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JHTR

Journal of Human-Technology Relations

SYSTEM-PHENOMENOLOGY

An Empirical Case for Collectives in Mediation Theory

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Article type: Research article
Review process: Double-blind peer review

DOI: 10.59490/jhtr.2024.2.7031
ISSN: 2773-2266
Submitted: 20 June 2024 Revised: 16 October 2024 Accepted: 16 October 2024 Published: 30 December 2024

How to cite (APA): Dameski, A., Spahn, A., Pouw, C. A. S., Kodapanakkal, R. I., Haans, A., Corbetta, A., Toschi, F., Ham, J., Bombaerts, G. (2024). System phenomenology: an empirical case for collectives in mediation. *Journal of Human-Technology Relations*, *2*(1), pp.1-22. https://doi.org/10.59490/jhtr.2024.2.7031

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Keywords

System-Phenomenology; Post-Phenomenology; Technological Mediation Theory; Crowds, Collectives, Empirical Analysis

Abstract

Postphenomenology and mediation theory strongly explain the micro-level interactions between human individuals and objects. Recently, humans as a collective have been added to the theory at the political macro-level, which we argue that is an important contribution. However, the enlargement of the theory would also merit a meso-level explanation of the role of collectives, in between the micro- and the macro-level. For this purpose, we introduce the mediation triangle, illustrating three bidirectional relations, all mediated by technology: human-object, human-collective, and collective-object. The mediation triangle we combine with three borrowed concepts from systems philosophy to aid in our framework design: differentiality, emergence, and irreducibility. This approach, named system-phenomenology, can explain the interaction between objects, individuals, collectives, political levels, and technology. We illustrate this using an empirical case of boarding and deboarding at train stations. We conclude that system-phenomenology is promising, but further research is needed to develop this theory conceptually.

1 INTRODUCTION

This article provides a system-phenomenological approach by proposing a mediation triangle and performing quantitative analysis for collectives in postphenomenology.

Postphenomenology (Ihde, 1990, 1993) and mediation theory (Verbeek, 2005, 2011), which we consider here as a sub-theory of postphenomenology, have continuously been optimized as theories that describe the interaction of individual human beings in the world.

A common criticism of the object-technology-human relation in postphenomenology in general and mediation theory in particular is that it does not sufficiently take macro-level phenomena into account. It predominantly focuses on the individual or micro-level, as the concept "I-technology relation" (Ihde, 1990) indicates. The answer currently gaining traction is to complement postphenomenology by introducing a socio-political perspective on technology-human interactions (Arzroomchilar, 2022; Botin et al., 2020; Feenberg, 2020).

In this paper, we will argue that, to enhance postphenomenology, there is also a need to complement this socio-political perspective with another domain of study focused on concrete collectives, such as crowds and groups. Thus, in line with the micro-level (individual) and macro-level (socio-political), we use meso-level to denote the concrete collective perspective. We use this to come to a broader framework that we call *system-phenomenology*, doing justice to micro-, meso- and macro-level. Its purpose is to cohere these levels of abstraction for (post)phenomenology. Our claim is that the system-phenomenological approach contributes to postphenomenology by making sense of cases involving concrete collectives, which are often difficult to understand and explain merely from the perspective of the object-technology-individual relation alone. Technology affects collectives, such as crowds, groups, and subgroups, etc., in addition to affecting individuals; and reversely, technologies are also designed, deployed, and used for collectives.

To achieve this, we embed our discussion in the existing postphenomenological debate in Section 2. Several authors have already made a plea to broaden the individual, micro-level to a political macro-level postphenomenology, and we suggest a gap of meso-level collectives in postphenomenology. In Section 3, we introduce the mediation triangle by extending the object-technology-individual interaction with meso- and macro-collectives. We embed this in a broader approach, which we call system-phenomenology, and formulate arguments for why the meso-level is warranted.

We use empirical findings to scaffold our postphenomenological study (Fisher Jr. & Stenner, 2011; Rosenberger & Verbeek, 2015a). In line with this empirical turn (Verbeek, 2015), we study how objects, train and train platform technology, individuals, and crowds interact at train stations. For this purpose, we use sensor data, algorithmic spatial group recognition, and heatmap analysis. We pair our findings with postphenomenological interpretations. We sketch the quantitative research on our two cases in Section 4 and describe the results in Section 5. In section 6, we discuss how individual-collective and object-collective relations add to postphenomenology. In Section 7, we conclude that a mediation triangle in system-phenomenology is a useful concept and propose further avenues for research.

2 BACKGROUND: THE MICRO-, MACRO- AND THE MISSING MESO-LEVEL OF POST-PHENOMENOLOGY

2.1 THE MICRO-LEVEL MEDIATION: INDIVIDUALS

Postphenomenology and mediation theory take a vantage point in individual experience, and therefore, the individual takes a central place in postphenomenological theory. This emphasis on individuals is referred to as the *micro-level* (Verbeek, 2020). Postphenomenology and mediation theory largely focus on the individual and their relationship with objects through technology. There are two main reasons for this.

First, postphenomenology emerged from phenomenology. Phenomenology, at least as developed by Edmund Husserl, begins with an analysis of how phenomena are constituted in the individual stream of consciousness. Husserl's strong emphasis on the transcendental ego (Husserl, 2013, 2019) has already been criticised by contemporaries. Martin Heidegger therefore introduces the intersubjective category of the Mit-Sein as an existential in Sein-und-Zeit and criticises the “Subject-philosophy” in Kant and Husserl. Therefore, we find that early phenomenology attempts to direct attention to intersubjective phenomena, often starting from personal relations (Zahavi, 2001). But except for Heidegger’s criticism of the "man” in *Sein und Zeit* (Heidegger, 1996), most of these attempts are not focussed on meso-level phenomena, but start from the phenomenology of personal relations between the ego and the alter. Similarly, postphenomenology has been criticised recently, as lacking attention to the dimension of collective and political phenomena. Within phenomenology, recent attempts have been made to investigate the category of social phenomena in greater depth, such as Dolezal and Petherbridge (2017), Salice and Schmid (2016), and Szanto and Moran (2015).

Second, individuals are in many theories implicitly or explicitly considered as a basic building block, so it makes sense for postphenomenology to take its level as the fundamental one i.e. the ‘micro’ one. This approach is understandable, pragmatic, and has been shown to be very successful. In this approach, Verbeek (2005), for example, lists, building on Ihde (1990), the four basic relationship types for mediation theory between people, technology, and the world: *embodiment* ((human - technology) → world), *hermeneutic* (human → (technology - world)), *alterity* (human → technology (world)), and *background* (human (technology/world)) relations. This and other conceptualisations allow for a two-fold advantage from the onset: it simplifies the analysis to a manageable level, while also utilising a perspective that is readily available to many philosophers.

However, this approach is still limited because it misses or struggles to explain a wide variety of phenomena that are collective or collectively-mediated and influenced. Some thinkers in ethics (Feenberg, 2020; Gee, 2013) and psychology (Barker, 1968; Bronfenbrenner & Morris, 2007; Sieben et al., 2017) recognise that many phenomena or behavioural patterns are hardly or not at all reducible to the analysis of individuals and require a macro- and a meso-level perspective.

2.2 THE MACRO-LEVEL MEDIATION: SOCIETY AND POLITICS

Recently, philosophers have attempted to better incorporate the dimension of the social into postphenomenology. These suggestions follow an often-voiced criticism that traditional postphenomenology does not adequately reflect on the importance of social, political, and cultural phenomena (Arzroomchilar, 2022; Feenberg, 2020; Verbeek, 2020).

There have been various suggestions in the literature on how to remedy this situation. Several authors make pleas to consider postphenomenology as a political influence. Rosenberger, for example, makes a plea for variational cross-examination to examine and influence multistability to “break potentially deeply-ingrained habits of perception and understanding” (2017, 2023:

2234). Feenberg criticized postphenomenology for a lack of political awareness and suggested placing a stronger emphasis on the political aspects of technology development and usage. He suggests changing *human* into *humans* (plural) to account for the importance of the collective dimension (Feenberg, 2020). Arzroomchilar has argued that one should incorporate elements of Social Constructivism of Technology (SCOT) into postphenomenology (Arzroomchilar, 2022). Botin and colleagues (2020) suggested combining ideas from critical constructivism with postphenomenology. Most recently, Melis Baş (2022) used the work of Hannah Arendt to analyse the political aspects of the mediation of intersubjectivity.

Verbeek has addressed the criticism and developed an outline, in how far the political has indeed a place in postphenomenology. According to him, technological mediation is a matter of micro-processes in which technologies shape human actions and perceptions, and macro-processes, forming social practices and cultural frameworks of interpretation. This is what can be dubbed as the *macro-level* of mediation theory study (Verbeek, 2020).

However, what these suggestions have in common is that they mainly regard the task of incorporating the social dimension as a call to reflect on the political macro-dimension of mediation. As it is a strength of postphenomenology to understand how (inter)subjectivity adds to interactions, it would be useful to understand how these political macro-dimension of mediation come about. For example, consider macro-level effects over the design and use of technology in the evolution of smoking at Dutch train stations. A loose smoking 'lobby' in the past at the level of wider society and politics has exerted the effect to be allowed to peruse tobacco at train stations, while later a (presumably) bigger or more powerful 'lobby' has exerted a countering influence on the socio-political macro-level, for example, by successfully enacting the National Prevention Agreement (Verweij & Dawson, 2019). This has resulted in the gradual containment of smokers into predetermined smoking spots, and finally, in the complete ban of smoking at the stations (O'Leary 2020). We argue that the political macro-dimension is only one possibility to interpret intersubjectivity, and that there are other equally important dimensions of intersubjectivity that deserve attention within mediation theory and postphenomenology. More specifically, we aim to highlight the importance of meso-level social phenomena that can allow for distinct explanations in mediation theory and postphenomenological analysis.

2.3 FILLING THE GAP WITH MESO-LEVEL MEDIATION

In our view, the macro-level postphenomenology study has a particular weakness of often lacking concreteness, which however cannot be solved by reverting to the individualistic micro-level. This is because many technologies and tools that humans use are designed for, or under the influence of, *concrete* collectives such as crowds and (sub)groups, and not individuals. Concrete collectives further mediate how the same technologies and tools are used by individuals who often cannot avoid this influence.

An additional key point was raised by Verbeek (2020) regarding intersubjectivity, by claiming that there is a need to reject considering individuals only as "atomistic and self-centered" by recognising the "fundamentally relational and mediated character of human existence" — by both technology and other people.

Finally, describing certain collective effects and phenomena from an individualistic lens becomes impossible when we discover that they consistently appear throughout multiple occurrences, where particular individuals are completely abstracted out (Dameski et al., 2022; Pesch et al., 2020). An example is the use of statistical analysis of multiple iterations of similar events, like we do in Section 4. below.

3 SYSTEM-PHENOMENOLOGY

Instead of simply adding the meso-level domain and trying to stitch it to the previously-developed micro- and macro-levels, we suggest a new framework that coherently incorporates all three levels. We call it *system-phenomenology.*

In it, by using concepts and approaches inspired by systems science, we aim to enhance the quality of our mediation theory study, especially regarding the relationships between individuals, collectives, and social systems. Besides this theoretical background, system-phenomenology currently works with the following tools that we lay out in this article: the *mediation triangle* and the *meso-level* of abstraction. However, our framework is open to further theoretical and practical contributions and enhancements.

3.1 THE MEDIATION TRIANGLE

Based on the structure of experience (Ihde, 1986, 1990; Spahn, 2015; Verbeek, 2015), we also make a distinction in the two-way object–technology-user relationship described above based on *effect direction*, that is, whether in a particular case the user affects the technology or/and vice-versa.

As "world" can have different translations in system sciences depending on what it refers to, such as environment, horizon, ultimate system (Luhmann, 1995; Luhmann et al., 2013)), we prefer to make a distinction between "world" and "object". Talking about the interaction between human beings and objects, we explicitly use "objects", and not world. As such, descriptions of relations will be different. "((human - technology) → world)", for example, becomes "((human - technology) → object)".

It is a distinction between the *user-object* and the *object-user* direction of effect in the mediation theory relationship. *User-object* focuses on how technology is designed, implemented, employed, and modified under the influence of its users. *Object-user*, on the other hand, is focused on how technology itself influences the behaviour, experience, and state of being of its users.

To help illustrate the mediation relation between individuals, objects, and technology, and now also collectives, we introduce the *mediation triangle.* It describes the three 'angles' of the system under study (object, individual, collective), as well as the relationships between them each. We stress that this mediation triangle is an instrument for analysing the three angles separately, whereas in reality, they always interact inextricably. The interaction between individuals and collectives cannot happen without the influence of objects and the mediation of technology; the interaction between objects and the individual very rarely can happen without the influence of the collective; and the interaction between the object (world) and the collective cannot happen without the influence of the individuals.

Postphenomenology in general, and mediation theory in particular, start from the relation between individuals and the object (world) mediated by technology. In our mediation triangle, this micro-level relation is represented by the horizontal lines at the bottom of the triangle from individual users to objects and from objects to individual users.

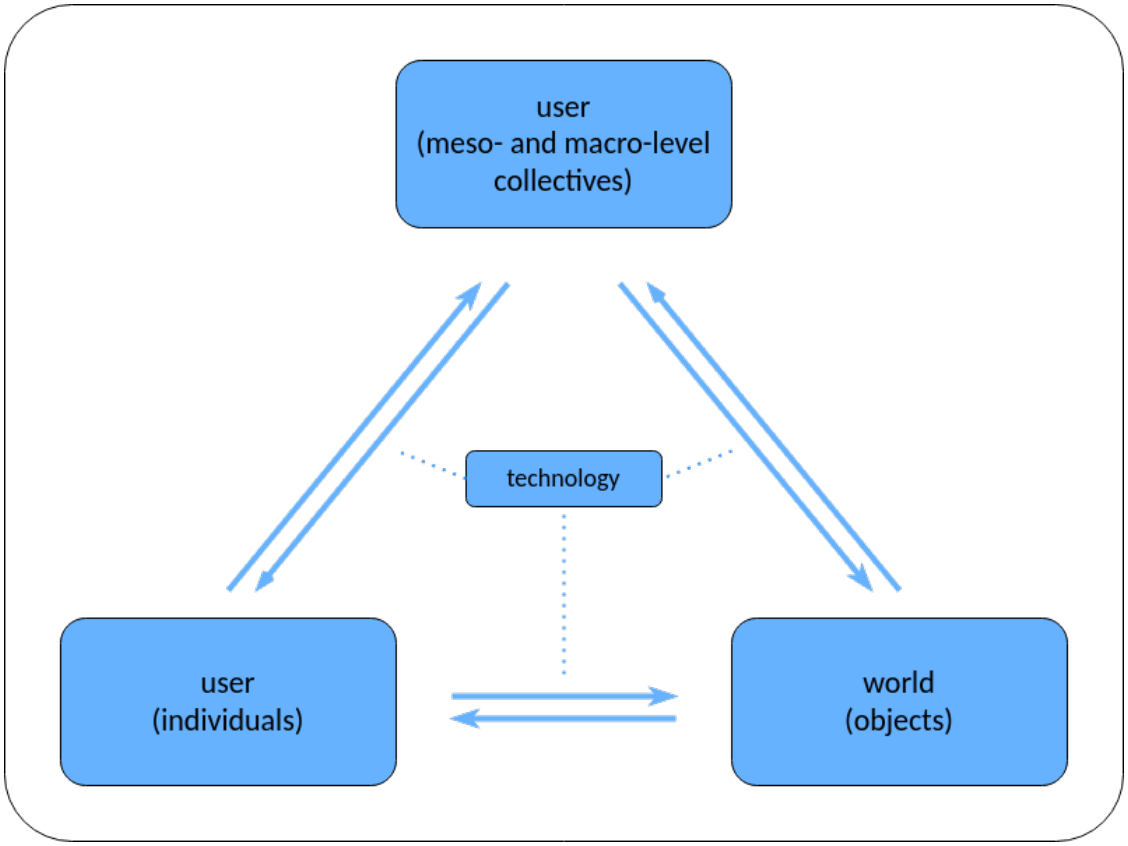

Figure 1: The mediation triangle: relationships between individuals, meso- and macro-collectives, and the objects (world), mediated by technology.

We argue that it is helpful to add collectives to this picture, converting the single bi-directional interaction line into a triangle. The socio-political macro-level is present as one interpretation of collective mediation. As we argued above, we think this level remains fairly abstract and adds less to the particular strength of postphenomenology to reveal the phenomenological structure. Therefore, collectives are presented as both meso-level concrete collectives and macro-level collectives.

The meso-level study is to be focused on exploring the behaviour, experiences, and effects of *concrete* collectives: *crowds* and *groups,* as opposed to the macro-level of state actors and collective institutions, especially when applied to behaviours, experiences, and effects pertaining to the design, deployment, and use of technology and tools. It is beyond the scope of this article to provide a precise definition of crowds and (sub)groups. For a multidisciplinary glossary, we refer the reader to Adrian *et al.* (2019). However, we use the following as our working definitions. Both crowds and groups are constituted of more than one individual. One distinction between crowds and groups is that a crowd is a collection of individuals that participate in the same activity at the same place through similar means with similar goals in mind, but does not possess a so-called *we*-mode and other entitative properties (Denson et al., 2006; Gee, 2013). On the other hand, (sub)groups do have these *we*-mode and entitative properties. In other words, (sub)groups not only intend a joint action but they intend the joint action *collectively* (Schweikard & Schmid, 2013).

Therefore, in the mediation triangle in Figure 1, besides the two-directional relationship between individuals and the objects (world), we add two additional bi-directional relations: between individuals and collectives; and between collectives and objects (world). It follows from

this addition that users of technology are no longer only individuals, but both individual(s) and collective(s) of users.

At times, and for the purposes of disambiguation, we enrich labels such as *user, technology* and *object* using subscript and parentheses. For example, if we want to specify that we are describing a relationship between individuals and collectives, both as users, we would use: $user_{individuals}$-$user_{collectives}$, or even more specifically, such as: $user_{traveller}$-$user_{smoking}$ *crowd*.

In further text, we also show that relationships can stretch over two or more sides of the triangle. For example, technology can affect individuals through crowds (*object-user-user*); or individuals can affect themselves in an extended fashion by being part of a group that influences a particular technology, which in turn has an effect on them as individuals, closing the loop (*user-user-technology-user*). This possibility arises from the co-constitutional nature of our relationship with technology, as explored by Verbeek (2015).

3.2 SYSTEM PHENOMENOLOGY

To enhance our study of collectives and the effects exerted over the two directions of the relationship with their environment and technology, we borrow an important concept from systems philosophy and information science: *differentiality*. As Niklas Luhmann (2013, p. 44) would aptly point out, 'a system *is* the difference between the system and its environment'.

Oizumi *et al.* (2014) use the phrase "a difference that makes a difference". We use this 'differential' definition with regard to concrete collectives both conceptually and empirically. Namely, conceptually, a collective is a difference in a particular set-up, something more than the simple sum of individuals comprising it. Empirically, we are searching to identify empirical evidence that reveals that concrete collectives actually do exert a substantive difference on people's behaviour and the design, deployment, and use of technology. Inversely, we are also searching for evidence of whether and how technology affects the formation, behaviour, and properties of collectives.

A second and related concept that we use is *emergence* (Luhmann, 1995: 105). For Luhmann, expectations of psychic systems (referring to individuals) make a social system emerge. A psychic system for Luhmann is fundamentally different from a social system. A psychic system has consciousness as a self-referential or autopoietic mechanism, whereas communication is a social system's autopoietic mechanism (Bombaerts, 2023; Valentinov et al., 2016).

A third related systemic concept to differentiality and emergence is *irreducibility*. In certain situations, collectives do make a difference that makes a difference, which means that their existence and effect are irreducible to the simple sum of individual social actors (see Bertalanffy (1968) on (non-)summativity and wholeness, as well as Oizumi *et al.* (2014) on integration, exclusion, and cause-effect repertoire).

As such, when we discuss system phenomenology, we intend to denote the interplay between objects, technology, individuals, meso-level collectives, and macro-level collectives.

3.3 IS ADDING THE MESO-LEVEL WARRANTED?

There are several arguments as to why adding the meso-level study will be beneficial for philosophy of technology in general, and for mediation theory in particular.

(1) Technology and concrete collective phenomena substantially interact with each other.

Particular concrete collective phenomena warrant our attention because they have a substantial effect in the *user-technology-object* direction on how technology is designed, implemented, and

used (refer again to our mediation triangle in Figure 1). Many peculiarities in this regard are difficult—if not impossible—to be explained from the micro- and macro-level of study.

An example is train station platform widths, which are designed to accommodate crowd formation while boarding and deboarding, and which cannot be explained by referring to individuals alone. Another example is train car dimensions, which are also suitable for transporting a typical crowd i.e. up to a hundred passengers, but not for single travellers, or thousands and millions.

Many technologies are even designed with *predominantly* having meso-level collectives (e.g. crowds) in mind. A train station platform and incoming trains, for example, are not primarily designed for *object-user*$_{individual}$ or *user*$_{individual}$-*object*. The design optimises *object-user*$_{collective}$, as to optimize the boarding of a crowd in a train station. And it uses *user*$_{collective}$-*object*, as it takes into account how crowds behave in train stations when confronted with particular platforms, trains, doors, signals, and so forth. We cover examples of this influence below.

(2) Collectives have a mediating influence on technology's effect on objects and individuals

In the *object-technology-user* direction of this two-way relationship, the aforementioned collectives have a mediating influence on the effect technology itself has on the objects and individuals. In many cases, the effect has to 'pass through' collectives before reaching individuals. What is of particular interest here are cases where collective phenomena make a difference that makes a difference.

Such occurrences can be, for example: individuals waiting in queue; sustaining a temporary decrease in personal space and of movement speed while in a crowd; considering position and movement vectors with respect to apparent groups that tend to stick together on a platform in a spatiotemporal context (e.g. families or groups of friends); experiencing elevated anxiety levels caused by uncertainty in getting a suitable seat; and so on.

What we are seeing here, in the *object-technology-user* effect direction, is that collectives mediate the effect technology has on the artifacts and individuals. Even if an individual does not belong to a collective while attempting to use a particular technology (e.g. while boarding a train and finding a suitable seat), the person is plenty of times unable to use the technology without being exposed to the mediating effect of a crowd or other meso-level collectives. This is what we describe as the collective being a difference that makes a difference. In other words, situations where existence and substantial effect (of collectives) on their environment cannot be avoided, and even more importantly, where they can be attested or extracted from available data. This is especially visible in iterative cases, where this collective effect can be noticed statistically across multiple iterations of similar events, meaning that individuals are fully abstracted out.

(3) Technology mediates the formation, behaviour, and properties of collectives

An additional point in *object-technology-user* effect direction is that technology and tools influence the formation, behaviour, and properties of collectives. Crowds form at particular spots around train stations, bus stations and airports in large part due to how the latter were designed and built.

For example, crowds form and behave differently at airports and train platforms because airports typically employ more structuring, such as explicit corridors, queuing barriers, designated exclusive entrances and exits, security enforcement measures, and other. Other peculiarities of implemented technology and tools affect whether and how much groups stick together spatiotemporally, how they purchase products and services, and how they peruse them. Because of the way a particular technology is designed, in some situations, individuals are

better off using it in a collective manner. An example would be discounts for collectively- and simultaneously purchased tickets.

(4) Collectives are experiencing a resurge of research in a variety of domains

Recent work in philosophy, ethics, systems science, and the social sciences (especially sociology and psychology) has made renewed strides towards collective phenomena and entities (see, for example: Astola et al., 2021; Dameski et al., 2022; Gee, 2013; Laes & Bombaerts, 2021). There is also significant effort put in the so-called field of *physics of social systems*, where various methods from physics and mathematics are used to analyse social behaviour and phenomena, typically in a collective fashion (see, for example: Corbetta et al., 2015; Gabbana et al., 2022; Pouw et al., 2020). We especially mention physics of social systems because much of the physics methodology and concepts (e.g. flow, flux, pressure, compressibility, crystallisation, etc.) used in this field are significantly more fitting for studying collective behaviour than individual behaviour.

4 EMPIRICAL CASE

Context. We start from a typical boarding and deboarding event at a Dutch train station, which most readers might be familiar with. Arriving at the platform through stairs or an escalator, a traveller is greeted with a crowd of people waiting for passengers in the train cars to deboard, after which boarding can start. Some of the boarders might be calm, others might not be paying much attention and minding their own business, others might be anxious to get on board and catch a good spot to sit so they slowly 'compress' towards the door, while others still are running on the platform because they might miss their ride. Most boarders wait in two groups left and right from the train doors, leaving a space like a corridor so that deboarders can exit the trains.

Aim. In the previous section we mentioned some generic examples of the interplay between collective phenomena at the meso-level and technology. Here, we further focus on the above intuitive every-day cases of technology used at Dutch train stations by discussing empirical research findings. Our aim here is to strengthen our postphenomenological mediation triangle claims introduced in Section 3.2, adding $\text{user}_{\text{individuals}}$–$\text{user}_{\text{collectives}}$ and objects-$\text{user}_{\text{collectives}}$ to the objects-$\text{user}_{\text{individuals}}$ interactions. We aim to add strength to the claim through empirical research (Fisher Jr. & Stenner, 2011; Rosenberger & Verbeek, 2015a, 2015b; Verbeek, 2015).

Case selection. To be able to study the two new bidirectional interactions, we will discuss two cases. To study the bidirectional $\text{user}_{\text{individuals}}$-$\text{user}_{\text{collectives}}$ interaction, a first case will examinethe interactions between deboarders and boarders. To study the bidirectional object-$\text{user}_{\text{collectives}}$ interaction, we study the influence of stairs on train boarder collectives.

Data Gathering. We use pedestrian tracking data acquired on platform 3 at Utrecht Centraal station, The Netherlands. Since 2017, platform 3 has been equipped with 19 commercial pedestrian tracking sensors, each of which captures 3D stereo images at f = 10 frames per second, with localization precision O(5–10)cm. Data are processed in a fully anonymous way, e.g. without facial recognition and according to strict data law followed by ProRail, the Dutch governmental organisation for the maintenance of the national railway infrastructure, the rail capacity allocation, and rail traffic control. The total area covered by the set of sensors consist of a covered area of approximately 450 m^2. Figure 2 shows an overhead view and a plan of Utrecht Centraal's platform 3.

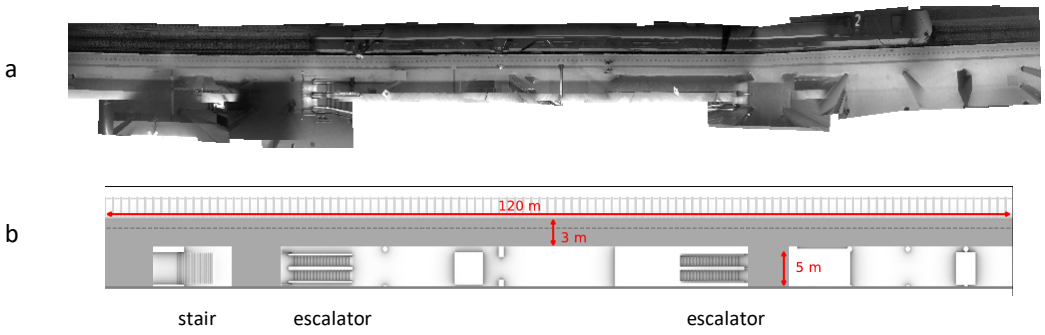

Figure 2. a) Utrecht Centraal's platform sensor overhead view; b) platform's plan

Ethical approval. ProRail collected data in a fully anonymous way. The university research group has a legal agreement with ProRail for analysing the existing data. The research group has written confirmation from the university's Ethical Review Board that no ethical approval is needed in this specific case to perform analyses on the data.

5 RESULTS

5.1 USER$_{INDIVIDUALS}$-USER$_{COLLECTIVE}$

Our first empirical example focuses on exploring the bidirectional *userindividuals-usercollectives* relationship. For this purpose, we explore empirical data on *deboarder corridor width* (see below) among queuing crowds on platforms at the Utrecht central station. The movements and position of people boarding and deboarding trains were tracked over a time period of 2017 to 2020.

The general scenario at the Utrecht Centraal train station is as follows. Train cars arrive right next to a platform, stop, and open their doors. People outside typically form a queue around the doors in two subcrowds, while those onboard the cars start disembarking; this interplay between the two crowds results in forming a temporary corridor in physical space for deboarders located between the two boarder subcrowds. Once onboard passengers disembark, queued crowd(s) begin boarding. Finally, after the time allotted for boarding passes, train doors close, and trains are on their way to the next station.

Figure 3.1 holds six extracted frames from a rendered video, which is a reconstruction of traveller movement during one deboarding and boarding event from sensor data. In it, we are using an algorithm to classify and count pedestrians belonging to either of the two boarding subgroups (left and right), as well as, the area and width of the deboarding corridor between them. We classify pedestrians belonging to the left or right boarding group by employing a density-based clustering algorithm. The space occupied by each boarding group is approximated by calculating the convex envelope for each cluster. The distance between the convex envelope for the left and right boarding group is used to define the width of the deboarding corridor.

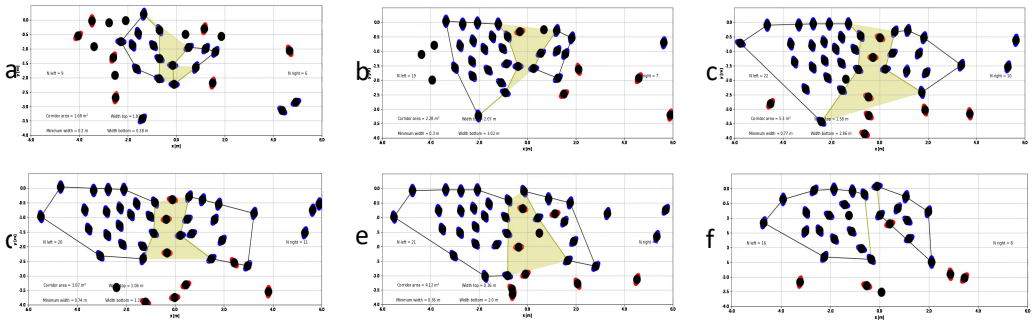

Figure 3.1. Six frame extractions from an animated video that follows a deboarding – boarding process. Total video length: 30 seconds. Frame extracted at time (seconds): a – 0; b – 4; c – 12; d - 18; e – 22; f – 26. Colour linear coding: blue – boarders; red – deboarders; lime-coloured polygon – deboarding corridor area. Linear grid on x and y coordinates in meters. Train door located at coordinates 0, 0. The original video can be found at: https://mfr.de-1.osf.io/render?url=https://osf.io/download/7b5dp/?direct%26mode=render

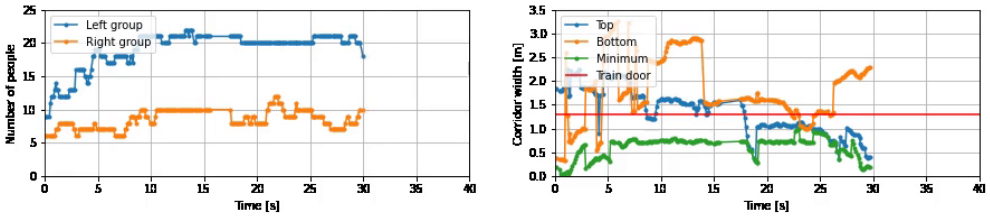

Figure 3.2. A value plot over time of several parameters extracted from the video in Figure 3.1 above. Left image plots population per each boarding crowd (left and right). Right im-age plots deboarding corridor width at three different spatial areas (top, bottom, train door) as well as its minimal size (minimum).

Through statistical and spatial analysis it was found that the width of the corridor of deboarders is dependent on the *ratio* between boarders and deboarders: a *higher ratio of people waiting to board tends to result in a narrower corridor for deboarders* (see Figure 4 and Figure 5). Figure 6 depicts the spatial statistical distribution (contour plot) of the deboarding corridor.

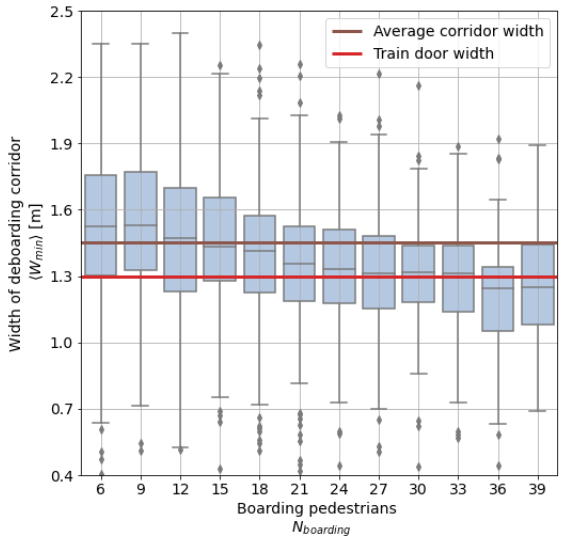

Figure 4. A plot of the relationship between number of boarders (X-axis) and corridor width (Y-axis) at the Utrecht train station platform. Number of boardings considered N=5628

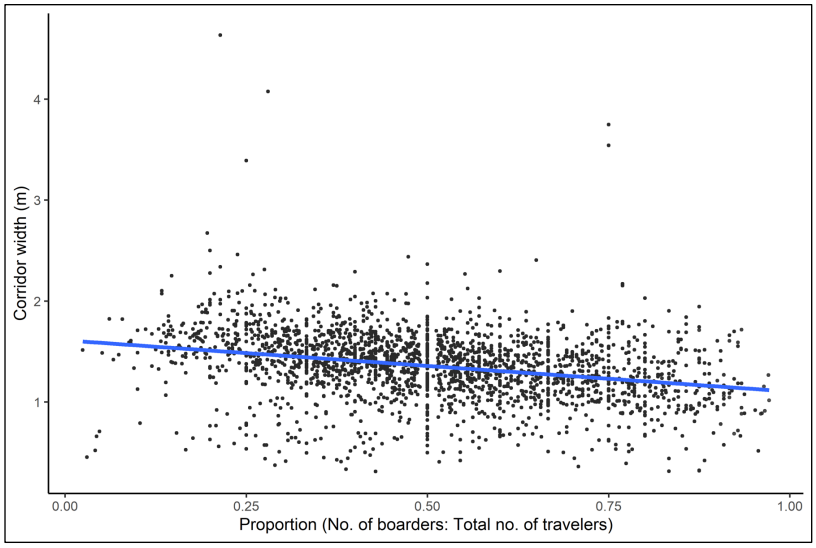

Figure 5. A plot of the relationship between the corridor width on the Y-axis, and the ratio of boarders vs. total travellers on the X-axis.

The higher the number of queuing boarding passengers in relation to the total number of passengers, the narrower the deboarding corridor is. The inverse also applies: the higher the number of deboarding passengers in relation to the total number of passengers, the wider the deboarding corridor is.

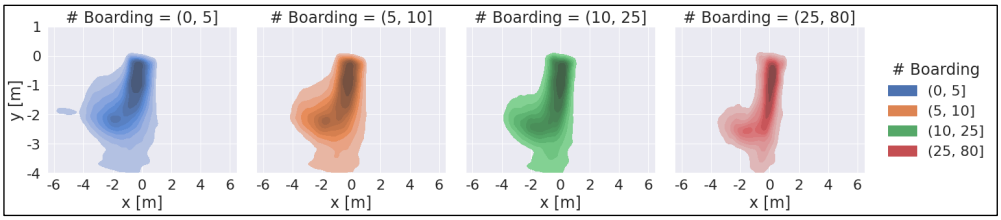

Figure 6. Statistical contour plot of the position of deboarding people as a function of the number of boarding travellers, in four different boarder population configurations: 0-5, 5-10, 10-25, 25-80. Colour codes for the number of boarders (see on the right). X and Y co-ordinates depict two-dimensional space in meters, relative to train door whose centre is located at plot coordinates 0, 0.

5.2 OBJECT-USER$_{COLLECTIVES}$

Our second empirical example focuses on exploring the *object-usercollectives* relationship. Therefore, we focus on how platform design, more precisely, the presence of stairs (and escalators, as they are commonly located together), affects boarding crowd formation, behaviour, and properties. Similar to the corridor width case, here crowd formation was also tracked throughout multiple boarding events over the same period of 2017 – 2020.

The general boarding scenario described in the corridor width case is applicable here as well. In addition, we focus on the position of stairs on the platform. The 'nearer' area is 8 meters away from the stairs, while the 'farther' area is 20 meters away. Figure 7 shows the general setup and the areas under study.

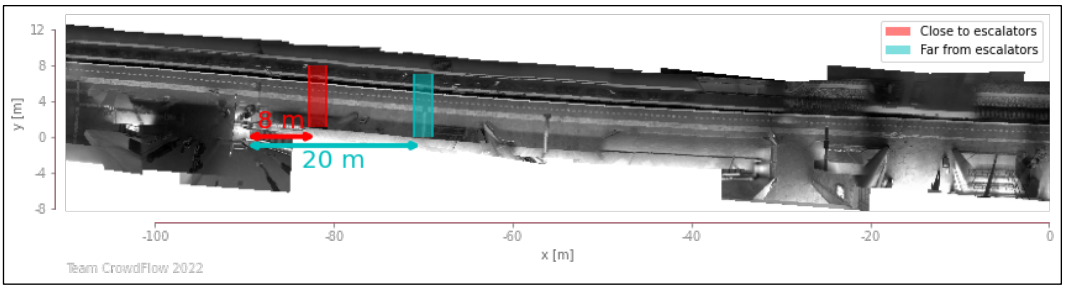

Figure 7. red area is closer to the stairs/escalator, while turquoise area is farther from them. The stairs/escalator is immediately on the left of the red area.

Heatmap and statistical analysis show that the two boarding groups — one forming at each side of the door — are more similar in size and shape when the door is closer to the stairs. Boarding groups around doors farther away differ in size, with the group closer to the stairs being more populated (see Figure 8 below).

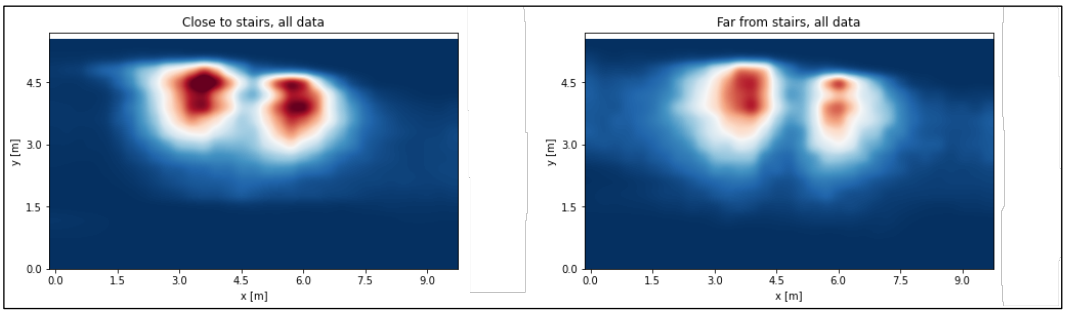

Figure 8. Left, collated heatmap of all data under study for boarding crowds closer to the stairs; right, collated heatmap for boarding crowds further from the stairs. The intensity of colour, from dark at the outside of the picture over light to dark again in the middle of boarding crowds, is dependent on the probability that a traveller occupied that spot during analysed (de)boarding events. Train doors located at coordinates (X, Y): 4.5, 5.0.

6 DISCUSSION

6.1 USER$_{INDIVIDUALS}$-USER$_{COLLECTIVE}$

6.1.1 MICRO-LEVEL MEDIATION THEORY EXPLANATION

We will start by exploring this case in a 'classical' manner, from the perspective of the individual. Our idea is to show that doing so is difficult, cumbersome, and in some cases, impossible where collectives have a substantial 'difference that makes a difference' effect.

An individual passenger needs to take a train at Utrecht Centraal in order to travel around the country. The person enters the station, buys a ticket, and successfully arrives at the platform where a ride in the desired direction will take place. A train arrives, and other individuals gather around the doors, queuing, and waiting for passengers already inside the train cars to deboard. From the eyes of our passenger, there is a certain 'corridor' or 'channel' forming by and for the deboarding passengers as they exit the doors. The deboarder crowd seems to be able to push back against the crowds of boarders that wait in queue.

Now, let us address the issue of the changing deboarding corridor width as a function of the number of boarders and deboarders. When looking at this phenomenon from the eyes of an individual, we can only attest that this is taking place. Individual boarders might feel pressure to board the train as quickly as possible, so they become anxious and move closer and closer to the doors. This tightens up the space deboarders have.

The problem we see with this explanation is that *nothing of this accounts for the collective effect (pattern) that we observe across thousands of boardings from the data*. The same effect seems to consistently appear throughout, even though, in each discreet case, there are *different individual participants* in the events. In order to explain them all, we need to qualitatively explore why each different individual, with different mood, character, and moral disposition, behaves so similarly while deboarding and boarding. This is obviously too complex, impractical, and, even in some situations, probably impossible to explain on the micro-level of the individual.

6.2.2 USER$_{INDIVIDUAL}$-USER$_{COLLECTIVE}$ EXPLANATION

Now, we will explore the same scenario at the meso-level. As queuing passengers form a crowd before the doors (at peak times with significant density and population), deboarding passengers *as a crowd* need to discover a way to exit the train and move towards another place at the station, typically the stairs, stores, escalators, or elevators. Thus, deboarding passengers, as a crowd, collectively 'push back' against the crowd of queueing people and form a corridor with a particular width. This width is a balance point between the pressure exerted by the two crowds. The 'push back' effect of the deboarders collective influences the corridor width and is related to how many deboarders are attempting to exit the doors (Figure 4) and the ratio of boarders and deboarders (Figure 5). In addition, the special spread of deboarders is determined by the number of boarding travellers.

A single deboarder is unlikely to exert significant pressure upon the queuing crowd in order to ensure a corridor for himself, but we attest that a crowd of deboarders can. These crowd 'pressure' and 'counter-pressure (pushback)' effects are statistically extracted from multiple boardings across various times and (de)boarding events from the specified period, which means that they completely abstract individual participants. And since they can be extracted as recurring collective phenomena from data, they are, in fact, differences that make a difference.

Now, this attested difference has a direct effect on how individuals use the technology in question (trains and platforms). When data is animated (i.e. tracked through time in a visual fashion) we notice patterns in individual behaviour. One such pattern is that most individuals opt to join the crowds and synchronise (with) their behaviour. For example, when a boarding crowd queue has formed before the doors, arriving individuals typically go to the end of the queue and wait to board. There are always some rare individuals that do not join or abandon the queue and move to other doors, as well as, even rarer occurrences where individuals ignore the collective queuing social norm and disregard the queue. However, these are exceptions. *In general, individuals that desire to board during a particular (de)boarding event are 'forced' to use the technology in a crowd-mediated fashion*. In this sense, the crowd sits—and thus mediates—between individual users and technology.

In terms of deboarding, it is noticeable that most deboarding individuals remain in the deboarding crowd and follow the corridor shape, instead of attempting to move through the boarding crowd. Their use of technology is doubly-mediated by the crowds, in both an 'encouraging' and 'discouraging' fashion. The encouraging aspect is that deboarders, as a crowd, form a corridor that makes leaving the train and the platform easier, both from physical and cognitive perspective (for example, while deboarding, travellers do not even need to pay significant attention to the process; they can simply follow other deboarding persons ahead). The discouraging aspect is that queued boarding crowd forms a seemingly hardly-penetrable 'wall' that discourages deboarders from leaving their corridor.

Consequently, what we can conclude is that the deboarding corridor width is a result of how technology, in this case train cars, doors, and platforms, is designed and implemented, in combination with how individual users and collectives (passengers) choose to use it. We can also see that collectives (e.g. crowds) have a mediating effect on how this technology is designed, implemented, and used by individuals and other collectives.

We have shown how collectives make a difference that makes a difference by mediating how individuals and other collectives use technology. This mediation is difficult, maybe even at times impossible, to be avoided by individual users, as well as, explained through an individualistic perspective.

6.2 OBJECT-USER$_{COLLECTIVES}$

6.2.1 MICRO-LEVEL MEDIATION THEORY EXPLANATION

Now, let us attempt exploring the platform design through the lens of an individualistic approach of mediation theory.

Similar to the first case of corridor width, a traveller that needs to take a train ride arrives at the platform using the stairs or escalator and is commonly greeted by a waiting crowd. As we have shown above in the corridor width case, if the train has arrived, it is likely that crowds form around the entrances of the train car, commonly split into two sub-crowds of boarders on the right and left of a deboarding crowd corridor.

For the purpose of increasing efficiency and chances of taking the ride, our individual traveller attempts to find the door closest to her designated seat (or otherwise, door closest to her with an 'acceptable' amount of queueing boarders), and heads to the boarding crowds there. Other individual passengers do the same, which again results in the doubling of boarding crowds in the typical split shape mentioned above.

The heatmap finding shows that split boarding crowds formed around the deboarding corridor are more homogenous in shape and population when they are closer to the stairs—and vice-versa. However, an individual passenger is not focused on the homogeneity of a boarding crowd. Boarders are unaware thereof of their role in improving or worsening it. Instead, all a traveller typically cares about is taking the ride in as comfortable, safe, and efficient manner possible, while respecting queueing and other applicable social norms.

Therefore, we can see that classical individualistic exploration of such a situation is unable to explain why split boarding crowds have different properties depending on closeness to stairs, and why such a change statistically propagates across numerous (de)boarding events. However, meso-level system-phenomenological exploration can explain this.

6.2.2 OBJECT-USER$_{COLLECTIVE}$ EXPLANATION

If we compare the distance of the two doors under our heatmap analysis, we can notice that the door that is closer to the platform entry points (in the image, on the left) has a more even distribution of travellers in the split boarding crowds, while the farther spot has fewer travellers in the sub-crowd on the right of the door.

Now, if we also take into consideration the distance between the entry spots on the platform, which are the stairs and the escalators, we can see that the closer the door is to the entry spot, the more people are there to 'fill' the boarding crowds. This appears to result in a more even distribution of people in each crowd. On the other hand, the split crowds that form around the farther door get their 'supply' of individual members mostly from the left side of the platform, since the platform entry points are closer. Thus, for the farther door, the left side looks similarly populated with crowds on the closer door, but the right side is significantly less populated, resulting in a less-intense probability heatmap in Figure 8 above.

Here, we can observe a clear example of the *object-usercrowds* effect. Because of the particular platform design at the Utrecht train station, crowd formation is altered. This effect statistically propagates through all the analysed data, regardless of the particular individuals that participate in the boarding crowds at each discrete boarding event. As we have shown in the individualistic micro-level analysis above, individual travellers do not typically care whether split boarding crowds are evenly distributed around the doors, and whether there should be a balance. At that moment, they predominantly care about boarding their ride, looking for the most efficient and effective way to do it. However, the way technology is implemented on the platform has an effect on how boarding crowds, in which these individual travellers participate, form.

How the boarding crowds form will, of course, also have an additional effect on how individuals use the technology as well. For example, if a traveller finds himself waiting at the farther door and in the right subcrowd, the person might enter the train quicker because his crowd, and thus his queue, is likely to be smaller. This seems to support our previously mentioned assertion that crowds have an effect on how individuals use technology: *userindividual-usercrowd-object*.

5 CONCLUSION

In this article, we performed a quantitative analysis case for collectives in postphenomenology by putting forward the concept of system-phenomenology and the mediation triangle. We extended the bidirectional *object-individual* relation in postphenomenology with two other bidirectional relations: *object-collective* and *collective-individual*. This lead to the formation of the mediation triangle. Collective here stands for the broader socio-political macro-level and the more contextual meso-level of concrete groups or crowds. We illustrated this with quantitative studies from two train platform situations in which objects, individuals, meso-level collectives, and technology interact. We demonstrated that *object-collective* interactions cannot be reduced to *object-individual* reactions. A technology does not only interact with individuals, but also with collectives. An individual traveller is unable to simply (de)board her train car of choice if there is a crowd already waiting before the door to enter or exit. In another example, a train car or platform design that cannot accommodate the typical traveller crowd would be received poorly and be the subject of critique focused on their inappropriateness and inefficiency. In the inverse direction, technology affects the behaviour of individuals, but also the behaviour and formation of collectives. The same crowd (and by extension, individuals within it) behaves differently while on a wide train platform in contrast to being in a tight exit tunnel.

Therefore, we propose a system theory approach for postphenomenology, which we call *system phenomenology*. The 'classical' micro-level interpretation of *object-individual* is not abandoned, but is instead extended to and supplemented with a collective level to a broader systems approach.

Our approach has certain limitations. First, we opted for a situation in which the importance of the *object-collective* interaction is very strong compared to the *object-individual* interaction. It help us to illustrate that the collective level is important. It would be interesting to examine other situations in which the individual and collective aspects seem of more equal importance to even better understand the interactions at hand. Second, we started from existing macro-level postphenomenology and argued that meso-level postphenomenology is important. Neither our theoretical model, nor our empirical research describe the mutual influences of macro- and meso-level interactions in postphenomenology. Empirical research and existing theories on macro-levels could provide more insights here. Third, our quantitative research provided strong results. However, the interpretation of quantitative results for philosophical analysis, such as postphenomenology, is a difficult endeavour. We certainly do not argue that the results show that an individual approach in our cases is useless, and that a collective approach is the only possible solution. However, we argue that our inquiry showed that quantitative research can be used in postphenomenological research and that it at least adds information that is very useful for further discussion.

This article is an introductory probe into the subject and warrants further attention. One appealing avenue of research is the extraction of behavioural patterns related to individual and collective adherence to social norms (such as queueing, exhibiting predictable and safe behaviour, and other). Another interesting subject is pairing qualitative psychosocial and ethical methods (e.g. surveys, questionnaires, psychometric tests, and other) with sensor pattern extraction to improve their interpretational power. A third avenue is perusing the extracted behavioural patterns from sensors to devise social simulations which can help in designing and

testing behavioural nudges implemented by stakeholders (such as Netherlands' ProRail and NS), aimed at both collectives and individuals. A fourth subject would be the study of extended mediative effect chains that span multiple sides of the mediation triangle. We hope that the system-phenomenology developed here can contribute to, and supplement, the endeavour of micro- and macro- approaches in postphenomenology and technological mediation theory.

Data Access Statement

N/A

Contributor Statement

This research paper is a result of a joint research work of the Crowdflow research group at the Technical University of Eindhoven (TU/e), and the overlapping HTCrowd and SRCrowd groups.

The principal authors of the paper are Andrej Dameski, Andreas Spahn and Gunter Bombaerts, focused on the ethico-philosophical research, conceptualisation, argument development, and on the writing and editing. Caspar A. S. Pouw and Rabia Kodapanakkal contributed with the statistical and heatmap research of individual and crowd behaviour. Caspar A.S. Pouw, Alessandro Corbetta and Federico Toschi contributed with suggestions and improvements from the aspect of physics of social systems. Rabia Kodapanakkal, Antal Haans and Jaap Ham contributed with suggestions and improvements from the aspect of psychology and sociology. Federico Toschi is the head of the Crowdflow research group.

Use of AI

No artificial intelligence (AI) was used creatively in any part of this paper. All of the included text, graphics, images, and other material and data are solely the creation of its authors, except for cited material.

Funding Statement

HTSM research programs "SRCrowd: Individual and collective agency in Socially Responsible nudging of Crowd", and "HTCrowd: a high-tech platform for human crowd flows monitoring, modeling and nudging" with project numbers 18754, 17962, and the VENI-AES research program "Understanding and controlling the flow of human crowds" with project number 16771, all financed by the Dutch Research Council (NWO).

Ethical approval

ProRail collected data in a fully anonymous manner. The university research group has a legal agreement with ProRail for analyzing existing data. The research group has written confirmation from the university's Ethical Review Board that no ethical approval is needed in this specific case to perform data analyses.

Acknowledgments

N/A

Conflict of Interest Statement

The authors have declared that no competing interest exists.

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