Investigating sociophysical attributes underlying train boarding efficiency and their importance for nudging

Safety Science 177 (2024) 106568

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Investigating sociophysical attributes underlying train boarding efficiency and their importance for nudging

Rabia I. Kodapanakkal [a], Antal Haans [a,*], Jaap Ham [a], Rinke J. Giesen [a], Nesrin D. Güneş [a], Tanja M.L. Markink [a], Jelle M. Osinga [a], Caspar A.S. Pouw [b,c], Gunter Bombaerts [d], Alessandro Corbetta [b], Andrej Dameski [d], Andreas Spahn [d], Federico Toschi [b,e]

[a] Human-Technology Interaction Group, Eindhoven University of Technology, Eindhoven 5600 MB, the Netherlands
[b] Department of Applied Physics, Eindhoven University of Technology, Eindhoven 5600 MB, the Netherlands
[c] ProRail BV, Moreelsepark 2, Utrecht 3511 EP, the Netherlands
[d] Philosophy and Ethics Group, Eindhoven University of Technology, Eindhoven 5600 MB, the Netherlands
[e] CNR-IAC, Rome, Italy

ARTICLE INFO

Keywords:
Nudging
Public spaces
Train boarding
Interdependence
Social norms

ABSTRACT

Nudging has become a popular method to change the behavior of pedestrians in public spaces. However, nudges often do not work as intended because they are based on an incomplete understanding of the nudging environment, physical (e.g., pedestrian trajectories), but not psychological data is used in their development, and behavioral theories are often inadequate or not (correctly) applied. In this article, we argue that the design of nudges can benefit from complementary psychological data analyzed using relevant social and environmental psychological theories. Adequate theories, we argue, are those that aim at describing the objective (i.e., person independent) attributes of the environment or situation and how these affect human decision-making. Using the example of train boarding, and in particular the formation of the deboarding corridor, we demonstrate how psychological theories like interdependence theory and social norms theory can be applied to relevant psychological data—in our case obtained with two focus groups—to better characterize the sociophysical attributes of the train boarding situation. The focus group, or sometimes called a "group discussion", is a qualitative research method in which data is generated from guided discussions amongst research participants following pre-defined discussion topics. Based on the thematic analysis of the focus group data, we find that a high level of competition and interdependence are related to structural aspects of the train boarding situation. Subsequently, we use these insights to provide tentative explanations for, or hypotheses about micro- and macroscopic behavior patterns observed during train boarding. Finally, we discuss how these insights, in turn, can inform the design of nudges that can be further investigated in future research.

1. Introduction

The use of nudging and other behavioral interventions is becoming increasingly popular in public spaces. A nudge is defined as a modification in the choice architecture (the context in which people make decisions) to change behavior in a non-coercive way and without drastically changing economic incentives (Thaler and Sunstein, 2008). Nudges have been used to encourage healthy behaviors (e.g., taking the stairs; Steuns and Dierx, 2018), encourage sustainable behaviors (Demarque et al., 2015), and improve road safety (Imrie, 2012). However, implemented nudges do not always work as intended (Sunstein, 2017) and in some cases they can even make the targeted behavior worse (Stibe and Cugelman, 2016). There are various reasons why nudges in public spaces may not produce the desired behavior change. First, the nudge may be based on an incorrect or incomplete understanding of the existing choice architecture/wider nudging environment and how it influences people (Meder et al., 2018; Sunstein, 2017). Second, the kind of data typically available when designing nudges in public space, such as traffic data, are often ill-suited for understanding the cognitive processes that underlie the observed choice behavior (Bandsma et al., 2021). Third, behavioral theories that could aid in such understanding often lack relevance to, or are difficult to apply by urban

* Corresponding author.
E-mail address: a.haans@tue.nl (A. Haans).

https://doi.org/10.1016/j.ssci.2024.106568
Received 30 October 2023; Received in revised form 27 May 2024; Accepted 28 May 2024
Available online 17 June 2024

planners (Churchman, 2008; De Ridder et al., 2020).

Based on these limitations, we argue that the designing of nudges in public space could benefit a) from complementing the physical data (e.g., traffic data) with relevant psychological data (in our case obtained via focus groups), which b) should be analyzed with a theoretical lens that is relevant to urban planners. Since nudging is, first and foremost, an intervention that alters the environment in which people make decisions, we argue that rather than focusing on theories related to the individual and their dispositions, focusing on person-independent attributes of the environment or situation, and how these affect human decision making is more relevant. In this paper, we will apply two such psychological theories: interdependence theory and social norms theory. To illustrate our approach, we focus on a specific context in public space, namely train boarding, where potential nudges can be implemented to improve efficiency.

1.1. Background

Approaches to understand human crowds and train boarding mostly use tools and techniques from technical fields such as physics, computer science, engineering, and mathematics. Knowledge generated from these approaches helps in understanding human crowd movement in public spaces (Corbetta and Toschi, 2023). In places like train stations, bottlenecks that disrupt crowd flow are usually observed at the escalator/stairways when people arrive at or leave the train platform (Hoogendoorn et al., 2007) and also at the train doors where pedestrians are either getting in or out of trains (Qu et al., 2019). Research on train boarding efficiency (i.e., how fast people deboard and board trains) has mainly focused on how aspects of the physical environment affect train boarding, such as platform and train design (Coxon et al., 2009; Thoreau et al., 2016), the size and density of crowds, or the proportion of boarders (de Ana Rodríguez et al., 2016; Olsson and Haugland, 2004; Seriani et al., 2016). In this paper, we will focus on one particular finding by Kodapanakkal and colleagues (2023). Analyzing pedestrian trajectory data of over 3000 boarding situations on Utrecht Central station in the Netherlands, they demonstrated that a higher number of boarders and higher proportion of boarders (as compared to deboarders) was associated with lower amount of space left for deboarders when exiting the train (see Fig. 1). Specifically, the deboarding channel (a macroscopic structure formed by boarders waiting on two sides of the train door) was narrower when the number of waiting boarders was higher. This narrower channel width consequently lowered the deboarding flux/efficiency of the deboarders. These findings show that a macroscopic structure (the deboarding channel) is formed due to certain behavior exhibited by waiting boarders, but that this behavior is not executed efficiently resulting in lowered deboarding efficiency in bigger crowds.

These findings (Kodapanakkal et al., 2023) provide some insights into the process of train boarding, but just like in the case of observational traffic data mentioned earlier (Bandsma et al., 2021), the pedestrian trajectory data alone do not provide sufficient understanding of how attributes of the environment affect human decision making. For example, from this data, it is hard to say why people narrow the deboarding channel which would be important to know when developing a nudge. Moreover, this data is limited because attributes of the sociophysical environment include more than such physical parameters as platform width or the proportion of boarders in the crowd. Instead, the sociophysical environment is also characterized by, for example, written and unwritten rules and why they are followed (e.g., social norms; Bicchieri et al., 2011), situation-specific behavioral programs (as in behavior setting theory; Barker, 1968; Wicker, 1979), and affordances that provide possibilities for action in the situation (Gibson, 1979). These types of attributes of the sociophysical environment can be considered as objective (i.e., person-independent) as platform width or

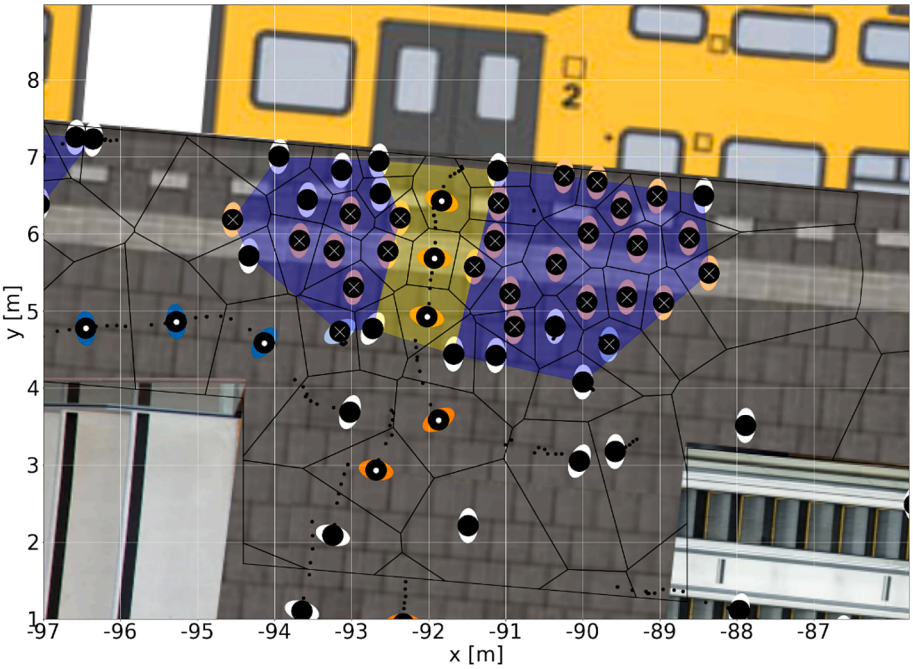

Fig. 1. A visual representation of real-life data of a train deboarding. Each pedestrian is represented by a solid back circle on top of an ellipse that indicates the orientation of the pedestrian's body. Based on the observed path of the pedestrian, several further classifications are made. Pedestrians marked with a white cross (in the solid black circle) have entered the platform via the stairs or escalators. Pedestrians with a white dot will leave the platform. The color of the ellipse refers to the train door that the pedestrian used or will be using. In this case, orange refers to the door seen in the figure, while the pedestrians in blue deboarded from another door. Pedestrians without any markings or with a white ellipse could not be classified, for example because of broken trajectories. The black polygon around each participant reflects the available space for that individual based on Voronoi areas. The pedestrians in the blue area are waiting to board the train. The yellow area depicts the deboarding channel. From: Kodapanakkal et al. (2023). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the proportion of deboaders, albeit less easily quantifiable (Magnusson, 1978).

With limited understanding of the sociophysical environment in which human behavior and decision making occurs, it is hard to know why people would behave in a particular way and what their decision-making process looks like. Developing a nudge without this knowledge could limit the effectiveness of the nudge. Since the effects of the sociophysical environment on behavior reveal themselves in recurring and extra-individual patterns of behavior (Barker, 1968; Kalinauskaitė et al., 2018), the macroscopic deboarding channel presents an interesting candidate for investigating the situational and environmental attributes that affect train boarding decisions. To do so, we augment the pedestrian trajectories with qualitative data obtained from focus groups with train travelers. Analyzing this data through the lens of social norms theory and interdependence theory—both focusing on the less quantifiable attributes of the boarding situation—will allow us to understand and extract the sociophysical attributes specific to the train boarding situation that might explain why the deboarding channel narrows and hampers deboarding efficiency when the number and proportion of boarders increases. In the sections below, we explain why we choose these two theories and how they can provide a useful framework to analyze data and extract sociophysical attributes of the situation.

1.2. Psychological approaches

As argued above, the psychological theories most relevant to the designing of nudges are those that assist in understanding how features of the sociophysical environment affect individual decision making. We specifically choose interdependence theory and social norms theory as they provide a suitable lens for analyzing our focus group data. Both theories describe features of the situation, such as the social structure of the situation, and demonstrate what kind of unwritten rules (social norms) people follow in the specific situation, the different ways in which people are dependent on each other in attaining their goals, and how this affects individual decision-making and behavior.

1.2.1. Interdependence theory

Interdependence theory is an important theory in the social sciences that comprehensively approaches social interactions (Kelley et al., 2003; Kelley and Thibaut, 1978; Rusbult and Van Lange, 2008; Thibaut and Kelley, 1959). Interdependence is defined as the way in which behaviors and outcomes of individuals influence and are influenced by the behaviors and outcomes of other individuals (Van Lange and Balliet, 2015). Instead of focusing on dispositional characteristics of individuals and individual decision making that does not consider how decisions influence and are influenced by people's surroundings, interdependence theory takes into account the social structure of the situation people are in, what people make of the situation, and how people learn from these interactions for better outcomes in future interactions (Van Lange and Balliet, 2015). Rusbult and Van Lange (2008) consider it analogous to the approach in physics where interactions between particles are as important as the properties of the particles themselves, the difference being that individuals have more autonomy. Given that interdependence theory considers the individual, interactions with others, and situation structure all in one approach, we argue that it is relevant to specific contexts in public space such as train boarding and can provide additional knowledge to existing pedestrian dynamics research. It provides a framework within which researchers can simultaneously consider multiple aspects of train boarding and crowd behavior rather than studying these aspects disjointly or not addressing them.

One of the important things to consider when using this framework is to understand the structure of interdependence. The structure within which social interactions occur can shape people's behavior which might be in line with their goals and motives or counter them as people could either choose to follow their self-interests or also take into account others' interests. According to interdependence theory, structure can be described in terms of six dimensions that describe different ways in which the form of interdependence between individuals can vary (Gerpott et al., 2018). These dimensions are 1) mutual dependence, the extent to which individuals' actions affect only their own outcomes or also others' outcomes, 2) power, how much influence/control an individual has over their own outcomes, 3) conflict, whether a good outcome for one individual means a worse outcome for another individual (zero-sum game), 4) coordination, whether outcomes for individuals are dependent on how well they coordinate with each other, 5) information certainty, the extent to which individuals know how other individuals will behave, and 6) future interdependence, how much the outcomes in the current situation would affect outcomes in future interactions.

These dimensions are perhaps best explained by considering a well-known social dilemma: The prisoners dilemma (Poundstone, 1992). In this fictive decision-making situation, two members of a criminal gang are caught by the police. Once isolated from each other, both criminals get the option to testify against their partner in crime. They are informed that if both remain silent, then they are both sentenced to one year in prison. They are also told that if one testifies against the other, then the first goes free while the other is charged with three years of imprisonment. However, in the case that both testify against each other, then both are sentenced to a reduced two years in prison. The structure of this particular decision making situation can be comprehensively described by the interdependence theory dimensions. First, this is a situation of mutual dependence as one's decision affects the other in achieving their goal of avoiding imprisonment. Second, it is a situation of low power, as one has but two options of which the consequence are fully determined by the situation. Both decisionmakers, however, have equal power, so there is no power imbalance in this situation. Third, this is a conflict situation, as the best outcome for oneself can only be achieved at the expense of the other. Fourth, this is a situation low in coordination. Due to being isolated, there is no possibility of negotiating with one's partner in crime. Fifth, although the rules and consequences of this particular decision-making situation are clear, there is some information uncertainty in not knowing what the other person will decide. Last, future interdependence is high in this particular decision-making situation as the two criminals are likely to engage in future interactions.

Interdependence theory argues that these six dimension can adequately describe a wide range of interactions and activities between dyads in the context of daily live (Rusbult and van Lange, 2008), such as between romantic partners and for activities like cleaning the house or cooking (Columbus et al., 2021). Interdependence theory is usually applied in these type of dyadic contexts. We argue that even when the group goes beyond a dyad, like a crowd of passengers at the train station, these dimensions of interdependence are relevant and provide an appropriate framework to understand sociophysical attributes of the situation.

1.2.2. Social norms

Social norms are generally defined as "unwritten rules shared by members of the same group or society" (Bicchieri et al., 2011). A social norm exists when people expect these unwritten rules to be followed (empirical expectation) and people also believe that others expect them to follow the same (normative expectation; Bicchieri, 2010). Social norms emerge from social interactions and are beneficial for cooperation and social order (Cialdini and Trost, 1998; Young, 2015). They are action-oriented and inform decision-making because they provide a framework for people to use in these situations while making decisions (Anderson and Dunning, 2014). Researchers argue that social norms often vary and are specific to situations (Postmes and Spears, 1998; Reno et al., 1993). Changes in aspects of the situation such as who is following the norm (e.g., friends, colleagues, strangers) can change how the norm is perceived (Bicchieri et al., 2011). Thus, to fully understand the sociophysical attributes of the train boarding context, it becomes relevant to understand the unique social norms that surround this context. The

social norms theory provides a framework through which this can be done.

Since social norms restrict individual goals but increase overall efficiency at the group level (Gross and Vostroknutov, 2022), a good understanding of when and why people break norms to maximize their own goals at the cost of others is similarly important for a better understanding of the sociophysical context of train boarding. In the Netherlands, boarders form two groups on either side of the train door and wait there until the deboarders leave the train (see Fig. 1). This likely is a social norm as most people tend to follow this unwritten rule and people also think others should do the same. Depending on the situation, violation of such social norms can have consequences for the individual who broke them as others might view this as worth punishing (Villatoro et al., 2010). Yet, an individual breaking this social norm might enhance their chances of getting a seat in a crowded train; maximizing their personal interests and motives, but probably slowing down the deboarding and boarding process.

1.3. Research aim

In the current research, we answer the following question: What are the sociophysical attributes specific to the train boarding situation that affect the decision making of individual train travelers? This is an important question to answer because it helps explain macroscopic patterns in pedestrian trajectory data and will be beneficial in designing nudges which are essentially a change in the sociophysical environment or situation. Using the train boarding context as an example, and in particular the formation of the deboarding corridor, we illustrate how these attributes can be identified by analyzing the goals, strategies, and perceptions of passengers through the lens of interdependence theory and social norms theory, and how this information can be useful for developing nudges to improve train boarding efficiency.

2. Method

To gain a deeper understanding of passenger motives, goals, and strategies during the train boarding context and analyze them using the proposed theoretical frameworks, we conducted two focus groups where participants could discuss their experiences with train boarding in the Netherlands. The focus group method, or sometimes called the group discussion method, is a qualitative social science method in which the data is generated from discussion between research participants on a set of selected topics (Finch et al., 2014). In contrast to a group interview, where participant respond to and engage in a discussion with the researcher, participants interact and respond to each other. The role of the researcher, instead, is to select the to be discussed topics and to moderate the discussions. The latter involves, amongst others, to ensure that all participant are included in the discussion, to direct the group's attention to interesting comments that otherwise may be ignored, and to steer the discussions when they go off-topic.

We decided to use this method for two reasons. First, the process of interactive discussion with other participants, and reflecting on each other's perspective, helps participants articulate their goals, motives and strategies during train boarding that otherwise may not be readily accessible to them. Second, focus groups have been shown to be highly affective in uncovering group or social norms (Bloor et al., 2001).

2.1. Participants

Most participants in the two focus groups were recruited through the JF Schouten participant database of Eindhoven University of Technology in the Netherlands. However, due to a low response rate, seven participants were recruited via personal networks of the Master students who led the focus groups. A total of 12 participants participated in the focus groups, with six participants in each focus group. The participants were split into two groups of six to make it easier for interaction and discussion, as it would be harder for everyone to contribute if 12 people discussed the topic together. The participants were all students, five were female and seven were male, between the ages of 20 to 22. Only Dutch speaking participants were recruited so that the discussions could be held in their native language, which would help participants be more comfortable in sharing their opinions. Only participants who traveled regularly (three times a week) for at least a year and had no mobility limitations were recruited.

While we acknowledge that a more diverse sample would yield additional insights, we opted for these inclusion criteria for several reasons. First, limited resources prevented us to include a more diverse population. The more heterogeneous the population of interest is, the higher the number of participants, and thus the higher the number of focus group sessions that are needed before saturation of the data is achieved (Hennink and Kaiser, 2022). Second, they ensured that all participants were sufficiently familiar with train travelling and boarding to be able to discuss its structural properties and to distinguish between typical and atypical boarding situations (e.g., in case of a delay), which was one of the discussion topics.

2.2. Procedure and topics

Participants arrived in the discussion room and were welcomed by the discussion leaders with snacks and beverages. To provide a comfortable setting for the participants, the discussion leaders first began the session by introducing themselves and encouraging participants to freely discuss and provide their opinions during the session. Participants were informed that the session would be recorded, and would be transcribed later. The content would be anonymized and the original recordings would be deleted. Participants signed a consent form if they agreed to this and were also told that they could still leave the session halfway if they no longer wanted to participate.

The discussion started with a round of short introductions by the participants after which the discussion leaders asked a general question as an easy topic intended to have participants engage in discussion with each other (so-called icebreaker): "What do you like or dislike about train travel?". This was followed by topics related to participants' goals and strategies before boarding. For example, what they do when they see the train arriving, and how do they position themselves on the platform. Next, the discussion was steered by the moderators towards boarding and deboarding. Participants discussed what they like or dislike about boarding and deboarding, what they consider just before boarding, and how they expect others to behave during boarding and deboarding. Next, the discussion focused on what kind of habits people have developed over their train traveling experience, and how do they experience boarding during atypical situations (e.g., train delays). During the discussion, the topic of social norms automatically came up without the discussion leaders explicitly mentioning them. This topic was further discussed in terms of how people are expected to behave during boarding, what happens if people do not follow norms, and how does this in turn affects their own behavior. A more detailed description of discussion topics is provided in Appendix A. Each focus group discussion lasted around one hour.

2.3. Analytical approach

The recorded focus group data were transcribed into text, and we analyzed this text using thematic analysis (Braun and Clarke, 2006; Nowell et al., 2017). We first read the entire text of both focus groups to familiarize ourselves with the data. Next, we generated initial codes for both focus groups with simple codes summarizing blocks of text, such as whether something was positive or negative, whether it related to a motivation or goal, related to boarding or deboarding, related to a strategy etc. In a second iteration, we established relationships between different codes combining them into topics that were discussed by the participants, such as motivation/goals, strategies, social norms,

competition, responses to norms/competition etc. Next, applying the theoretical frameworks of interdependence theory and social norms theory, we created themes (and subthemes within) that explain the data in an analytical manner.

3. Results

Using the analytical approach described in Section 2.3, we derived four themes and 12 subthemes from the data (see Table 1 for an overview). These themes and sub-themes are explained in detail in the subsequent sections. We support our findings with relevant extracts from the focus group discussions that have been translated from the original Dutch conversation to English. Participants are indicated by a participant number between 1 and 6 and a code which refers to which focus group they were part of (G1 or G2). For example, Participant 4 in focus group 2 is labeled as G2P4.

Table 1
Overview of themes and sub-themes reported in the present study.

Themes	Sub-themes
1. Limited resources (e.g., few seats) increase goal conflict in the interdependence between boarders, leading to a zero-sum game.	1.1 Most boarders would like to acquire a seat on the train. Based on the situation (high vs low competition; rush hour vs no rush hour), they adapt their expectations around their goal to acquire seats. 1.2 This motivation to acquire a seat is higher when people want to use their time in the train to work/study.
2. Depending on their goals, boarders use a variety of strategies, and these strategies can change interdependence dimensions such as how much interdependence or conflict one has with/against the crowd.	2.1 Some boarders position themselves on the platform such that their deboarding is more convenient at the destination (e.g., closer to exits at destination). 2.2 Some boarders position themselves on the platform such that they can avoid crowds. 2.3 Some boarders position themselves at the door so that they are standing in front of the boarding group.
3. Competition during boarding can be directly linked to the interdependence dimension of conflict among boarders for number of seats.	3.1 The train boarding process is often a competitive situation. People vary in their response to competition: some people engage with it, whereas others disengage. 3.2 A competitive atmosphere is not only related to the number of boarders as in some situations of big crowds people do not find the atmosphere competitive or tense. 3.3 Although boarders compete to get into the train, they show low competition when getting out of the train implying that the motivations in the boarding process are different.
4. Passengers follow social norms because this is what most people seem to do (empirical expectations) and/or because this is what they are expected to do and what they expect others to do (normative expectations).	4.1 Social norms are easily identified by passengers—the most common social norm is that boarders wait for passengers to deboard before they enter the train. 4.2 Following norms is also considered practical and efficient. 4.3 People get frustrated when norms are violated. They respond either by confronting norm violators, use it as a cue to break norms themselves, or do nothing. 4.4 There seems to be no norm for queueing during the boarding process making it hard to tell who is first or last in line to enter the train.

3.1. Theme 1: Limited resources (e.g., few seats) increase goal conflict in the interdependence between boarders, leading to a zero-sum game

In some situations (e.g., rush hour) when the number of passengers is high, the number of seats are limited, and when most boarders want to acquire a seat, this increases conflict (a dimension of interdependence structure) among them leading to a zero-sum game. We argue that in this situation, boarders might try their best to achieve their goal of acquiring a seat which could lead to competition near the doors and result in people standing as close to the door as possible, leaving very little space for deboarders to leave the train.

3.1.1. Sub-theme 1.1: Most boarders would like to acquire a seat on the train. Based on the situation (high vs low competition; rush hour vs no rush hour), they adapt their expectations around their goal to acquire seats

Participants mentioned that they would like to have a spot to sit in the train. G1P2: “Yes, exactly. You want to have the best spot and you want to have a spot where you can sit by yourself because that is the most relaxed.”. Participants discussed that during the rush hour, they have to accept the fact that sometimes there are not enough seats for everyone, thus they modified their expectations with the situation. This explicit mention that there are not enough seats for everyone also shows that participants see boarding as a zero-sum game where one person’s gain of a seat means someone else will have to stand. G2P1: “And also accept a bit that if there are so many people, then you do not really need a spot to sit and that you can also stand once in a while (G2P6 nods: yes)”. G2P6: “Also differs when its rush hour or not (G2P2,5 nods, G2P4 agrees)". G2P5: “…indeed, if it is busier during rush hour, then I am often more reluctant (G2P1 nods), and, I will stand or remain standing. But otherwise yes, otherwise I want my seat”. Participants were more motivated to find a seat for longer journeys or when they were tired. G2P6: “Yes, for me it is very dependent on how long I have to travel in the train (G2P2 nods)". Thus, I do not know exactly where the boundary is, 15 min or so, and it is also about how you feel, if you think ‘Oh, I’m very tired, I have no desire to stand’, you become a bit more aggressive (G2P1 nods), more keen for these seats, and then yes, you become more annoying, but if you know just, ‘Oh, it is just ten minutes, I’ll be there soon, I will just sit on this bar or just stand’. That is also better for you, and then you also allow the others a chance to get their spot”.

3.1.2. Sub-theme 1.2: The motivation to acquire a seat is higher when people want to use their time in the train to work/study

Participants communicated that they found it a positive experience when they got a spot to sit in the train. In the train, participants engaged in activities such as work, study etc., which they cannot do when using other forms of transports. G1P2: “I really like that when you take the train, you can just study, you have your own spot and there you can just work on university [tasks]. Eh, let’s say, eh that you travel by car, then that is not possible". G2P6: “What I personally find really chill about train travel is that you can just sit. And just do something else(G2P1 nods)". G2P1: “I also find that chill. And I also think that when going to and from my parents, and if I would have to travel by car, then it feels like useless travel (G2P2,3 nod; G2P4,5,6 make agreeing sounds and laugh)”.

3.2. Theme 2: Depending on their goals, boarders use a variety of strategies, and these strategies can change interdependence dimensions such as how much interdependence or conflict one has with/against the crowd

We argue that people opt for different strategies based on tradeoffs between multiple goals which include getting a seat but also avoiding crowds. Often these go hand in hand because the fewer people are around you, the more chance you may have to get a seat on the train. One boarding strategy, hence, is to choose a door at which a relatively small number co-travelers will board. Regardless of the size of the

crowd, however, the most effective strategy is to obtain a waiting position in front of, or very close to the door; ensuring that one is (amongst) the first to board. These strategies change the level of dependence by lowering it when fewer people are around the passenger, and reducing conflict to get a seat. Being more assertive and standing in front of the waiting crowd increases the level of power in the interdependent situation and increasing the chances of those standing in front of the door. In this way, passengers' strategies provide a way for them to change how dependent they are on other passengers' to ensure their own outcomes. We elaborate different strategies that people use in the sub-themes below.

3.2.1. Sub-theme 2.1: Some boarders position themselves on the platform such that their deboarding is more convenient at the destination (e.g., closer to exits at destination)

When asked about what participants did before the train arrived to prepare for boarding, some mentioned that they waited at a particular spot on the platform at their boarding station so that they arrived near the stairs at their destination and could exit the train station more quickly. G1P4: "I, eh, wait in Breda at the back (of the train). Because I know that at Eindhoven, eh, stepping out at the back gets you closer to the stairs, then I can go down the stairs faster in Eindhoven (G1P2: hmmm, G1P2,6 nod)". G1P2: "I have the same in Den Bosch". This was also the case when they wanted to switch trains quickly. Then exiting near the stairs saved time and lowered the chances of missing the next train. G2P1: "If I have to switch trains in Utrecht… then I make sure that I sit in the train such that I get off the train approximately at the tunnel so that I can go on faster".

3.2.2. Sub-theme 2.2: Some boarders position themselves on the platform such that they can avoid crowds

Participants said that they would often walk a bit further on the platform to find a spot to wait where the number of people was not too high and then walk towards a door where the least number of people went. G1P5: "I go towards the back and then look where the train ends… and then I just walk to a door where not too many people are standing and then you get to the front [of the boarders waiting at the door] pretty quickly usually (G1P4 agrees, G1P1,2,3 nod)". Another strategy participants employed to avoid crowds during the boarding itself was by entering the train through the first class door and then walking through the train into the second class. This way they avoided the crowd waiting in front of the second class door. G2P2: "If it is very crowded on the platform and it is crowded everywhere then quite often I step in through the first class door, walk in through the first class so that I am faster at the second class… (except G2P3, all others agree)".

3.2.3. Sub-theme 2.3: Some boarders position themselves at the door so that they are standing in front of the boarding group

Some participants said that they stand as close to platform edge as possible to maximize their chances of being in the front at the train door. They also mentioned that over time they more or less knew where the doors are going to be and stood somewhere up front so that they would have a chance of getting a seat. G1P4: "Yes, I also stand relatively close to the tracks. Eh, in [the train from] Eindhoven to Breda, because the train stops approximately here, and the doors are here, and then I can stand pretty much in the front and don't need to wait". Participants also tried to gather more information so that they could know how busy the train was. G1P2: "Yes, then I also quite often look at the NS app because then I have something of a sign as to how many (G1P3: how full it will be, yes yes), yes exactly, then I know where I should stand and when I should stand very close (to the door) or when it is more relaxed to enter the train".

3.3. Theme 3: Competition during boarding can be directly linked to the interdependence dimension of conflict among boarders for number of seats

As mentioned in earlier themes, the interdependence dimension of conflict is relevant in the train boarding process and can be directly linked to competition. Participants talk about competition and conflict in terms of seats and about how they feel the need to be more assertive and dominant to acquire a seat by standing closer to the train door. This can again be inferred as a reason why boarders might try to push their way to the front and in the process reduce the space (i.e. the deboarding corridor) provided to deboarders to leave the train.

3.3.1. Sub-theme 3.1: The train boarding process is often a competitive situation. People vary in their response to competition: Some people engage with it, whereas others disengage

Generally, participants referred to the boarding process (especially during peak hours) as very competitive with many boarders competing for few seats and boarders often pushing each other during boarding. G1P4: "It feels very competitive(G1P3,6 nod)". G1P6: "Yes, and people become even more dominant then and…(G1P3 interrupts)". G1P2: "Yes, so like G1P6 said, secure your spot, and try to stay a bit more in the front to be close to getting a spot as the train will be super busy (G1P4 nods agreeingly)".

Although participants found the competition equally frustrating, they seemed to have different responses to competition. Some said that they found pushing rather extreme and often would step back if things got heated: G1P2: "I find pushing back to be extreme.", G1P4: "A bit frustrating but after that I get on with my day (G1P6 nods)", Others mention that they stand their ground and do not move away because they also would like to have a chance at getting a seat. G2P1: "…then you also do that, that you also sort of join in (P2 agrees) because then you think 'oh shit, otherwise I won't make it'", G2P2: "If everyone misbehaves, then I also feel like: 'Ya, what does it matter if I alone try to be nice to others?' (G2P1 nods)".

3.3.2. Sub-theme 3.2: A competitive atmosphere is not only related to the number of boarders as in some situations of big crowds people do not find the atmosphere competitive or tense

Participants discussed that sometimes even with a big crowd, they did not feel that the atmosphere was competitive or tense. For example, they mentioned a rush hour during Sunday evening when students return from their parents' homes back to the university and even though this was crowded, there was a sense of belongingness in the atmosphere which was positive. They also mentioned that sometimes if people were festive in the train, it could be a good atmosphere even though its crowded. Thus, it is important to distinguish that the existence of competition can go beyond just the number of people and also depends on the social context, social identity, and belongingness of the boarders (Templeton and Neville, 2020). G2P6: "…I think that is more an atmosphere that… on Sunday I have a slight feeling that we give each other credit: 'Ya, go ahead and sit' (G2P1,2 nod). And, eh, with a real rush hour is everybody for themselves". G2P2: "But I also think that during Sunday evening rush hour, it's all students, so they always have more bags (G2P6 gestures to agree) but you don't really notice that when you go on the train (P1 says no, no), because everyone is like: 'Ah you also have bags, go ahead, I will go after you'". G2P6: "Still, sometimes with parties and so, especially on the way there, even if you don't actually go there, it is nice to see (G2P1 agrees); that is a kind of nice atmosphere (G2P1,4 agree). Everyone is in the mood".

3.3.3. Sub-theme 3.3: Although boarders compete to get into the train, they show low competition when getting out of the train implying that the motivations in the boarding process are different

Participants note that the atmosphere in the train boarding process is very different from that of deboarding the train. The group of people who board can be very competitive and dominant, and then behave

differently when they are leaving the train. This is also related to the motivations and goals of the passengers at that time. During boarding, there is a real risk of not getting a seat or even not being able to step in the train but once that is over, the goal when getting out of the train is relatively straightforward and unrelated to conflict over resources like seats. G2P2: "Yeah, exiting the train is just, everyone sort of stands there and knows that we all need to go through these doors, it is all good, because you do not have the stress of: 'Oh I want to sit, I want to sit!' So there is no pushing (G2P1,3,6 nod; G2P1 agrees), because everyone has to go outside it is always more streamlined, even with a double-decker, you have a stream coming from above and a stream from below, and they can go out through the door next to each other (G2P1,4,5 nod) and if you have to enter the train it is all chaos and pushing and no organization.". G2P5: "But what I notice is that when people exit the train they also keep more distance from each other in the train, whereas…".

3.4. Theme 4: Passengers follow social norms because this is what most people seem to do (empirical expectations) and/or because this is what they are expected to do and what they expect others to do (normative expectations)

In line with the definition of social norms by Bicchieri and colleagues (2011), participants spoke about social norms in terms of both empirical and normative expectations. Regarding social norms in train boarding, participants said that they expected others to behave this way and they themselves were expected to behave this way as well. G1P6: "…no I think that it is common knowledge and should be seen as normal that you wait until everyone is out and you do your best to let everyone get out before you step in yourself". G1P5: "I think that I am not concerned with the expectation pattern of an individual but more just how it mostly works regarding the train, so indeed that you should wait until everyone has deboarded".

Participants further add that it is efficient and practical to follow social norms, and respond in frustration when social norms are broken. Although, participants mention that boarders should wait for passengers to deboard, they also mention that there is no norm of how such waiting and queuing is to be done, and, as a result, it is often unclear who is to get on the train first. We elaborate these points below in the subthemes.

3.4.1. Sub-theme 4.1: Social norms are easily identified by passengers—the most common social norm is that boarders wait for passengers to deboard before they enter the train

Participants confirm our expectations that boarders should wait for deboarders to exit the train before entering the train themselves. This is the social norm that is most discussed during both focus groups. Without being directly asked about it, participants mentioned this particular social norm. G2P6: "Well, in any case, the order of first leaving the train and then entering the train.". G1P4: "Just first let the people from inside [the train] get out, and then the people from outside go in".

Other social norms that participants mention are to respect people's personal space and be helpful to people. G1P2: "Uh, and certainly also with older people, because yes, we talked about that pushing and that thing and so on…… Uh, so there, uh, I just make sure there is room to get in and usually just let them go first". At the same time, assisting others, such as a deboarder with a pram/stroller, may also enhance one changes of boarding first and acquiring a seat: G1P1: "Because the moment you help, there is probably a greater chance that there will be space and that you can then be the first to get in".

3.4.2. Sub-theme 4.2: Following norms is also considered practical and efficient

In addition to expressing empirical and normative expectations, participants also indicated that waiting for passengers to deboard the train before boarding is practical because it creates more space inside the train for boarders to step inside once all the deboarders are out. They mention that it is more efficient and faster for the whole process. We speculate that this practicality could be a reason why this behavior developed into a norm in the first place. G1P3: "Eh yeh, that is just a lot more efficient to first let people out and then go in, it also goes much faster. Otherwise you get friction between people and then people with a big bag, or with a dog…then you don't move along and then there is again congestion, so yeh, just let people out first and then go in". G2P6: "Yeh, that is just thinking and if they are out first there is also just more space and then you know at least what you're getting into, and yeh".

3.4.3. Sub-theme 4.3: People get frustrated when norms are violated. Either use it as a cue to break norms themselves, or do nothing

Participants mentioned that when someone broke a norm they found it frustrating. A few participants mentioned that they have confronted people who were talking in the silent compartment G1P3: "I have quite often done that, I have said: 'This is a silent compartment, I am here because it is quiet not because you are sitting here talking on the phone'". However, most participants say that if others misbehave/break the norm of waiting for passengers to deboard, then they themselves do the same because otherwise they will lose out on getting a seat in the train. G1P5: "Ya well, sometimes if it is too crowded and if people are pushing, then I don't make myself, say, smaller than I am (G1P2 agrees). I just stay standing where I am and I don't go, yeh I also just want to sit". Yet others said that they usually do not engage or let things happen and move on with their day. G1P6: "I am mostly pushed to the back but I think I also allow that to happen".

3.4.4. Sub-theme 4.4: There seems to be no norm for queueing during the boarding process making it hard to tell who is first or last in line to enter the train

Participants mentioned that unlike in other situations that involve a waiting crowd, there is no real norm for queueing when it comes to train boarding. G2P6: "Just like sometimes with bars or concerts or so, in contrast to, I don't know, the neat rows of the Efteling [a theme park with queueing barriers], where you, there you cannot really overtake and there you can just nicely take your space, and yeh, that is not possible when changing the train…(G2P3 nods)". Moreover, and characteristic to train boarding is that boarders do not wait in one or two single lines, As a result it is often hard to identify who is first in line, and thus the first allowed to enter the train. Participants said that it feels like multiple queues are formed parallelly and they try to enter the train simultaneously. G2P6: "Deboarding is just two queues (gestures two queues with hands) that become one queue together but boarding is also sort of two queues but it's actually like six queues and then two people realize they don't actually fit… (G2P1,2,3 nod)".

4. Discussion

In this paper, we aimed to provide a better understanding of the environmental and situational characteristics of train boarding, and how these affect the decision-making and behavior of individual travelers. Whilst existing research on train boarding efficiency has mainly focused on physical features of the environment, such as platform and train design, the size and density of the crowd, or the boarders-to-deboarders ratio (de Ana Rodríguez et al., 2016; Coxon et al., 2009; Kodapanakkal et al., 2023; Olsson and Haugland, 2004; Seriani et al., 2016; Thoreau et al., 2016) we focused on the sociophysical characteristics of the train boarding situation, which includes less easily quantifiable features as written and unwritten rules and norms, and other structural aspects such as the degree of interdependence between individuals in the crowd. For this purpose, we conducted two focus groups, and analyzed the data through the lens of interdependence and social norms theory.

4.1. Sociophysical attributes of Train-Boarding situations

Our results, reveal the competitive nature of train boarding, especially during regular peak hours. We demonstrate that the goals of

individual passengers, such as obtaining a seat, conflict with each other, `and can lead, when resources (seats) are limited, to a zero-sum game. Whilst boarders differ in their goals, and in their response to this competition, we argue that this high level of interdependence is an objective (i.e., person-independent) characteristic of train boarding during peak hours. In other words. when an individual boarder, as part of the crowd of boarders, does not desire a seat, then this does not make the train boarding situation or the crowd as a whole less competitive. This high level of competition and interdependence is related to structural aspects of the train boarding situation, which at least in the Netherlands, is, except for a few social norms, rather unorganized; especially in contrast to other queuing situations such as airport security (using queuing guides or fences) or points of service that use ticketing systems. As a result, however, individual travelers have room to employ a variety of boarding strategies to reduce their dependence on other individuals within the crowd.

Below we will use these insights in the sociophysical attributes of train boarding situations to explain human behavior during train boarding, and in particular the narrowing width of the deboarding corridor that affects boarding efficiency, and explain how this can help with developing nudges.

4.2. Potential mechanisms explaining train boarding behavior and the width of the deboarding corridor

One recurring behavioral pattern that negatively affects train boarding efficiency is the corridor that people waiting to board create for those deboarding the train, which gets narrower with increasing numbers of boarders/ratio of boarders (Kodapanakkal et al., 2023). The insights gained with the focus groups and social norms and interdependence theory, allows us to formulate some tentative, and still at times perhaps speculative, hypotheses of why they occur.

We found that people want a seat in the train, even during peak hours when seats are a scarce resource. Without technologies such as ticketing systems or queuing guides, and without written and unwritten rules regarding who has first right of entrance, the chance of obtaining a seat is dependent on the behavior and success of others. This results in competition—and more experienced conflict—, which increases when there are more boarders, and thus more potential competitors per empty seat. At the same time, the rather unstructured boarding process allows individual travelers to use strategies to change their level of interdependence, power, and/or conflict by, for example, trying to position themselves close to the door. This is also evident in the reported pushing in front of the doors when the number of boarders is high. In situations of high competition, people might tradeoff collective gains (efficient boarding and deboarding as a group) to individual gains (increasing personal chances of getting a seat). Such selfish—but understandable—behavior may be intensified by the fact that future interactions with the same people are unlikely in train boarding situations. When people engage in the same interactions repeatedly with the same people, they tend to cooperate more with each other (van Lange et al., 2011).

There appear to be no written or unwritten rules regarding how much space deboarders should be given when alighting. While leaving ample space to deboarders might lead to faster deboarding, it may also give space to other boarders to take a more advantageous position, increasing the level of interdependence and likely reducing your chances to obtain a seat. Although the data from the focus group do not readily explain why a higher deboarder to boarder ratio widens the deboarding corridor, we speculate that a higher number of deboarders can as a group exert more influence on the waiting boarders, creating more space for themselves. In this case, the boarders are also dependent on the deboarders because a faster exit of deboarders would increase the chances of a boarder getting a seat compared to neighboring doors of the train that also compete for the same seats. This and the other above hypothesized mechanisms should of course be investigated and verified in future research.

4.3. Suggestions for nudging

It is beyond the scope of the present paper to provide concrete and fully formulated nudges. Instead, we will provide some suggestions that illustrate the importance of understanding the broader sociophysical characteristics of the situation when designing nudges. We in particular focus on interventions aimed at widening the deboarding corridor, as this provides a clear behavior for the nudges to target. Based on the sociophysical attributes of the boarding situation and the potential mechanisms underlying the formation of the deboarding corridor, we provide the following suggestions that can help researchers and practitioners in developing nudges. A more complete analysis of both the sociophysical situations and the targeted behavior is required before more precise nudges can be formulated. These nudges would further need to be tested to see how well they function in improving train boarding.

Given a) the interdependence in and thus the competitive nature of the boarding situation, b) the lack of a social norm regarding how much space deboarders should be granted, and c) the personal relevance of not leaving more than the minimal space, it may be beneficial to somehow mark how wide the corridor should be for efficient deboarding. Making the deboarding channel explicit by marking it on the floor would be a clear sign for people to stand behind the marked lines. Signaling what is expected from each individual boarder, these markings may assist in the behavior of waiting outside of the marked area to become a social norm. And if this develops into a norm, then the markings would also make clear if a person follows or breaks the norm. Since trains in the Netherlands do not always stop at the exact same position on the platform, physically marking lines is not practical. One possibility is to mark the floor using lights. These could be projected either from beams on the platform or from lights placed around the train door.

Another possible solution would be to nudge boarders into forming a queuing line. Based on our analysis, we see that there is currently no norm for queueing at the train doors. In addition, the physical environment does not restrict people like it does at an airport security or an amusement park queue. Together this results in bulk queueing where boarders form two groups along each side of the door. Competition within these groups narrows the deboarding corridor. Proper queueing lines may reduce such competition, as it becomes clear who is first in line. How to precisely nudge people in developing a new form of queueing is outside of the scope of the present paper, and we expect its design to be challenging. Since the trains do not stop at the same place on the platform each and every time, boarders do not know exactly where the doors will be. As a result, it is unlikely that the first in line is also the one who was first on the platform. While providing clarity as to who are first to board, this may also lead to feelings of unfairness amongst travelers.

Both these possible nudges target the location in which the deboarding corridor is formed, and thus directly change the choice architecture at the location where the behavioral decision is ultimately made. Whilst such nudges are probably most effective, there are other nudges to consider that may more indirectly affect the width of the boarding corridor. Since competition and conflict seem to be a reason why boarders do not provide sufficient space for deboarders, one suggestion for nudging would be to lower this competition and conflict. Providing information about available seats, length of the train, and how busy the platform is, may help boarders to decide where on the platform they would like to wait, and which train door they would like to enter through to maximize their chances for a seat. If people already know that a compartment has fewer seats, then those travelers that really prefer to have a seat might choose to move to a less busy compartment. In general, competition and conflict can be lowered by reducing the number of people waiting at each door. To do so, boarders may be nudged to distribute themselves more homogenously across the

platform. The distribution of boarders along the platform is known to affect a train's dwell time, and possible interventions to realize this have been described and tested in the literature (e.g., Christoforou et al., 2017; Zhou et al., 2020). However, these and our own findings also point to various challenges as people may have different motivations for waiting in a specific spot (e.g., to be close to the exit at the station of arrival, or to avoid crowds).

4.4. Limitations

There were several limitations to the present study. First, with two focus groups it is unlikely that we reached data saturation (Hennink and Kaiser, 2022). Although the two focus groups may have been sufficient to make inferences about the more general sociophysical characteristics of typical train boarding situations, a higher number of groups would likely increase the variety of, and thus nuances in experiences and strategies for more specific situations, as for example when neighboring doors appear to be boarding before yours.

The participants of the focus groups were all able-bodied young students who travel regularly and their experience might considerably differ from work-related commuters, people with physical limitations, people who travel with children, people travelling with luggage etc. It is also important to take into account these other experiences, especially when it comes to developing nudges as these might not work in the same way for other populations of travelers.

Participants of the focus groups were not all strangers to each other or to the researchers. The extent to which people know each other affects group dynamics, and thus the data obtained with the focus group method. As such, and unless the population of interest are, for example, groups of friends or work teams, it is typically advised to conduct focus groups with participants that do not know each other (Finch et al., 2014). Participants, for example, are often more open in their discussions and express themselves more freely when they do not know the other participants.

The social norms and context discussed is specific to the Netherlands. The presented analysis, inferences and suggestions for nudging directions follow from this specific context. Thus, the nudging recommendations may not directly apply to other contexts. That being said, the approach of conducting focus groups and analyzing the data through the lens of interdependence and social norms theories is generalizable to other contexts within public spaces and to other cultures. The levels of interdependence and other dimensions of interdependence will likely vary in other contexts and cultures, and what is counted as a social norm will also vary. Nonetheless, these frameworks can be used in other contexts to identify relevant social norms and people's reactions to breaking these social norms, and to estimate the level of interdependence, conflict, power, information uncertainty etc. in the specific situation.

5. Conclusion

We illustrated how understanding sociophysical attributes of the situation using the psychological lens of interdependence theory and social norms theory can be used to better understand the behavior of crowds in (semi-)public space, and how this, in turn, can inform the design of nudges. We demonstrate this through an example of the train boarding context, and in particular the deboarding corridor. Since nudges are a physical intervention in the environment in which decision making takes place, developing effective nudges without understanding the sociophysical attributes of the situation at hand is difficult. Using only physical data (e.g., pedestrian trajectories), our nudge ideas would be limited to the physical environment and not consider thesocial dimensions of the environment. Knowing why a behavior occurs informs us about underlying motivations and sets the behavior in a broader social context. Despite limitations regarding the number and diversity of focus group participants, the data and our analyses shows the potential of our approach when designing nudges. Of course, the proposed nudges still need to be tested in the specific context for their effectiveness, but understanding the situation in terms of its sociophysical attributes, likely increase the chances of an effective nudge.

Funding

This work is part of the HTSM-AES research programme "HTCrowd: a high-tech platform for human crowd flows, monitoring, modeling and nudging" with project number 17962, and the MVI top up grant "SRCrowd: Individual and collective agency in Socially Responsible nudging of Crowds" with project number 18754 both financed by the Dutch Research Council (NWO).

CRediT authorship contribution statement

Rabia I. Kodapanakkal: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Antal Haans:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Jaap Ham:** Funding acquisition, Conceptualization. **Rinke J. Giesen:** Investigation, Formal analysis, Conceptualization. **Nesrin D. Güneş:** Investigation, Formal analysis, Conceptualization. **Tanja M.L. Markink:** Investigation, Formal analysis, Conceptualization. **Jelle M. Osinga:** Investigation, Formal analysis, Conceptualization. **Caspar A.S. Pouw:** Conceptualization. **Gunter Bombaerts:** Funding acquisition, Conceptualization. **Alessandro Corbetta:** Funding acquisition, Conceptualization. **Andrej Dameski:** Conceptualization. **Andreas Spahn:** Funding acquisition, Conceptualization. **Federico Toschi:** Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A

The discussion topics for the focus groups were determined beforehand. The various topics and subtopics, and how they were to be introduced by the moderators are presented below. Since the discussion amongst participants may naturally deviate from preconceived plans, the actual phrasing of the topic introductions may have been different depending on the situation. Moreover the order in which the topics were discussed, may have deviated from this plan for similar reasons (e.g., participant started discussing social norms and behavioral expectations without being prompted). The topics and their introduction are translated from Dutch to English.

1. Icebreaker
   - Before we go into the main topic of train boarding, we would like to know what you like or dislike the most about commuting by train?
2. Prior to boarding (strategies & goals, potentially social norms)
   - We can now move on to the topic of boarding. However, the boarding process does not start only when the train doors open. When traveling by train you typically have to wait on the platform before you can board the train. While waiting on the train, where on the platform do you usually wait, and why?
   - Now, we have mainly discussed where you wait on the platform, but I would like you to discuss what you do when the train is arriving and why?
3. Boarding

- We talked about waiting for the train. Let's now discuss the actual boarding situation. How do you normally experience this? I am curious, how do you experience this?

4. Coping with variable situations (strategies & stress, potentially social norms)

- Okay, now we've discussed the general boarding process, but not every time you travel by train is the same. Have you ever experienced differences in your regular train travel experience?

5. Alighting

- Until now we mainly discussed the boarding process. Let's now talk about leaving the train at your destination. How do you normally experience that, and why?

6. Social norms

- Up to now we have mainly discussed what you do on the platform, and I would now ask you to discuss how you expect others to behave during boarding and alighting.
- How do the expectations of others affect your own behavior during the boarding process?

References

Anderson, J.E., Dunning, D., 2014. Behavioral norms: Variants and their identification. Soc. Pers. Psychol. Compass 8, 721–738.

Bandsma, K., Rauws, W., de Roo, G., 2021. Optimising nudges in public space: identifying and tackling barriers to design and implementation. Plan. Theory Pract. 22 (4), 556–557.

Barker, R.G., 1968. Ecological psychology: Concepts and methods for studying the environment of human behavior. Stanford University Press, Stanford, CA.

Bicchieri, C., 2010. Norms, preferences, and conditional behavior. Politics, Philosophy Econ. 9 (3), 297–313.

Bicchieri C., Muldoon R., Sontuoso A. (2011). Social norms. In: Zalta E. N. (Ed.), The Stanford encyclopedia of philosophy (Winter 2018 ed.). Retrieved from https://plato.stanford.edu/archives/win2018/entries/social-norms/.

Bloor, M., Frankland, J., Thomas, M., Robson, K., 2001. Focus groups in social research. Sage, London.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101.

Christoforou, Z., Collet, P.A., Kabalan, B., Leurent, F., de Feraudy, A., Ali, A., Arakelian-von Freeden, T.J., Li, Y., 2017. Influencing longitudinal passenger distribution on railway platforms to shorten and regularize train dwell times. Transp. Res. Rec. 2648 (1), 117–125.

Churchman, A., 2008. Environmental psychology and urban planning. Where can the twain meet? In: Betchel, R., Churchman, A. (Eds.), Handbook of Environmental Psychology. Wiley, pp. 191–202.

Cialdini, R.B., Trost, M.R., 1998. Social influence: Social norms, conformity and compliance. In: Gilbert, D.T., Fiske, S.T., Lindzey, G. (Eds.), The Handbook of Social Psychology. McGraw-Hill, New York, NY, pp. 151–192.

Columbus, S., Molho, C., Righetti, F., Balliet, D., 2021. Interdependence and cooperation in daily life. J. Pers. Soc. Psychol. 120 (3), 626–650.

Corbetta, A., Toschi, F., 2023. Physics of human crowds. Annu. Rev. Condens. Matter Phys. 14, 311–333.

Coxon, S., Burns, K., De Bono, A., Napper, R., 2009. The effect of suburban train carriage design upon punctuality, ingress and egress occlusion and passenger comfort. In: In 32nd Australasian Transport Research Forum, pp. 1–11.

de Ana Rodríguez, G., Seriani, S., Holloway, C., 2016. Impact of Platform Edge Doors on Passengers' Boarding and Alighting Time and Platform Behavior. Transp. Res. Rec. 2540 (1), 102–110.

De Ridder, D., Feitsma, J., Hoven, M., Van den Kroese, F., Schillemans, T., Verweij, M., Venema, T., Vugts, A., De Vet, E., 2020. Simple nudges that are not so easy. Behavioural Public Policy 1–19.

Demarque, C., Charalambides, L., Hilton, D.J., Waroquier, L., 2015. Nudging sustainable consumption: The use of descriptive norms to promote a minority behavior in a realistic online shopping environment. J. Environ. Psychol. 43, 166–174.

Finch, H., Lewis, J., Turley, C., 2014. Focus groups. In: Ritchie, J., Lewis, J., Nicholls, C. M., Ormston, R. (Eds.), Qualitative Research Practice: A Guide for Social Science Students & Researchers, second ed. Sage, London.

Gerpott, F.H., Balliet, D., Columbus, S., Molho, C., de Vries, R.E., 2018. How do people think about interdependence? A multidimensional model of subjective outcome interdependence. J. Pers. Soc. Psychol. 115 (4), 716–742.

Gibson, J.J., 1979. The ecological approach to visual perception. Mifflin and Company, Houghton, MI.

Gross, J., Vostroknutov, A., 2022. Why do people follow social norms? Curr. Opin. Psychol. 44, 1–6.

Hennink, M., Kaiser, B.N., 2022. Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Soc Sci Med 292, 114523.

Hoogendoorn, S.P., Daamen, W., De Boer, A., Vaatstra, I., 2007. Assessing passenger comfort and capacity bottlenecks in Dutch train stations. Transp. Res. Rec. 2002 (1), 107–116.

Imrie, R., 2012. Auto-disabilities: The case of shared space environments. Environ Plan A 44 (9), 2260–2277.

Kalinauskaitė, I., Haans, A., de Kort, IJsselsteijn, W.A., 2018. Atmosphere in an urban nightlife setting: A case study of the relationship between the socio-physical context and aggressive behavior. Scandinavian J. Psychol. 59 (2), 223–235.

Kelley, H.H., Holmes, J.G., Kerr, N.L., Reis, H.T., Rusbult, C.E., Van Lange, 2003. An atlas of interpersonal situations. Cambridge University Press, New York.

Kelley, H.H., Thibaut, J.W., 1978. Interpersonal relations: A theory of interdependence. Wiley, New York, NY.

Kodapanakkal, R. I., Pouw, C. A., Haans, A., Ham, J., Bombaerts, G., Corbetta, A., ... and Toschi, F. (2023). The Influence of Macroscopic Pedestrian Structures on Train Boarding Efficiency. arXiv preprint arXiv:2309.05476.

Magnusson, D. (1978). On the psychological situation. Reports from the Department of Psychology, no. 544. Stockholm, Sweden: The University of Stockholm.

Meder, B., Fleischhut, N., Osman, M., 2018. Beyond the confines of choice architecture: A critical analysis. J. Econ. Psychol. 68, 36–44.

Nowell, L.S., Norris, J.M., White, D.E., Moules, N.J., 2017. Thematic analysis: striving to meet the trustworthiness criteria. Int. J. Qual. Methods 16 (1).

Olsson, N.O.E., Haugland, H., 2004. Influencing factors on train punctuality—Results from some Norwegian studies. Transp. Policy 11 (4), 387–397.

Postmes, T., Spears, R., 1998. Deindividuation and antinormative behavior: A meta-analysis. Psychol. Bull. 123 (3), 238–259.

Poundstone, W., 1992. Prisoner's dilemma: John von Neumann, game theory and the puzzle of the bomb. Doubleday, New York.

Qu, Y., Xiao, Y., Liu, H., Yin, H., Wu, J., Qu, Q., Tang, T., 2019. Analyzing crowd dynamic characteristics of boarding and alighting process in urban metro stations. Physica A: Statistical Mech. Appl. 526, 121075.

Reno, R.R., Cialdini, R.B., Kallgren, C.A., 1993. The transsituational influence of social norms. J. Pers. Soc. Psychol. 64 (1), 104–112.

Rusbult, C.E., Van Lange, P.A., 2008. Why we need interdependence theory. Soc. Pers. Psychol. Compass 2 (5), 2049–2070.

Seriani, S., Fujiyama, T., Holloway, C., 2016. Exploring the pedestrian level of interaction on platform conflict areas at metro stations by real-scale laboratory experiments. Transp. Plan. Technol. 40 (1), 100–118.

Steuns, A., Dierx, J.A.J., 2018. Stimulating increase in daily activity by nudging stair use among bachelor students and lecturers. Eur. J. Pub. Health 28, cky218-042.

Stibe, A., and Cugelman, B. (2016). Persuasive backfiring: When behavior change interventions trigger unintended negative outcomes. In: Persuasive Technology: 11th International Conference, PERSUASIVE 2016, Salzburg, Austria, April 5-7, 2016, Proceedings 11 (pp. 65-77). Springer International Publishing.

Sunstein, C.R., 2017. Nudges that fail. Behavioural Public Policy 1 (1), 4–25.

Templeton, A., and Neville, F. (2020). Modeling collective behaviour: insights and applications from crowd psychology. Crowd Dynamics, Volume 2: Theory, Models, and Applications, 55-81. Modeling and Simulation in Science, Engineering and Technology. Birkhäuser, Cham.

Thaler, R.H., Sunstein, C.R., 2008. Nudge: Improving decisions about health, wealth, and happiness. Yale University Press, New Haven, CT.

Thibaut, J.W., Kelley, H.H., 1959. The social psychology of groups. Wiley, New York, NY.

Thoreau, R., Holloway, C., Bansal, G., Gharatya, K., Roan, T.R., Tyler, N., 2016. Train design features affecting boarding and alighting of passengers. J. Adv. Transp. 50 (8), 2077–2088.

Van Lange, P.A.M., Balliet, D. (2015). Interdependence theory. In: Mikulincer, M., Shaver, P.R., Simpson, J.A., Dovidio J.F. (Eds.), APA Handbook of Personality and Social Psychology, Vol. 3. Interpersonal relations (pp. 65–92). American Psychological Association.

Van Lange, P.A.M., Klapwijk, A., Van Munster, L.M., 2011. How the shadow of the future might promote cooperation. Group Process. Intergroup Relat. 14 (6), 857–870.

Villatoro, D., Sen, S., Sabater-Mir, J., 2010. Of social norms and sanctioning: a game theoretical overview. Int. J. Agent Technol. Syst. 2 (1), 1–15.

Wicker, A.W., 1979. An introduction to ecological psychology. Cambridge University Press, Cambridge, MA.

Young, P., 2015. The evolution of social norms. Annual Rev. Econ. 7, 359–387.

Zhou, M., Ge, S., Liu, J., Dong, H., Wang, F.Y., 2020. Field observation and analysis of waiting passengers at subway platform—A case study of Beijing subway stations. Physica A: Statist. Mech. Appl. 556, 124779.