do not move autonomously but combined with a human’s movements they can generate digital traces that are in turn displayed to the human. A portable information technology can act as a trace-making tool when it is capable of synchronously recording the mover’s movements through place so that these movements can be asynchronously represented and inspected. The process of digital trace-making, therefore, depends upon portable information technology that is ‘connected’ while in joint movement with the perceiving human, without intervening in a physical sense between the moving human and their environment. At the same time, as the technology depends for its function on the human’s and other’s intentional movement, the human’s movement becomes informed by the technology through an education of attention.

We next shift our analysis to the collective level. We consider how an education of direct perception, brought about by moving with a digital trace-making tool such as Strava, relates to and depends on collective activity and behaviour. We here emphasise the shared yet concealed nature of moving with Strava and link this to Gibson’s (1979) concept of niche.

### 6.4 | Joining the runner-with-Strava niche

Here, we return to our surprising account to argue that through the process we have so far described, Strava plays a consequential role in socialising those who move through the environment with it. Runners-with-Strava are educated to see a segment as valuable not only to themselves but also to one another, a phenomenon that Gibson describes as follows: ‘only when [a person] perceives the values of things for others as well as for herself does she begin to be socialized’ (1979, p. 141). The runner-with-Strava has learned to perceive her environment in terms of the app’s
segments, and so came to ‘inhabit’ the ‘same’ environment (e.g. Sydney Park Lake) differently from when she was just a runner listening to music on her phone (before using Strava fully).

Meanwhile, the lake segment’s distinctiveness and worth, derived from movement and competition, remained undetectable to non-users of Strava. We interpret this as a bifurcation that occurs when runners-with-Strava come to share a way of inhabiting the environment that ‘non-users’ do not, and cannot share. We thus suggest that at a collective level runners-with-Strava who perceive the path around the lake directly in terms of Strava segments, for example as compete-around-able, come to occupy a different niche (i.e., a different set of affordances) within the environment than non-runners-with-Strava. To draw on Gibson’s language, we can interpret this collective of runners-with-Strava as akin to a ‘sub-species’ that inhabits the same habitat as other groups but does so differently. We continue to call such groups ‘digital sub-species’ to retain an ecological connotation when discussing collectives of mobile technology ‘users’, who see and inhabit the same ‘digital niche’ in the environment.

We point out that the runner-with-Strava ‘niche’ is not detectable or perceivable to non-Strava users. It is not possible for a person walking around the lake without a mobile device, and/or without having used the Strava app, to inhabit the runner-with-Strava niche, even though they share the same ‘habitat’. This is because without having one’s attention educated through taking part in the app’s digital trace-making, it is not possible to directly perceive the environment in terms of Strava segments.

This interpretation, we argue, discloses a quite novel phenomenon. Even though ‘non-users’ also cannot perceive the environment directly in terms of, for example, skateboarding, a skateboarder’s activities are perceivable (e.g. visible and audible) to those who are not skateboarding. Running-with-Strava and the traces it generates are, however, completely hidden from those who do not use the application and have not become attuned to its way of seeing. Thus, even when runners-with-Strava and runners-without-Strava share the same habitat, ‘non-users’ do not have access to the traces that runners-with-Strava make and trace over, and therefore cannot ‘see’ that they are crossing through segments that are significant to this group. This can lead to actions that are surprising to non-users (e.g. seemingly random speeding up and slowing down of runners-with-Strava), because there may be no physical markers ‘in’ the environment that denote significance.

### 6.5 From ‘mobility’ to moving-with-technology

In summary, we have reinterpreted our earlier account using Gibson’s theory thus: moving through the environment with an exercise app changed the runner’s direct perception of her environment through an education of attention by means of digital trace-making that facilitated a new way of seeing and acting in her environment, that was common to other runners-with-Strava, which we linked to Gibson’s notion of niche as the characteristic way that a particular species of animal lives in its environment. This reinterpretation resolves the surprise because there remains no disjunction between the runner’s experience and Gibson’s alternate theory. This resolution thus suggests that the ecological concepts that we used – direct perception, education of attention, trace-making and digital species and niches – provide the basis more generally for an alternate understanding of the human plus mobile technology which we will term moving-with-technology.

Moving-with-technology contrasts with the mainstream understanding that we identified as implicitly informing current mobile technology literature (and which gave rise to our surprise) of a technology user who carries a portable device along with their existing motion, a device which stands between the user and their task environment, and provides information which must hold their attention to be effective. Instead, moving-with-technology denotes a moving, perceiving and socially embedded ecological unity of human and trace-making technology together, perceiving and acting within digitally marked-up niches in the environment, that have become directly perceivable to (and only to) new kinds of groups akin to digital sub-species.

In the next section, we will explore what this new understanding can offer to mobile technology research and practice.
DISCUSSION: BROADER IMPLICATIONS OF MOVING-WITH-TECHNOLOGY

By following a structured process of problematizing a revelatory surprise, and reinterpreting the empirical account of that surprise using key concepts from Gibson, we have arrived at a new understanding of what is conceptually new and different about ‘mobile technology use’ that we term ‘moving-with-technology’. We now consider the implications of moving-with-technology and its contribution to future research, beyond the specific context in which the surprising observation occurred.

First, we show that mobile technologies such as exercise-tracking apps are now becoming part of what we term ecological feedback loops, where trace-making is beginning to play a role in actually re-shaping the urban environment that these ‘digital sub-species’ inhabit. Second, we reflect on the societal implications of digital feedback through trace-making within digital niches. For example, such technologies are beginning to impact on the way we see ourselves and thus our social identities. Finally, we propose moving-with-technology as a new analytical perspective for future research and outline new phenomena that can be studied as a result of this shift of perspective, which in turn prompts the use of innovative research methods.

7.1 Ecological implications: Digital niche formation and bifurcation

The collective act of moving-with-technology can have macro-level ecological implications through what we will term ecological feedback loops. For example, a significant portion of Strava’s revenue stream comes from packaging and selling compiled user data to planning agencies. The company sells city-scale ‘heat maps’, a popular visualisation of cyclist routes and activity to urban planners (Walker, 2016) who ‘are making use of data aggregated from individuals’ route tracking apps to understand how people move around cities, with a view to improving infrastructure’ (Middleton et al., 2014, p. 505). The data and traces generated by commuter cyclists-with-Strava are aggregated and visually presented in a way that makes what we would refer to as the cyclist-with-Strava niche legible (Scott, 1998) to decision-makers. A feedback loop is thereby established between the digital sub-species of Strava users and their environment, via civic planners who use aggregated trace-making data to plan and influence public space use.

By 2016, 76 cities and regions around the world were using such ‘Strava Metro’ data, including Glasgow, Reykjavik, Stockholm and Brisbane (Walker, 2016). The co-founder of Strava explained in an interview with The Guardian that this visualised data ‘…helps show the return on investment, on the tax dollars being used by authorities for things like cycle lanes…They want to be able to show this was money well spent, or to learn that there was something they could have done better’ (Walker, 2016). In this quote, an ecological feedback loop between user-groups and the environment is implicit and is being positioned in a positive light. Data from Strava use are reportedly being used to improve ROI by catering to cyclists-with-Strava, shaping the urban environment to suit how this group inhabits it. Today, ‘over 300 public agencies around the world use Strava Metro to evaluate and improve bicycle and pedestrian infrastructure’ (Strava Metro, 2019).

Such a strategic planning focus on a particular niche could, however, bring unwanted consequences. The ecological feedback loop we identify has the capacity to amplify certain traces of activity and thereby to diminish the attention given by decision-makers to the activities of those who are not rendered legible in this digitally enabled way, that is, those cyclists who are not enrolled in Strava use, or who do not wish to engage in the trace-making and competition that exercise-tracking implies and, as our researcher discovered, to an extent demands. The routes that ‘cyclists-without-Strava’ follow are not represented in the Strava data sets and visualisations that planners are

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10Strava users have the option of labelling a bicycle ride as ‘commute’ so as not to interfere with performance statistics achieved during recreational and/or competitive rides.
purchasing (Schneider, 2017). Furthermore, non-cyclists and non-competitors are not accounted for in Strava’s records of movement through these urban habitats. The way ‘non-users’ move through the same environment is therefore not legible to and likely to be overlooked by those who have the capacity to shape a habitat shared by many.11

Thus, our concept of ecological feedback loops provides a useful basis for furthering current IS research on the ‘performative’ role of data (Marjanovic & Cecez-Kecmanovic, 2017) as well as the implications of commercialising data in the form of ‘behavioural surplus’ (Zuboff, 2019). Specifically, we bring into question a narrow focus on economic principles (e.g. ROI) and encourage more research into how local ecologies are being altered by such trace-making technologies, in ways that privilege and reinforce certain niches over others.

Research questions aimed at furthering our understanding of ecological feedback loops could include: Where are these ecological feedback loops in operation? Which technologies and business models support them? How do user groups exploit legibility to advocate for infrastructure that enhances their particular niche? Are trace-making apps becoming Obligatory Passage Points (Rydin, 2013) for such ‘advocacy’? And, how do non-users adapt to interventions that are aimed at enhancing the niche of a user group (e.g. commuter cyclists)?

7.2 | Societal implications of moving-with-technology

We further highlight that the phenomenon of ecological feedback loops cuts both ways – for the environment and the ‘user’. ‘Mobile technology’ is indeed embedded ‘into our daily lives’ (Middleton et al., 2014, p. 505). We add to this point a more critical insight: that moving through the environment with trace-making technologies can have fundamental implications for how we see and act, including how we see ourselves. In the following, we draw further on Gibson’s thesis to develop this point.

Gibson (1979, p. 141) sketches his theory out from the situated view of the active perceiver. In orienting his theory of perception from this ‘occupied’ point of observation, he emphasises the mutuality of the perceiver and the perceived:

…to perceive the world is to perceive oneself...The awareness of the world and of one’s complementary relations to the world are not separable.

The mutuality of this perspective is important and relevant because Gibson is pointing out that a perceiver is co-implicated in what they perceive. This means that when the runner-with-Strava perceives the path as a segment in terms of competition she becomes a competitor.

The societal implications of such co-implication are worthy of consideration. Given that ‘perception is economical’, we argue that as technologies educate our attention to see in certain ways, we are backgrounding or even precluding other ways of seeing the world and ourselves. As ‘users’ come to occupy one niche they may no longer perceive the set of affordances that together make up another way of life, even in the same geographic location. This leads us to ask: what does the need to digitally inscribe our presence and movements (through traces, segment competition, photographs, selfies, check-ins and updates) mean for how we perceive ourselves as we move through the environment? And what does this self-perception cost us on a personal and societal level?

Of course, this is not an entirely new phenomenon – even wearing a timepiece influences how we perceive ourselves and others (as punctual, beholden to a schedule, etc.) (Ballard, 2007). However, the arguments made in this article offer new ways of understanding, studying and conceptualising the implications of moving in an unreflective

11As Gibson alludes, the negative effect that such a feedback loop may have for non-human animals is also relevant: ‘There is only one world, however diverse, and all animals live in it, although we human animals have altered it to suit ourselves. We have done so wastefully, thoughtlessly, and, if we do not mend our ways, fatally.’ (Gibson, 1979, p. 130)
way through the environment with digital technology that is specifically capable of leaving behind and communicating traces of our activity to ourselves and others. This new perspective complements what is usually termed the ‘quantified self’ phenomenon (Lupton, 2013) because we point out that our runner was unwillingly pulled into competition and found herself acting and seeing differently in response to her use of an exercise-tracking app. This change was not entirely ‘voluntary’. ‘Mobile technology’ in this case did not show up as a tool that was instrumentally put to use; rather, the role it played was largely emergent and covert.

We should ask: if mobile technology makes it possible to see many places and moments in terms of competing, working, or consuming, does this mean we are always primed to perceive ourselves as competitors, workers, or consumers? And what alternatives are lost? How do business interests shape the education of perception? For example, how do mechanisms of gamification (designed to promote engagement) used by apps like Strava encourage or direct users to see and act in terms of their system? What ways of acting and seeing are routinely or frequently lost as a result? How do users disentangle themselves from niches by unlearning affordances, to see and act without technology? And can users learn to switch vantage points, for example between different app communities?

7.3 | Implications for mobile technology research

The aim of problematization research is to enable a shift in thinking and a consequent change in direction for a particular area of enquiry. This article makes several contributions in this regard. We propose moving-with-technology as

(a) a new analytical perspective, which (b) brings new phenomena to the fore that in turn (c) invite novel research methods capable of capturing the real-time experience of moving with technology.

New analytical perspective: The hyphenated phrase ‘moving-with-technology’ implies a new analytical perspective that focuses on a human ‘user’ with a mobile device (including associated infrastructure such as 4G, GPS, apps, application servers, etc.) moving through space, over time. In order to capture the way that digital trace-making facilitates socialisation of user groups, what has thus far been conceived of as ‘mobile technology use’ needs to be expanded beyond instances of deliberative interaction of a static user with a discrete mobile device at a particular moment. An analytical perspective that encompasses ‘humans + technology + space + time’ (see also Yoo, 2010) instead prompts us to study how mobile technologies fuse with a human user in movement and how as a result the user’s perception of, and relationship with, their environment and others are altered over time.

New phenomena: Studying moving-with-technology as a new analytical perspective reveals new phenomena. As we have explained, moving-with-technology enables digital trace-making that (a) makes individuals’ activities in the environment visible to other users in a way that (b) brings coherence to new kinds of groups that are akin to digital sub-species who (c) inhabit digital niches in the environment. Digital sub-species inhabiting digital niches are thus two new phenomena that our ecological understanding brings to the fore.

Furthermore, digital sub-species learn through trace-making to inhabit the same environment in the same way, but at different times. This constitutes a new phenomenon we term asynchronous co-location. For example, the runner-with-Strava in our account was competing against other runners-with-Strava across the same stretch of path, but never at the same moment. While she did not ‘meet’ these other users during her runs, she did share her unique way of inhabiting that particular place with other members of her digital sub-species, asynchronously.

The phenomena of digital sub-species, digital niches and asynchronous co-location open up new directions for research on mobile technology. For example, we can ask: What digital-ecological niches are currently inhabited? Who is inhabiting them? How are such digitally enabled niches sustained and when and how do they disappear? Are there moments of breakdown or conflict at points where these niches intersect? How does asynchronous co-location enabled by digital trace-making compare with existing research on online communities, social media use and insights from neighbouring disciplines such as social anthropology?

New methods: To study moving-with-technology, and to investigate the phenomena it reveals, IS researchers will need to explore innovative research methods that can effectively address movement. Because of the emphasis
on the real-time experience of environments while in motion, moving-with-technology is not suited to survey research, interview studies, laboratory experiments, or single context observations. Instead ambient, in situ methods are needed that can capture a tight perception/action relation, time extension, space extension, multiple levels of collectivity and close actor-technology-environment relations. Autoethnography (Bødker & Chamberlain, 2016; Chang, 2016; Riordan, 2014) communicated through storytelling (Davison, 2016) is a promising starting point here, as this method is uniquely suited to revealing the life-world from a first-person perspective and can, therefore, deal well with everyday experiences of moving-with-technology. ‘Multisensorial ethnography’ (Pink, 2011; Pink, 2015) could provide a unique phenomenological approach to perception on the move (see also Dourish & Bell, 2011). Longitudinal practice theory based methods will also be relevant for studying the emergence and maintenance of digital niches (Nicolini, 2009; Nicolini, 2012; Schatzki, 2009), though this lens and associated techniques would need to be adapted to include a greater ecological emphasis on the environment and actors’ relationship with it.

Neighbouring disciplines offer further alternative ‘mobile methods’ (Büscher, Urry, & Witchger, 2010). For example, ‘following the people’ (Marcus, 1995) is a form of sociological shadowing where the research follows people’s movements, ‘their strolling, driving, leaning, running, climbing, lying, photographing, and so on’ (Büscher et al., 2010, p. 8). Participating in patterns of movement is another option, through ‘walking with’ or ‘street ethnography’, which involves taking part in the movement as well as interviews or focus groups with the people under study (Ingold, 2004; Ingold & Vergunst, 2008). Time–space diaries require respondents to ‘record what they are doing and where, how they move during each period, and the modes of movement’ (Büscher et al., 2010, p. 9; Kenyon, 2006). ‘Mobile positioning’ methods (Büscher et al., 2010) involve making use of the macro-level data, such as Strava heat maps, that collective moving-with-technology generates, to investigate movement from a ‘zoomed out’ (Nicolini, 2009) perspective.

Innovative methods will be an essential part of taking movement seriously in mobile technology research. Future methodologically oriented researchers could, therefore, investigate questions such as: What methodologies can deal with real-time experiences of movement with technology? How can digital traces be used in IS research on moving-with-technology? What can we learn from neighbouring disciplines that are more experienced in studying, for example, digital subcultures, covert communities, geographies and movement as a cultural practice?

8 | CONCLUSION

In this article, we have used problematization to answer three research questions prompted by the surprising observation that an exercise-tracking app unwittingly changed how the lead author moved through and perceived her environment while running: (a) What assumptions underpinning the field of mobile technology research are revealed by our surprising observation? (b) What theoretical resources can be used to make new sense of the phenomenon? and (c) What are the broader implications of such a new understanding of the phenomenon for the field of mobile technology research?

First, our finding that mobile technology can become intimately implicated in how we perceive and act in the world, even when it does not have focal attention, provides insight into the significance of mobile technology beyond familiar considerations of portability and connectedness. In this article, mobility is not treated as a property of a technology-thing. Instead, we demonstrate how mobile technologies accompany us in movement and argue that, while these technologies are often not the focus of our attention, they may nevertheless play a fundamental and significant role in focusing our attention – attuning us to certain vistas, affordances, ways of moving, and ultimately ways of being – individually and collectively.

Second, we found that Gibson’s ecological theory of perception was an ideal external resource for making sense of our revelatory surprise because of its concern with how attention, perception and action depend on movement, which we identified as central to the surprise. Reinterpreting our account of running with Strava using Gibson’s
concepts of direct perception, the education of attention, trace-making tools and niches, we have developed a new ecological understanding of the phenomenon of moving-with-technology.

The article responds to calls for research on ‘digitally mediated embodied experiences in everyday activities through everyday artefacts that have embedded computing capabilities’ (Yoo, 2010, p. 213). It contributes to IS research the new analytical perspective of moving-with-technology, the phenomena of digital sub-species, digital niches, and asynchronous co-location, and a provocation to explore novel research methods such as autoethnography and alternative ‘mobile methods’. In addition, it contributes to the IS literature an example of problematization (Alvesson & Kärreman, 2007) inspired by a surprise. We have illustrated how this approach can lead to new insights and research directions by interrogating ‘mobile technology use’ from an ‘occupied’ point of observation. Furthermore, while Gibson’s notion of affordances is firmly established in IS, here we have shown the efficacy of less familiar elements of Gibson’s work on attention, movement and perception to articulate what is ‘new’ and ‘different’ about mobile technology beyond the property of ‘mobility’.

To practice, we offer new insights into how individual ‘use’ of mobile technology while moving is capable of generating ecological feedback loops through emergent data-driven planning practices. We have highlighted that a ‘digital niche’ can be physically reinforced when the traces that ‘digital sub-species’ produce through ‘asynchronous co-location’ are aggregated and taken into account by planners and designers, thereby establishing an ‘ecological feedback loop’. Our research paves the way for further studies on ecological feedback loops, particularly in the field of Smart Cities.

Regarding the generality of our findings and applicability to future research, we have focused on a particular kind of technology – an exercise-tracking application on a smartphone. We used this as a starting point to articulate opportunities for research on other technologies that can be understood as ‘trace-making tools’, for example, on how Instagram draws Instagrammers to see in terms of ‘Instagrammable’ vistas (Nicolao, 2018) while moving around their environment. Detailed studies that combine (auto)ethnographic and novel ‘mobile methods’ with more macro-level studies of the use and impact of data sets generated through moving-with-technology will shed light on the generality of our account of the role of ICT in perception on the move.

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