Collective Dynamics

Pedestrian Crowd Management Experiments: A Data Guidance Paper

Ann Katrin Boomers[1] · Maik Boltes[1] · Juliane Adrian[1] · Mira Beermann[2] · Mohcine Chraibi[1] · Sina Feldmann[1] · Frank Fiedrich[4] · Niklas Frings[4] · Arne Graf[1] · Alica Kandler[1] · Deniz Kilic[1] · Krisztina Konya[2] · Mira Küpper[3] · Andreas Lotter[4] · Helena Lügering[1] · Francesca Müller[4] · Sarah Paetzke[1] · Anna-Katharina Raytarowski[1] · Olga Sablik[3] · Tobias Schrödter[1] · Armin Seyfried[1,3] · Anna Sieben[2,5] · Ezel Üsten[1]

[1] Institute for Advanced Simulation, Forschungszentrum Jülich, Jülich, Germany
E-mail: a.boomers@fz-juelich.de, m.boltes@fz-juelich.de
[2] Chair of Social Theory and Social Psychology, Ruhr-Universität Bochum, Bochum, Germany
[3] Faculty of Architecture and Civil Engineering, University of Wuppertal, Wuppertal, Germany
[4] Faculty of Mechanical Engineering and Safety Engineering, University of Wuppertal, Wuppertal, Germany
[5] School of Humanities and Social Sciences, University of St. Gallen, St. Gallen, Switzerland

Received: 8 February 2023 / Last revision received: 27 April 2023 / Accepted: 28 April 2023
DOI: 10.17815/CD.2023.141

Abstract Understanding pedestrian dynamics and the interaction of pedestrians with their environment is crucial to the safe and comfortable design of pedestrian facilities. Experiments offer the opportunity to explore the influence of individual factors. In the context of the project CroMa (Crowd Management in transport infrastructures), experiments were conducted with about 1000 participants to test various physical and social psychological hypotheses focusing on people's behaviour at railway stations and crowd management measures. The following experiments were performed: i) Train Platform Experiment, ii) Crowd Management Experiment, iii) Single-File Experiment, iv) Personal Space Experiment, v) Boarding and Alighting Experiment, vi) Bottleneck Experiment and vii) Tiny Box Experiment. This paper describes the basic planning and implementation steps, outlines all experiments with parameters, geometries, applied sensor technologies and pre- and post-processing steps. All data can be found in the pedestrian dynamics data archive.

Keywords CroMa project · controlled experiments · train platform · crowd management · single-file · personal space · boarding and alighting · bottleneck · tiny box · 3D motion capturing · electrodermal activity · heart rate · luggage

1. Introduction

This paper gives general information about the experiments performed within the project CroMa (Crowd Management in transport infrastructures) [1]. In addition, experiments from other projects such as CrowdDNA [2] were carried out in the context of this experiment series as well as experiments that cannot be assigned to a third party funded project. The paper includes information about the overall organization, the experimental site, the procedure and timeline, the participants, the data collection technique and gives an overview of all experiments. Further detailed information of single experiments, especially data analysis, will be found in focused papers on these experiments. All data gathered by the sensors used will be made freely accessible in the pedestrian dynamics data archive [3] with the publication of the first scientific results at the latest. General data mentioned in this paper like the overall composition of the test persons based on handed out questionnaires and a measurement course can also be found in the data archive [4].
The CroMa project itself is focused on developing and enhancing different strategies, such as building regulations, crowd management, and innovative action strategies to increase the efficiency of pedestrian facilities in railway and underground stations. These strategies aim to increase the robustness and efficiency of railway stations during peak load and to avoid crushes in the event of critical crowd densities. Research within the framework of CroMa includes the investigation of pedestrian flow in traffic facilities and the study of pedestrian behaviour within dense crowds. These research fields have also been assessed by means of the large-scale experiments described in this paper in which several external (structural) and internal (characteristics regarding the test person sample) parameters have been varied on a controlled basis.

2. Preparation of Experiments

The CroMa-experiments were conducted from October 8, until October 11, 2021 in the Mitsubishi Electric Hall (MEH) in Düsseldorf, Germany. The MEH is a multipurpose event hall with an interior hall size of 3500 m^2 and an additional main and side foyer. The planning and preparation were divided into two interlocked parts. One being the overall organization and provision of rooms and material and the other being the scientific planning of the individual experiments. Several preparatory meetings were held to discuss issues related to the variety of tested scenarios and statistical significance relative to available time and personnel. A temporal and spatial setup was developed to account for the level of information given to the participants about the aims of the study as well as their learning effect over the course of the day. The experimental plans were simplified, concretized and the times for conducting the experiments, announcements, walking routes, filling in the questionnaires and taking small breaks were calculated to test the feasibility of the setup. Originally, the experiments were planned for March 2020 and had to be postponed due to the growing SARS-CoV-2 (Covid-19) pandemic. When the experiments were conducted in October 2021, the setup was revised regarding compliance with safety measures and expanded to include a hygiene and safety concept.

2.1. General Framework

The experiments were performed in a circuit training model. This means that three experimental setups were performed at the same time at three different sites, and participants were guided from one site to the other in designated groups. The three groups were marked with wristband colors: red, green or blue. The experimental sites were labeled alphabetically 'B', 'C' and 'D' (Fig. 1). The experimental sites were separated by black curtains that shielded the view but were not sound proof. To limit the view on to the experiment, the waiting areas within the experimental sites were shielded by curtains as well. Each day (day 1-3) consisted of six experimental time slots lasting 1 hour each, therefore participants attended each experimental site twice a day, but never participated twice in the same experimental setup, as those changed from one time slot to the next. A rough time schedule is shown in Fig. 2.

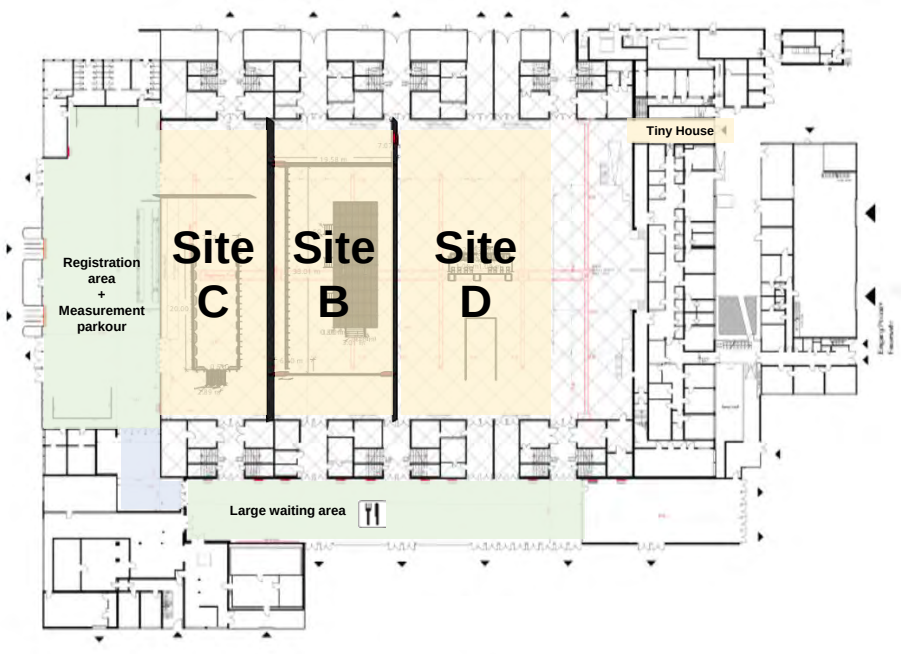


Figure 1 Room plan of experiment hall. Yellow patches indicate experimental sites in the interior hall. Green patches indicate open areas. Blue patch indicates corridor between open areas that was used as an 'icebreaker' experiment c.f. Sec. 2.5.

The following experiments were performed in site B:

- Train Platform Experiment (day 1-3; Sec. 3.1)

The following experiments were performed in site C:

- Crowd Management Experiment (day 1-3; Sec. 3.2)
- Single-File Experiment (day 4; Sec. 3.3)
- Personal Space Experiment (day 4; Sec. 3.4)

The following experiments were performed in site D:

- Boarding and Alighting Experiment (day 1-3; Sec. 3.5)
- Tiny Box Experiment (day 1-3; Sec. 3.6)
- Bottleneck Experiment (day 4; Sec. 3.7)

Day 4 was different in that participants were divided into only two groups: Group yellow consisted of 80 people and group red of 120 people. Group red took part in the experiments at site D in all six time slots. Group yellow took part in the experiments at site C for the time slots 1 to 3 and also came to site D for time slots 4 to 6.

(a) (b)

Figure 2 a) Rough time schedule of days 1-3 showing which group (red, green, blue) attended which experimental site at each time slot. b) rough time schedule of day 4 colored by the group affiliation.

2.2. Recruiting Process

Participants were recruited by spreading information via various channels including printed and social media as well as e-mail lists of former experiments. The information included a short summary of the project, dates and payment. A QR code and link to a registration website was provided. The website included further information on conditions of participation, days available as well as a registration form. The conditions of participation (originally in German) included:

- minimum age of 18 years and recommended age of younger than 75 years
- body height of 1.5 m to 2.0 m
- not being affected by limited mobility or claustrophobia
- wearing dark clothes without lettering and not wearing large bags/backpacks
- agreeing to being filmed and the material to be published in a data repository

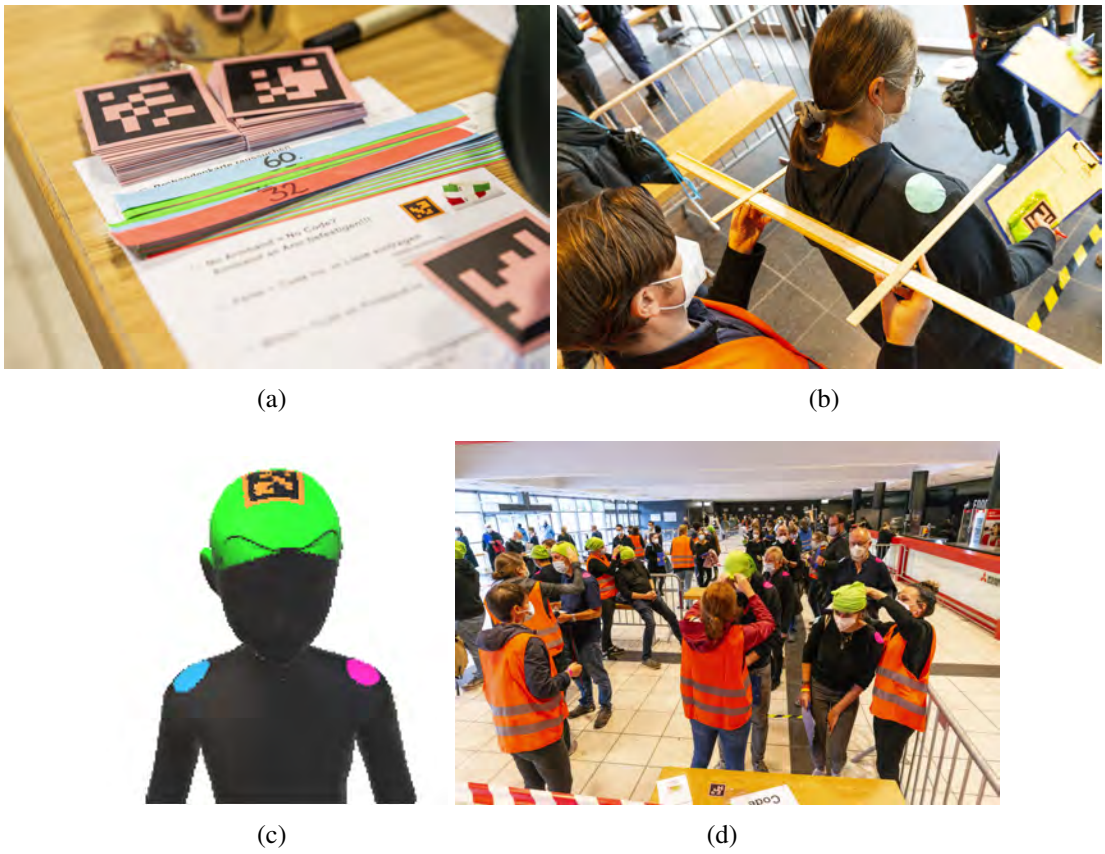
After submitting the registration form, the potential participants received an e-mail that their registration had been received. People were assigned to days based on their statements of availability and evenly divided among the days if they were available for multiple days. People were only able to register for one of the three first days and additionally for the fourth day.
After allocation to the days, participants received an e-mail with allocation information. Two weeks prior to the experiments, a reminder was sent including current information on the hygiene and safety concept. The hygiene concept to protect against infection by Covid-19 was a necessary requirement of the authorities and institutions involved. One week prior to the experiments, participants received an e-mail with a reminder of their personal assigned dates and important things to remember and bring along with them (e.g. ID card, comfortable shoes, wear dark clothes).

2.3. Registration and Measurement Course

At the time of arrival participants had to undergo a rapid Covid-19 test outside of the building where the experiments took place. The testing was performed by qualified hired personnel. The Covid rapid test stations were open starting from 8 a.m. People could only enter the building with a negative Covid-19 certificate. Registration started at 8:30 a.m. After checking the Covid certificate and an identity document, people could enter the Mitsubishi Electric Hall and proceed to the registration desk in the main foyer. During registration the identity documents were checked again, participants signed forms that they consented to the conditions of participation, and they were handed a green hat, personal ID code (Aruco Code dict_6X6_1000 [5]) and corresponding number on a wristband (Fig. 3 a) as well as a clipboard with questionnaires and declaration of informed consent to be filled out.

The wristbands had three different colors (red, blue, green) and were handed out alternately. That way participants were divided into three experimental groups on arrival. Participants who arrived in social groups were therefore split among our experimental groups, although it cannot be completely ruled out that people who know each other were in the same experimental group. The wristbands were labeled with numbers (Fig. 3 a) referring to the number associated with the personal ID code. The number was used for all questionnaires throughout the course of the day, to allocate sensor information and trajectories to a participant without revealing personal information.
After registration participants entered a course that led them to a sequence of stations. At these stations, information was collected and subjects were provided with markers and utensils:

- measuring height
- measuring shoulder width (Fig. 3 b)
- measuring weight
- checking color of top and handing out black long sleeve shirt if necessary



(a) (b)

(c) (d)

Figure 3 Figure showing pictures taken in the measurement course: a) shows a picture of personal ID codes with matching colored wristbands labeled with the corresponding ID number that were handed out at the registration desks, b) picture showing helper measuring shoulder width at a station of the measurement course, c) schematic of accessories each participant was equipped with, namely a green hat, a personal ID code on top of the hat and markers on the shoulders (pink at left, blue at right shoulder), d) picture showing helpers checking correct fit of the hats and codes.

- applying shoulder markers to top (Fig. 3 c)
- putting on green hat and attaching personal code (Fig. 3 c, d)
- checking correct fit of hat with code and telling people to leave the hat on for the entire day
- time for questions
- final check if declaration of informed consent was signed and questionnaires were filled out correctly
- targeted addressing of suitable people to ask if they were willing to wear additional sensors (3D motion capturing suit, heart rate sensor)

After completing the measurement course participants could check their bags at a cloakroom and proceed to a large waiting area.

2.4. Test Person Sample

To perform the experiments we accepted 1500 people for the duration of the four days. Of these, 1038 people attended the experiments. The sample of test persons included people from the age of 18 to 85 years (median=31, $\sigma = \pm 17$), with 47 % being male, 51 % female and 2 % not specified. Some of the distributions of the demographic data collected via questionnaire are shown in Fig. 4. Data that had to be measured such as body height, body weight and shoulder width were collected by employees during the measurement course (Fig. 3 b). On average, the participants were 1.75 m ($\sigma = \pm 0.1$) tall, weighed 79 kg ($\sigma = \pm 21$) and had a shoulder width of 45 cm ($\sigma = \pm 4$). Female participants were shorter, more lightweight and slimmer at the shoulders on average. Further personal data were collected via questionnaires. Differences in distributions for the different days and experimental groups can be found in the App. A.1. More data can be found in the archive [4].

2.5. Notes Related to Covid-19 Pandemic

At the time recruiting started as well as at the time of the experiments, Germany was at the beginning of a third Covid-19 wave (Fig. 5). Of the enrolled people, 90 % declared that they had been fully vaccinated.
Due to the pandemic, a number of precautions were taken:

- a hygiene and safety concept was developed by the team and approved by the crisis committee of Forschungszentrum Jülich and the competent regulatory authority of the city of Düsseldorf
- participants had to be recovered, vaccinated or tested (referred to as “3G” in Germany)
- everyone was tested at the time of arrival and people were only allowed to enter the building with a negative test result
- participants had to wear surgical masks at all times (except when eating or drinking at a seat in the waiting area)

In the first year of the Covid-19 pandemic, Germany’s regulations prohibited people from getting together in large groups and required them to keep a distance of 1.5 m between people not belonging to the same household. During the summer of 2021 these restrictions were dropped for vaccinated people. In public it could be observed that people kept wearing masks and kept their distance to other people to a large extent on a voluntary basis.
Because our experiments were designed for situations in which high densities may occur, we attempted to mitigate the behavioural changes described above. In order to get people accustomed to larger groups and higher densities again, we performed an ‘icebreaker’ experiment. Participants were not informed about the icebreaker experiment, which was performed as part of the walkway to the first experiment. After registration people waited in a large waiting area (Fig. 1 green shading). When the registration was finished up to

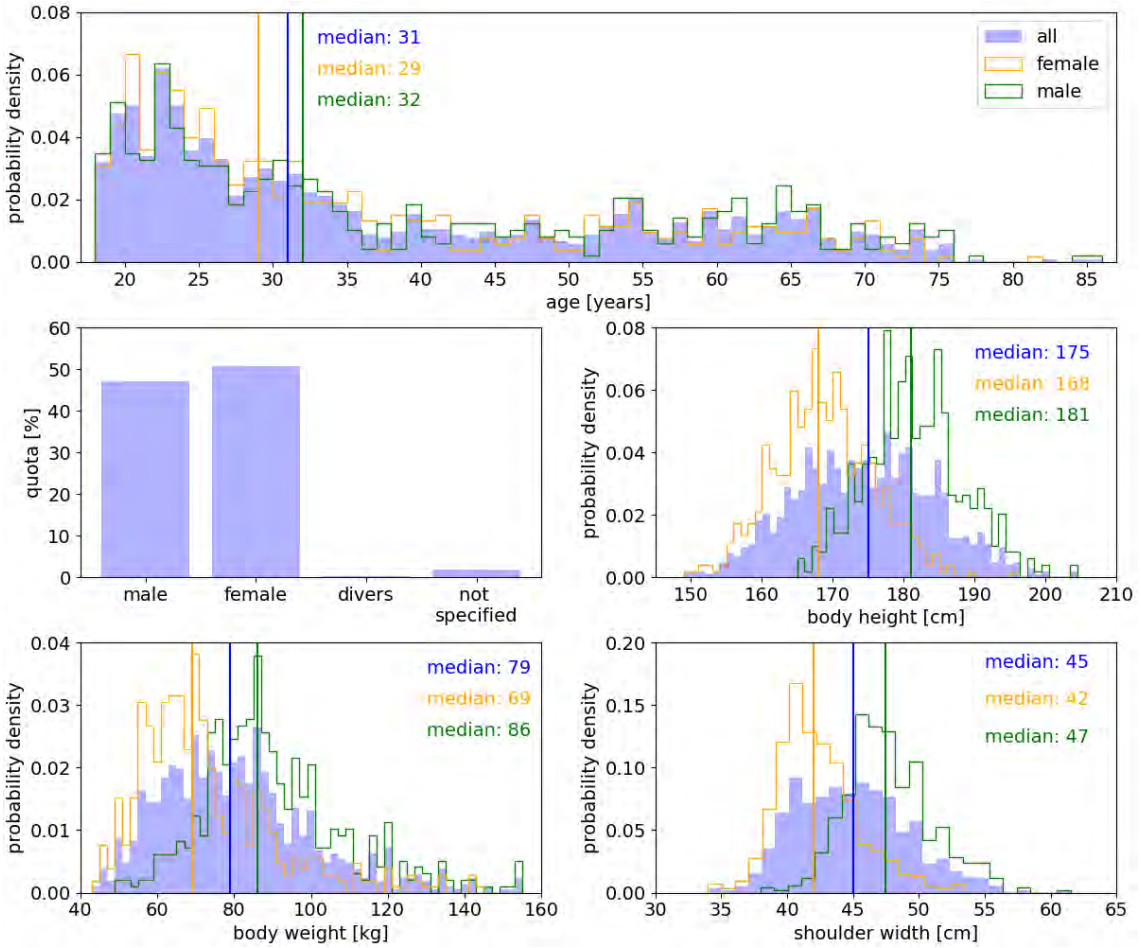


Figure 4 Figure showing histograms of different demographic factors of the participants for all four experimental days: age (top), gender (middle left), body height (middle right), body weight (bottom left) and shoulder width (bottom right). Data displayed in blue includes all data, data displayed in yellow includes data of all female participants and data displayed in green data of all male participants. Respective medians are shown in the same color as the data.

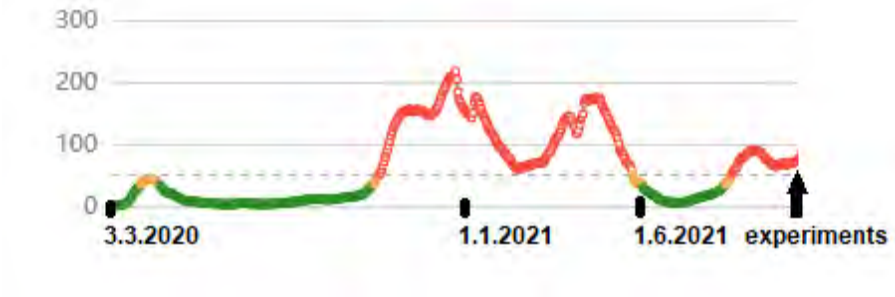


Figure 5 Course of 7 days incidence of Covid-19 pandemic for Germany. ([6], modified)

100 people were asked to walk to the first experiment at a time (based on the color of their wristband). A person in charge, responsible for an experimental area, walked them into a corridor with two doors (Fig. 1 blue shading). The person in charge asked people to wait until the last participant had arrived in the corridor. The rear door was closed when everyone had arrived (the density in the room was about 1 P/m^2). Then the person in charge waited for another few minutes before releasing participants into another open space. The icebreaker was performed once every morning for each group.

To assess the extent to which participants were influenced in their actions by the thought of the pandemic, everyone was given a questionnaire about perceptions of various risks (focusing, in particular, on perceptions of risks of Covid-19 infection) and about the potential influence of the Covid pandemic on the experiments, at the end of each experimental day. The questions were answered on a 7-point scale from "strongly disagree" (1) to "strongly agree" (7). The questionnaire started with the general items about whether participants felt uncomfortable in the crowds during the experiments. Participants were then able to rate how much the following seven factors influenced their discomfort: Crowding, concern about contracting Covid, concern about contracting an other illness, unclear instructions, physical exertion, stress caused by the experimenters, being with many people. Two more questions directly addressed the mental engagement with Covid. In addition, participants could indicate in which setting (e.g., in the registration course) and in which type of experiment (e.g. bottleneck) they were most concerned about Covid with a yes/no answering format. In the two final questions, subjects estimated whether they would have behaved differently before the pandemic and indicated whether they had already been in a crowd before the experiments since the onset of the pandemic. N = 1000 participants filled out the questionnaire on the four experimental days. Descriptive statistics are reported for the questionnaire data (Tab. 12).

The results of the questionnaire suggest that the Covid pandemic did not have a major impact on the answers of the participants. The concern about infection was reported to be low (mean value M between 1.98 and 2.45). Subjects self-reported that their actions were not significantly different than before the pandemic (M = 2.69). A self-selection effect certainly plays an important role for these results: Presumably only people who were not very concerned about Covid signed up for the experiments. This can also be seen in the last question. The statement that they have already been in a crowd elsewhere was often agreed with (M = 4.02). Furthermore, these results reflect the extensive safety measures that apparently reduced the fear of contagion. In general, a low expression of discomfort was reported in the experiments (M = 2.61). The factors that caused the most discomfort were crowding (M = 3.37) and physical exertion (M = 3.49). Subjects thought most strongly of Covid in the morning registration and measurement course (38 % answered with yes). We explain this by the fact that the registration came immediately after a mandatory Covid test. This meant that the topic of the pandemic was very present at that moment. On days 1-3 participants thought about Covid most often in experiment site C (26.2 %), followed by site D (16.1 %) and B (10.4 %). On day 4 participants thought about Covid quite a lot in the experiment site D (37.9 %) and very little in experiment site C (6.6 %).

3. Configuration of Experiments

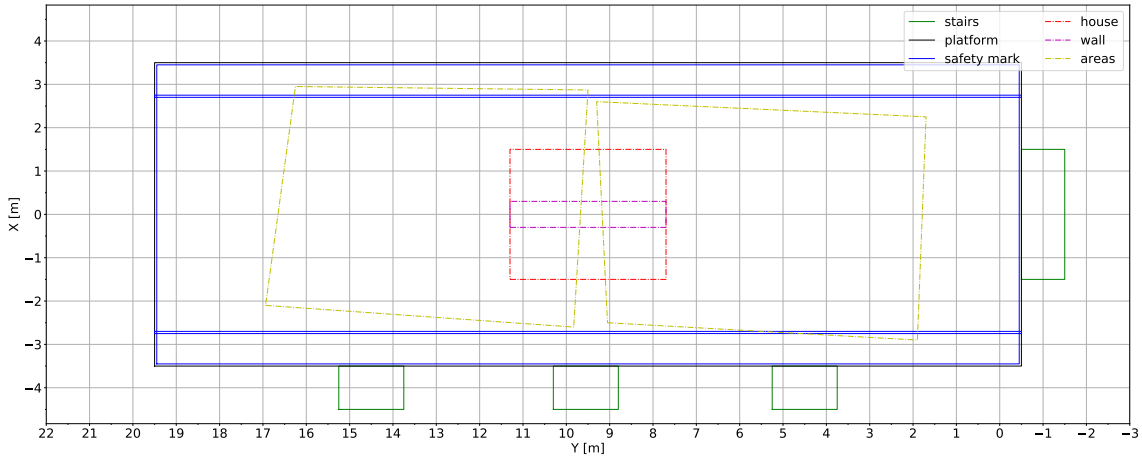
3.1. Train Platform Experiments

In this experimental site two different experiments were performed. The first one investigated the waiting behaviour of people on a simulated train platform under varying physical or social psychological factors, the second one investigated types of social influence in ambiguous situations on train station platforms.
The outer dimensions of the platform were 7 m x 20 m x 0.8 m. The ascent and descent was realized by stairs secured with railings and organized in a way that resembled one primary access and three stairs to "board the train" that only a few people could stand on at the same time. The stairs at the narrow side were 3 m wide while the stairs at the long side of the platform were each 1.5 m wide. The smaller stairs were movable and the positions for save attachment to the platform were only visible for helpers moving the stairs. The platform's edge was marked with adhesive tape (width 0.05 m). White adhesive tape marks the safety distance (0.8 m) from the edge of the platform, which is a standard for platforms in Germany. A loudspeaker box with recordings of railroad sounds was placed under the platform during all of the experiments to reduce the influence of sound from the neighbouring experimental sites.

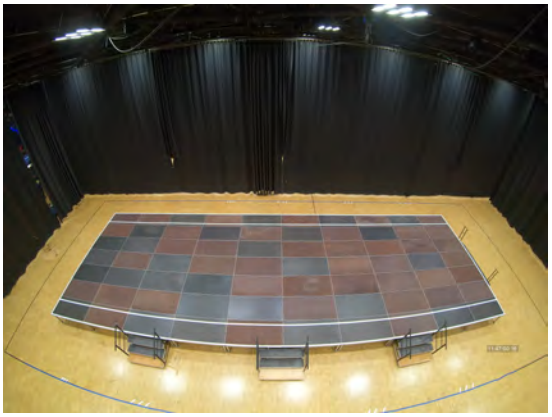
Cameras were mounted to record the experiment. They are listed in Tab. 2. Experimental runs in which 3D motion capturing data were recorded are listed in Tab. 11. The mood of the participants (cf. Sec. 4.7) was recorded for all runs. Trajectories were generated as described in Sec. 4.2. The coordinate origin's location was centred in relation to and 0.5 m from the short platform border (Fig. 6a), with the y-axis pointing to the left, parallel to the longer edge and aligned with the midpoint of the large stairs. The data of the Train Platform Experiments are provided online [7].

Waiting Experiments In this experiment instructions were given in the waiting area of the experimental site directly in front of the entrance to the experiment. The waiting area was separated from the experiment by a black curtain and thus the participants could not see the setup during the waiting phase and the instructions. In runs in which questionnaires were completed, this was done after the respective runs in a second waiting area at the opposite side. With the instructions, the participants were informed that the train they intend to board would arrive on the left hand side of the platform. The instructions read as follows, "Imagine you are at a train station. Behind those curtains is the platform, which you will enter through the stairs. You plan to take the train that will arrive in a few minutes at the platform at the left-hand side". The following parameters were varied (a detailed list of performed runs and combinations of parameters can be found in App. A.3):

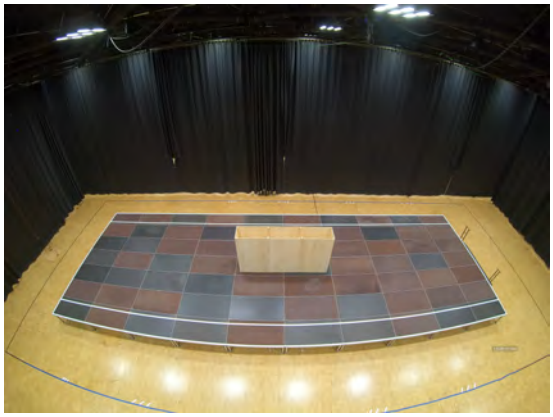
- number of participants: 40, 80-100, (140-180)
- obstacle on platform: none (blank), wall, house (Fig. 6 b-d)
- inflow: every 2-3 seconds, in groups of ten
- waiting time on platform: 2, 4 minutes



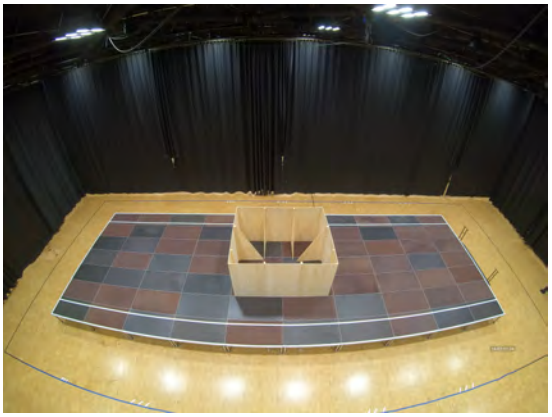
(a)



(b)



(c)



(d)

(e)

Figure 6 a) Schematic showing coordinate system of simulated train platform with all obstacles as well as screenshot of setup of experimental runs b) without obstacles with stairs present, c) with a wall, d) with a house, e) with marked areas on the floor.

The degree of familiarity of participants, as well as talking being allowed or prohibited was not manipulated, as in the experiments on decision making described below. The measurements of the wall were 0.6 m x 3.6 m x 2 m and of the house 3 m x 3.6 m x 2 m. Both were aligned symmetrically to the borders of the platform. In runs with 40 people, participants waited either 2 or 4 minutes. The waiting time was counted from the moment the last participant entered the platform. Additionally, the inflow sequence to the platform was varied, for the experimental runs without obstacles. The participants entered individually or in groups of ten. The groups of ten entered the platform with an interval of 35 seconds. For the platform without an obstacle and the setup with the house, additional runs with an larger number of participants were performed. In those runs the group of participants assigned to the corresponding experimental slot entered the platform first. After those participants had positioned themselves on the platform, participants from another group were brought in. Therewith the total number of passengers on the platform was unknown to all participants.

Experiments on Decision Making For the experiment, the participants of each run were instructed directly in front of the platform. They entered the platform using the stairs on the long side. On the platform, two areas were marked, one slightly larger than the other. Participants were instructed to wait in the larger area but not instructed on how they should know which area was the larger one (because it was not easily visible). The instructions read as follows, "Imagine you are at a train station and want to leave on the next train. The platform is marked with a white safety strip at the long sides. Two areas are marked in yellow, the so-called 'yellow squares', one on the right and one on the left. You will only be able to board the train from the larger area. Please proceed to the larger of the yellow squares". Depending on the experimental condition the instruction was continued, "Please, do not talk to each other during the whole experiment" or "You are allowed to talk to each other during the experiment". The curtains to the waiting area of the experimental site prevented the participants who did not take part in that specific run from observing the active participants of the run while carrying out the task. Questionnaires were completed for all runs both before entering and after leaving the area.

The following parameters were varied (a detailed list of performed runs and combinations of parameters can be found in App. A.3):

- number of participants: 10 (small groups), 23-41 (other groups)
- special design: 2 marked areas (Fig. 6 e)
- inflow: all at once per group
- waiting time on platform: up to 5 minutes
- degree of familiarity of the participants with each other: no connection at all, short acquaintance before starting the experiment, being in the same group for hours before the experiment
- special announcements: talking allowed, talking prohibited

The marked areas were placed on the platform asymmetrically (Fig. 6 a) or e)), and had a size of 35 m^2 (left) and 36.7 m^2 (right).

3.2. Crowd Management Experiments

This series of experiments investigated the extent to which physical parameters such as the number of line-up gates or the width and the shape of the barrier layouts influence the formation and the density of a queue. For this purpose, an admission situation under the assumption of "admission to the concert of your favorite artist" was simulated using barriers and line-up gates typical to those used at large events. Furthermore, non-physical parameters were considered. The following parameters were varied (a detailed list of performed runs and combinations of parameters can be found in App. A.4):

- setup structure grid (narrow): straight, small bend, 90°-right bend with and without lines (floor markings) (Fig. 7, 8 c-)
- setup structure grid (wide): none, lines, signs (above the line-up gates construction) (Fig. 7, 8 a-b)
- no. of open line-up gates: 1, 3
- motivation: low (enough time and guaranteed seat ticket), high (the general admission ticket)
- norm specification: none, 70%, 85%, 95%, 100%
- special announcements: no interruption (nI), with interruption (wI) (along with HRV sensors (Sec. 4.4))
- reference runs to record free walking speed (solo_ref)

Instructions according to the motivation and the run were given directly in front of the entrance to the experiment before participants could see the experimental setup. At the time of the instructions, participants were separated from the experiment by a black curtain. If a norm specification was given, every participant was given a slip of paper with a note on it saying either "In the following experiment, behave as you always would" or "Imagine that you are a very selfish person. Push yourself to the front during the experiment". The percentage refers to the amount of paper notes prescribing normal behaviour. After each

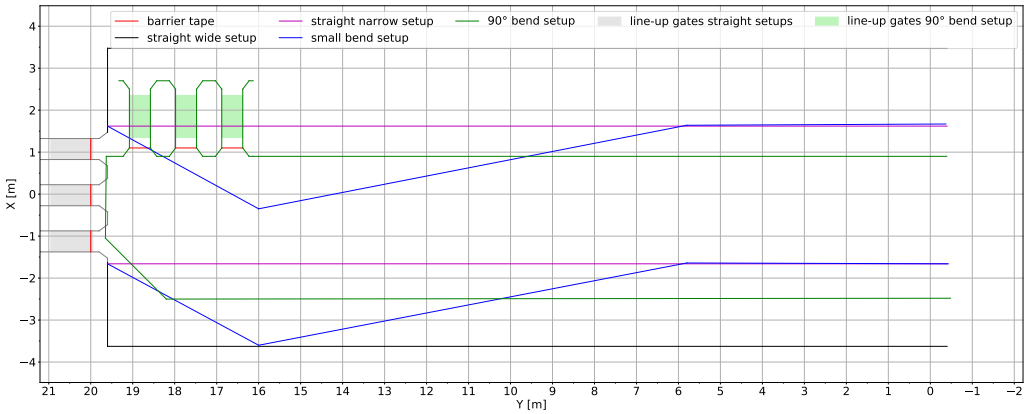


Figure 7 Schematic showing coordinate system and setup of all Crowd Management Experiments performed on day 1-3 in one.

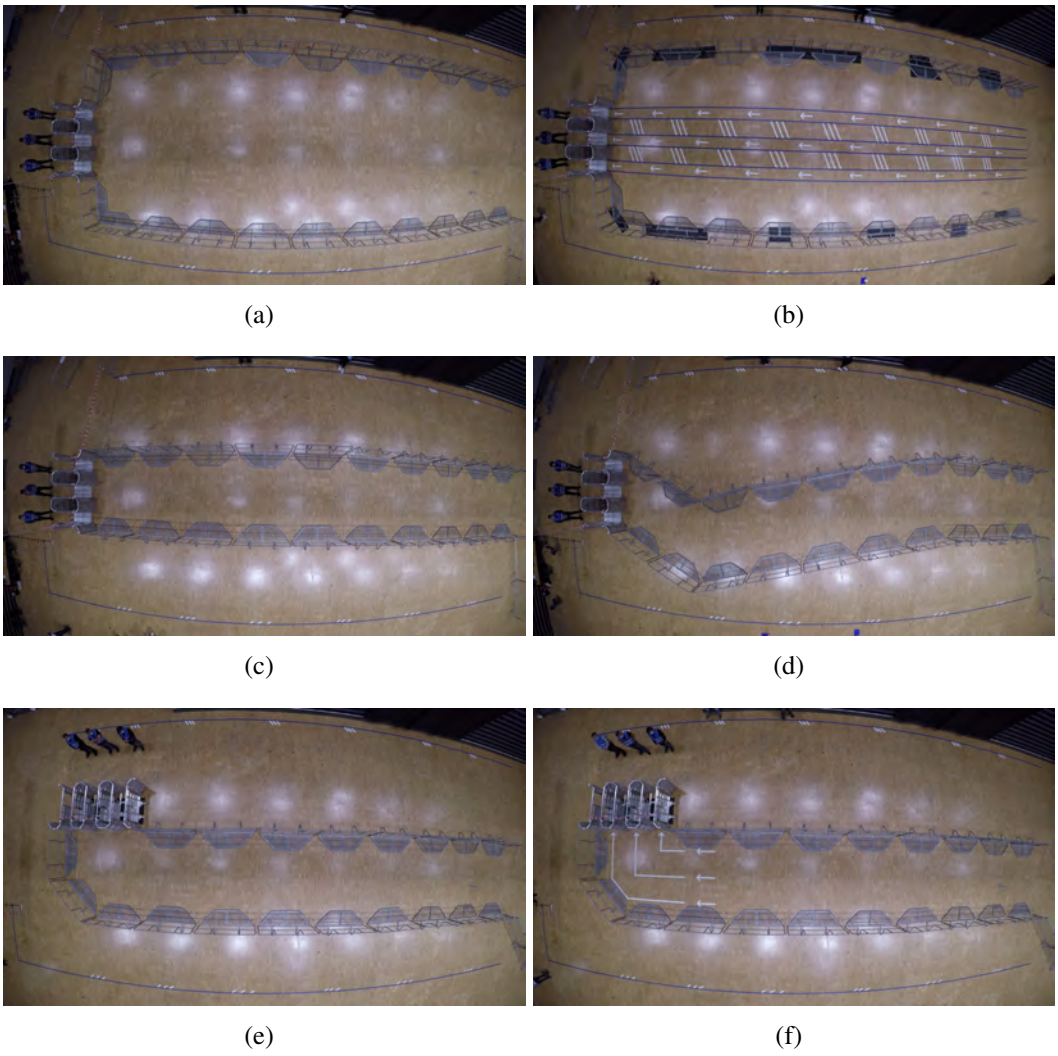


Figure 8 a) - f) Snapshots of overview cameras showing a) setup straight wide, b) setup straight wide with lines, c) setup straight narrow, d) setup small bend, e) setup 90° bend and f) setup 90° bend with lines.

run, participants were directed back to the area where the instructions were given and questionnaires distributed. HRV Sensors were collected (if given) after each group had finished their respective runs. Within the framework of the experiments, a comparison of the estimated and the physically measured density of people was carried out. Some assessors had been previously trained to the Level of Service and had been given further knowledge of density estimation, while others were untrained. Time-dependent densities ranging from low to medium to high were estimated [8] and documented. In addition, positive and negative factors influencing the density estimation of the observers were surveyed using questionnaires.

The outer dimensions of the experimental area were 7 m x 20 m. The line-up gates construction was 2.5 m x 3.3 m x 1.18 m (length x width x height) with a passage width of 0.5 m each. The line-up gate construction at the 90°bend setup was 30 cm wider. Police

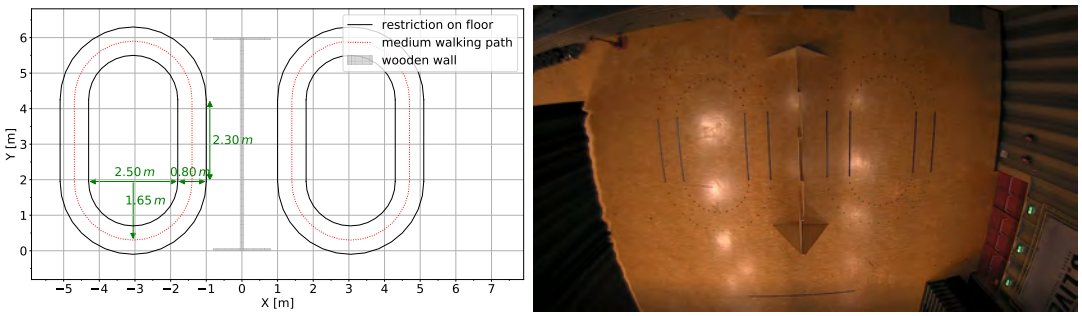
barriers with dimensions of 2.0 m x 0.94 m x 1.1 m were used to set up the structure grid. Cameras were mounted to record the experiment and are listed in Tab. 3. Experimental runs in which 3D motion capturing data were recorded are listed in Tab. 11 and runs in which HRV data were recorded in Tab. 10. The mood of the participants (cf. Sec. 4.7) was recorded for all runs. Trajectories were generated as described in Sec. 4.2. The coordinate origin was located where participants enter the experimental area, with the y-axis pointing in walking direction and aligned with the midpoint of the middle entry gate (Fig. 7). The data of the Crowd Management Experiments are provided online [9].

3.3. Single-File Experiments

This series of experiments investigated how walking speed and density affect physiological arousal. For this purpose, subjects were equipped with electrodermal activity (EDA) and heart rate variability (HRV) sensors (cf. Sec. 4.3, 4.4). Additionally the effect of gender on walking speed and density was investigated. The experiments were performed in the setup of classical single-file experiments, where people walked in ovals behind each other. Overtaking was prohibited. The instructions read, “Please walk one behind the other in the oval until a signal to stop is given. Do not push or overtake”. The following parameters were varied (a detailed list of performed runs and combinations of parameters can be found in App. A.5):

- number of participants
- gender: male, female, mixed
- running order by gender: random, alternating

Instructions to start or to stop were given by a person standing between the two experimental setups without using technical amplification. Participants walked in the oval for at least 2 minutes or until they had walked one round at very high densities. The width of the ovals walking paths was 0.8 m with a circumference of 14.97 m as measured from the middle of the indicated walking width (Fig. 9a). The course was indicated by colored markers on the floor. Two oval experiments were performed at the same time. They were separated by a wooden wall (Fig. 9b).



(a) (b)

Figure 9 a) Schematic showing the dimensions of the oval. b) Screenshot from Camera showing the setup of two ovals separated by a wooden wall.

Cameras were mounted to record the experiment and are listed in Tab. 4. Experimental runs in which EDA and HRV sensors were recorded are listed in Tab. 9 and 10. Trajectories were generated as described in Sec. 4.2. The coordinate origin was located at the lower side of the two ovals' in the axis of the screen wall (Fig. 9a). The data of the Single-File Experiments are provided online [10].

3.4. Personal-Space Experiments

This experimental series investigated physiological arousal when personal space is violated at low densities. Seven participants were positioned within an area marked on the floor and then passed by ten other participants (individually or several simultaneously) from all directions without being touched. Passing Participants were instructed to "Enter the area and walk around until a signal is given to leave the area" and standing participants to "Stand on one of the floor markings. Then remain in place until a signal is given to leave the area". All participants assigned to be standing in the designated spots were equipped with electrodermal activity (EDA) and heart rate variability (HRV) sensors (cf. Sec. 4.3, 4.4). Instructions were given without using technical amplification as the groups were small. Eight runs of four minutes each were performed in total (a list of performed runs can be found in App. A.6).

(a) (b)

Figure 10 a) Schematic showing the dimensions of the experimental area on a 1 m x 1 m grid with positions of standing participants. b) Snapshot of experiment with standing and passing participants.

The dimensions of the experimental area were 12.1 m x 5.3 m. The experiment was performed next to the Oval Experiments outlined in the previous subsection. There was no visual shielding between the two experiments and it was possible for participants to pass unhindered between the two experimental sites. Participants with EDA and HRV sensors were placed at positions indicated as red dots in Fig. 10a. Passing participants were participants who were not currently on runs in the neighbouring Oval Experiment. Questionnaires were completed at the end of the whole experiment set including the runs of the Oval Experiment.

Cameras were mounted to record the experiment and are listed in Tab. 5. Experimental runs in which EDA and HRV sensors were recorded are listed in Tab. 9 and 10. No trajectories were exported for this experiment. The data of the Personal Space Experiments is provided online [11].

3.5. Boarding and Alighting Experiments

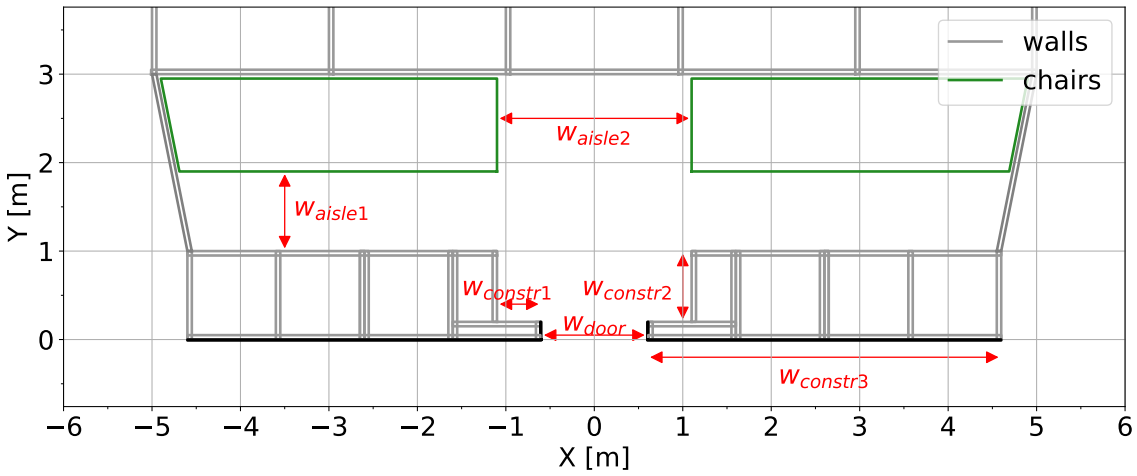
This series of experiments investigated how different parameters influence the boarding and alighting process of a train car. For this purpose, the boarding area of a local train was mimicked. Sliding doors could be opened from outside the experimental area via ropes without interfering with participants. Different parameters were varied (a detailed list of performed runs and combinations of parameters can be found in App. A.7):

- number of persons boarding/alighting/staying in train car
- luggage: none, backpack, suitcase, baby stroller, mix
- cooperation: none, work together for fast boarding and alighting
- motivation: normal, hurry, pushing, distracted by using phone
- line-up: none, throng, corridor, 45°
- groups: none, pairs, groups of 3, groups of 5, mix
- norm: none, 70%, 80%, 100%

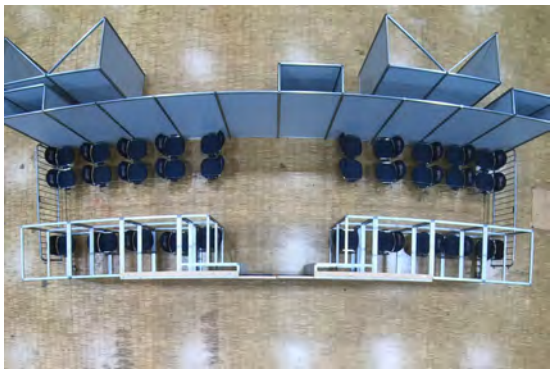
Instructions indicating 'the arrival' and 'the departure' of the train as well as the opening and the closing of the doors were given without using technical amplification from a person standing behind the waiting/boarding pedestrians. Special announcements were made via slips of paper or by directly addressing individuals by the investigators to make individual, targeted announcements when necessary to achieve the study objective. These kinds of announcements as well as handing out luggage were done in the waiting area to the left of the experimental area. Persons assigned to a group got sticky dots of the same color and had the instruction to stay together during the boarding process. For the variation of norm, the percentage in the list above refers to the amount of paper notes prescribing 'normal', considerate behaviour whereas the remaining persons got the information that pushing is allowed. Where questionnaires were completed, this was done after the respective runs in the waiting area.

The outer dimensions of the experimental area were 20 m x 20 m. The inner dimensions of the train car were approximately 9.2 m x 3 m (the exact dimensions can be extracted from Fig. 11a) and aim to mimic a typical local train in Germany with the measurements $w_{door} = 1.2m$, $w_{const1} = 0.5m$, $w_{const2} = 0.8m$, $w_{const3} = 4.0m$, $w_{aisle1} = 0.9m$, $w_{aisle2} = 2.2m$ as indicated in Fig. 11a.

Cameras were mounted to record the experiment and are listed in Tab. 6. Experimental runs in which 3D motion capturing data were recorded are listed in Tab. 11. The mood



(a)



(b)

(c)

Figure 11 a) Schematic showing coordinate system of simulated train car as well as screenshots of the setup in b) top view and c) front view.

of the participants (c.f. Sec. 4.7) was recorded for all runs. Trajectories were generated as described in Sec. 4.2. The coordinate origin was located on the axis of the front of the bottleneck in the middle between the two bottleneck sides. The data of the Boarding and Alighting Experiments are provided online [12].

3.6. Tiny Box Experiments

This experimental series investigated the relationship between density and physiological arousal while waiting. For this purpose up to eight participants waited in 'tiny boxes' under different conditions. All participants were equipped with electrodermal activity and heart rate variability Sensors (cf. Sec. 4.3, 4.4). The following parameters were varied (a detailed list of performed runs and combinations of parameters can be found in App. A.8):

- number of people in box
- communication: speaking allowed, speaking prohibited

Figure 12 Snapshot of the tiny box experiment without participants.

The tiny boxes were four wooden boxes of 1 m × 1 m and a height of 1.5 m (Fig. 12). Participants could enter and exit the boxes through a one-sided swinging door. The experiments were performed in a delivery channel close to experimental site D (cf. Fig. 1) to shield participants as well as possible from acoustic and visual influence of the experiments performed at the same time. Participants were chosen based on age and gender from the respective groups taking part in the experiments at site D. Instructions were given without technical amplification as the groups were small. Where questionnaires were completed, this was done after the respective runs in an area in front of the delivery channel.

Cameras were mounted to record the experiment and are listed in Tab. 7. Experimental runs in which EDA and HRV sensors were recorded are listed in Tab. 9 and 10. No trajectories were exported for this experiment. The data of the Tiny Box Experiments are provided online [13].

3.7. Bottleneck Experiments

This series of experiments investigated different physical and social-psychological aspects in a bottleneck scenario. The following experimental parameters were varied (a detailed list of performed runs and combinations of parameters can be found in App. A.9):

- bottleneck width: 0.6 m, 0.7 m, 0.8 m, 1.0 m, 1.2 m, 1.6 m
- bottleneck length: 0.2 m, 2.0 m

- motivation: normal, hurry, full commitment
- number of participants
- initial line-up: directly at the bottleneck, 2 m semi-circle, special positions at 4 m circle
- special announcements: none, active pushing / slowing, abort signal, interruption (with information passing on)

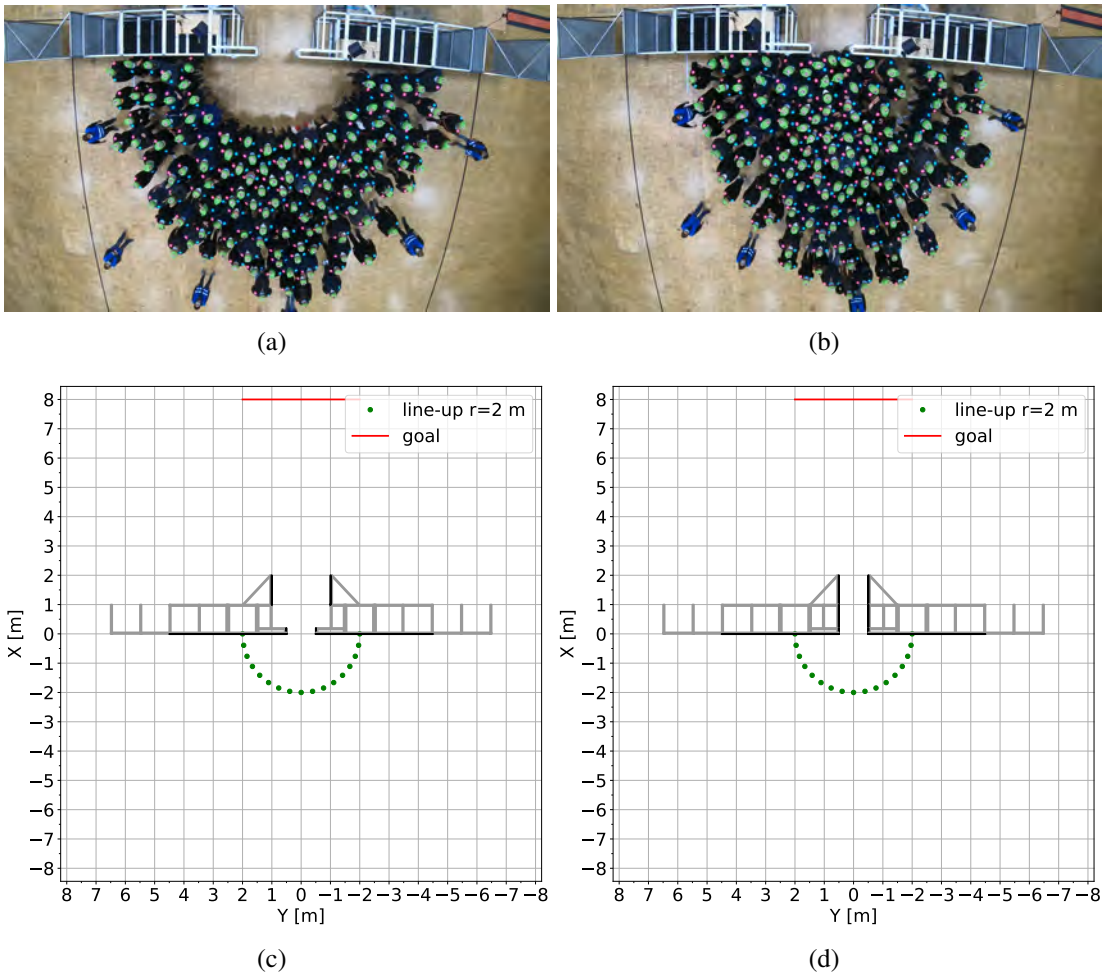


Figure 13 Snapshots of experiments with 0.2 m bottleneck length and an initial line-up being a) a 2 m semi-circle and b) standing directly at the bottleneck. Schematics of a setup with a bottleneck length of c) 0.2 m and d) 2 m.

The experiments were performed on day 4 at experimental site D. The announcer and further observers were standing on a scissor lift that was parked behind the bottleneck construction and raised to a height of several meters to have a good overview. All announcements were made with a microphone connected to a portable loudspeaker. To increase the initial density, the participants in the first row were asked to stay in place

while everyone else was asked to take one step forward, before each run. The intended initial density was $1\,P/m^2$. Whenever special targeted announcements were necessary to achieve the study objective, they were made via slips of paper or by the investigators directly addressing individuals. In 'normal' condition runs participants were instructed as follows: "You are in a crowd where people walk through a door at a normal pace. You yourself move purposefully, but without haste." In 'hurry' conditions the instructions were "You are in a crowd where people are in a hurry to pass a door. You yourself are also moving briskly", and in 'full commitment' conditions "You are in a crowd where everyone wants to pass through a door as quickly as possible and pushes their way through. You yourself do everything you can to get to the front and through quickly as well."

Fig. 13 shows snapshots of two example experiments and sketches of the bottleneck construction. The outer dimensions of the experimental area were 20 m by 20 m. The bottleneck construction consisted of an 4 m x 2 m x 1 m aluminium frame with gray plastic panels, weighing 250 kg per side. They were each visually extended to be 6 m long by adding trade fair walls. Each side was secured against slipping with anti-slip mats and 750 kg concrete blocks which were bolted to the bottleneck construction. Participants were to maintain their motivation until they crossed a finish line 8 m behind the bottleneck. The way to the finish line was marked with barrier tape. Beyond the finish line, participants could return to the line-up area by turning to either sides. Where questionnaires were to be completed, this was done after the respective runs in an area to the left of the experimental area.

To take safety precautions, a practised crowd manager was present at the experiments equipped with an air pressure horn. The horn was activated whenever a participant indicated discomfort during an experiment by calling out 'stop' aloud or if the crowd manager himself identified a situation as critical or potentially harmful. At the beginning of the day, all participants were trained in what was to be done in the case of the horn being activated. The procedure included immediately stopping in the current position without further movement. Designated helpers that were close to the crowd at all times started tapping people at the shoulder once the crowd had come to a full stop. On the signal of 'shoulder tapping' participants were allowed to turn around and move to the far back of the experimental site. The procedure was continued until every person was tapped at the shoulder. Apart from the test run where the horn was activated on purpose, two runs (4D250, 4D280) were aborted and resolved in the way described above.

Cameras were mounted to record the experiment and are listed in Tab. 8. Experimental runs in which 3D motion capturing and pressure sensor data were recorded are listed in Tab. 11. Pressure sensor data (cf. Sec. 4.5) and the mood of the participants (cf. Sec. 4.7) were recorded for all runs. Trajectories were generated as described in Sec. 4.2. The coordinate origin was located on the axis of the front of the bottleneck walls in the middle between the two bottleneck sides. The data of the Bottleneck Experiments are provided online [14]. The scientific content of some of the bottleneck experiments in this series is part of the CrowdDNA project.

4. Sensors

Different combinations of sensory systems were used in the different experiments. This included camera recordings, electrodermal activity sensors, heart rate variability sensors, pressure sensors (at the wall as well as on participants), 3D-motion capturing systems and mood buttons. The design and use of the individual sensors as well as their synchronization in time will be described in the following sections.

4.1. Time Synchronization Between Sensors

Accurate time synchronization is required for reliable connection of data from multiple sensor sources. Depending on the sensors' technical settings, different technical solutions need to be adopted to enable synchronization. In an ideal setup, all sensors operate with the same frequency, are connected to the same metronome to capture the exact same instance in time and have the same time code. However, in reality different sensors operate on different frame rates, are not pairable with a metronome or might show a drift in time. In order to keep the deviations as small as possible, a global time was introduced and distributed by Tentacle timecode generators [15] and as many sensors as possible were attached to submodule metronomes.

Camera Synchronization with Global Time All Marshall cameras (Sec. 4.2) were operated with a multi-camera video review system Simplylive Ref&Box8 Mini and the Rosendahl NanoSync [16] metronome. Sony RX0M2 cameras were operated with the connected control box CCD_WD1 and handled remotely via direct web access. All cameras were synchronized with the Tentacle timecode by filming the Tentacle global time (approx. every 45 minutes) and shifting time data to coincide with the global time in the aftermath. If the global time could not be read in the video (GP4_1, GP4_2), synchronization was performed based on movement patterns of individual participants. Due to the regular recording of the timecode and subsequent adjustment, the drift in time was negligible.

3D Motion Capturing System Synchronization with Global Time The 3D Motion Capturing System (Sec. 4.6) was attached to the Tentacle timecode generator for the course of the experiments. The MVN software syncs the time between the Tentacle timecode generator and the Xsens hardware once every second. The timecode is stored in the data set for every sample point.

HRV/EDA and Pressure Sensor Synchronization with Global Time The computers controlling the other sensors (wall pressure sensor (Sec. 4.5), body pressure sensor, EDA (Sec. 4.3), HRV (Sec. 4.4)) were filmed each morning and evening together with the Tentacle timecode generator. The time difference Δt between the tentacle time and the internal time of the corresponding computers was determined (hh:mm:ss:ff) and data was shifted to coincide with the global time. No drift over time was detected.

4.2. Camera and Trajectories

Camera recordings can be used for experiments in many ways. On the one hand, they make it possible to get a qualitative view of behaviour and to reconstruct the actual execution of the day and any deviations from the plan that may have occurred, as well as to reconstruct announcements and their intonation via the audio track. On the other hand, cameras can be used specifically to obtain measurement results such as extracting walking paths (trajectories) or documenting facial expressions of participants in response to the experiments.

In total, 21 cameras were mounted in order to perform the above tasks. Cameras intended for extracting trajectories and serving documentation purposes were mounted under the ceiling ($\approx$ 8.65 m) facing straight downwards. Camera views were overlapping and mounted in such a way that the occlusion of people was minimized. All cameras used for trajectory extraction were backed up since image loss would have been fatal for the experiments. The approximate fields of view at head height for cameras mounted in the main experimental sites are shown in Fig. 14 and listed in Tab. 2 to 8. The camera types and settings are listed in Tab. 1.

Table 1 Camera models of the 21 cameras mounted in the experimental sites, with short name of cameras used in the text, their type, the amount of cameras used and settings the cameras were operated with.

camera name	camera type	no.	camera settings
SL_cam3, SL_cam6, SL_cam8	Marshall CV365-CGB camera with lens VS-M2812-2	3	HD (1920 x 1080p), 50 fps, shutter: 1/300, brightness: 20
SL_cam1, SL_cam2, SL_cam4, SL_cam5, SL_cam7	Marshall CV365-CGB camera with lens VS-M226-A	5	HD (1920 x 1080p), 50 fps, shutter: 1/300, brightness: 20
RX0_cam1, RX0_cam2	Sony RX0M2	2	4K (3840 x 2160p), 25fps, RX0_cam1: shutter: 1/320, ISO: 320, RX0_cam2: shutter: 1/400, ISO:1000
GP7_1, GP7_2, GP7_3, GP7_4, GP7_5	GroPro 7	5	4K (4000 x 3000p, wide), 25fps, shutter: - , ISO: - (Protune: off)
GP4_1, GP4_2	GroPro 4	2	4K (4000 x 3000p, wide), 25fps, shutter: - , ISO: - (Protune: off)
X3000_1, X3000_2	Sony X3000	2	4K (3840 x 2160p), 25fps, shutter: - , ISO: -
Sony PJ	Sony PJ740	1	HD (1920 x 1080p), 25fps, shutter: - , ISO: -
Sony PXW	Sony PXW Z150	1	4K (3840 x 2160p), 25fps shutter: - , ISO: -

Table 2 Cameras mounted in experimental site D during the Train Platform Experiments (Sec. 3.1) and their purpose.

camera type	purpose	trajectories exported	sound
SL_cam1	trajectories	x	-
SL_cam2	trajectories	x	-
SL_cam3	code reading	x	-
GP7_2	overview (top-side view)	-	x
Sony PJ	code reading backup	-	-
X3000_1	record facial expressions	-	-
X3000_2	record facial expressions	-	-

Table 3 Cameras mounted in experimental site C during the Crowd Management Experiments (Sec. 3.2) and their purpose.

camera type	purpose	trajectories exported	sound
SL cam4	trajectories	x	-
SL cam5	trajectories	x	-
SL cam6	code reading	x	-
GP4_1	overview, backup	-	x
RX0_cam2	code reading backup	-	-

Table 4 Cameras mounted in experimental site C during the Single-File Experiments (Sec. 3.3) and their purpose.

camera type	purpose	trajectories exported	sound
SL_cam4	trajectories	x	-
SL_cam6	code reading	-	-
GP4_2	overview	-	x
RX0_cam2	code reading backup	x	-

Table 5 Cameras mounted in experimental site C during the Personal Space Experiments (Sec. 3.4) and their purpose.

camera type	purpose	trajectories exported	sound
SL_cam5	trajectories	-	-
SL_cam6	code reading	-	-
GP4_1	overview	-	x

Table 6 Cameras mounted in experimental site D during the Boarding and Alighting Experiments (Sec. 3.5) and their purpose.

camera type	purpose	trajectories exported	sound
SL_cam7	trajectories	x	-
SL_cam8	trajectories	x	-
GP7_1	overview	-	x
RX0_cam1	code reading backup	-	-

Table 7 Cameras mounted in experimental site D during the Tiny House Experiments (Sec. 3.6) and their purpose.

camera type	purpose	trajectories exported	sound
GP7_3	overview	-	x

Table 8 Cameras mounted in experimental site D during the Bottleneck Experiments (Sec. 3.7) and their purpose.

camera type	purpose	trajectories exported	sound
SL_cam7	trajectories	-	-
SL_cam8	trajectories	-	-
GP7_1	overview	x	x
RX0_cam1	code reading backup	x	-
GP7_4	record facial expressions	-	x
GP7_5	record facial expressions	-	x
Sony PXW	faces bottleneck exit	-	x

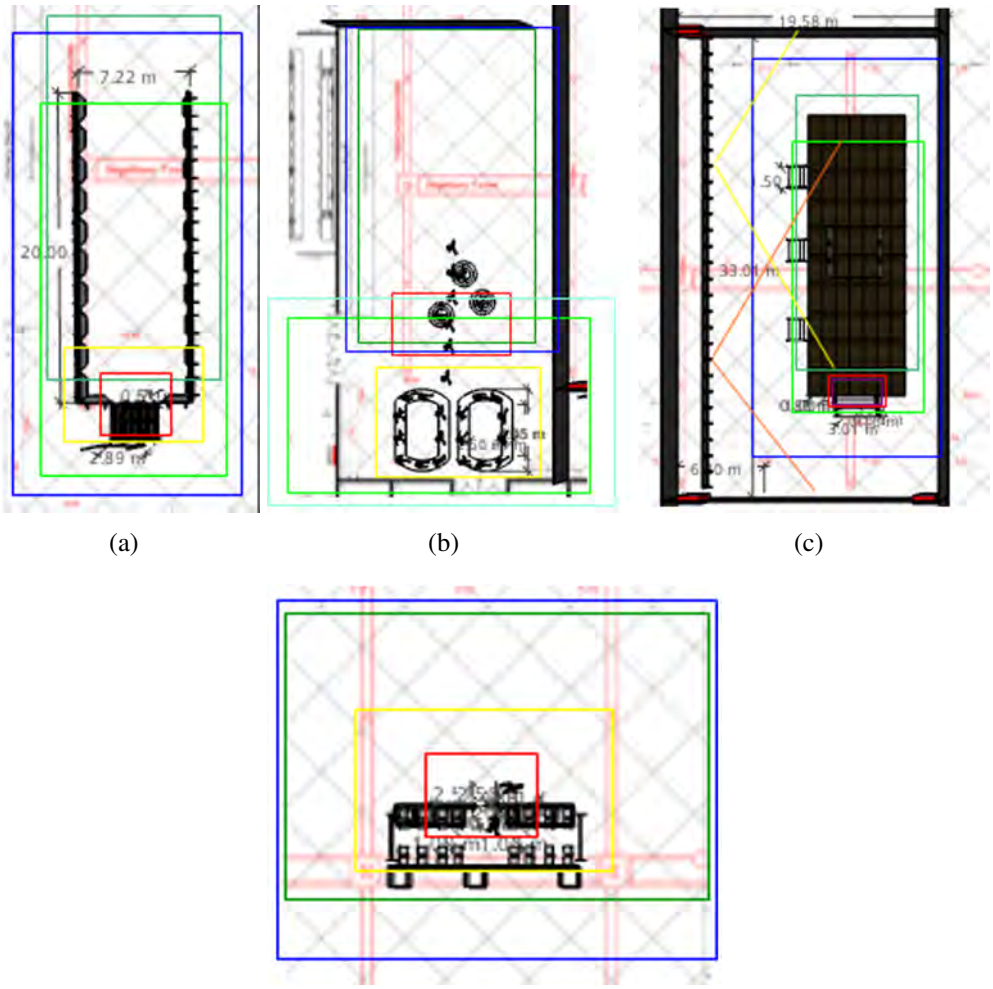


Figure 14 Schematic showing approximate field of view at head height for mounted cameras in each experimental site.
a) experimental site C on day 1-3; dark green: SL_cam4, light green: SL_cam5, red: SL_cam6, blue: GP4_1, yellow: RX0_cam2;
b) experimental site C on day 4; dark green: SL_cam5, light green: SL_cam4, red: SL_cam6, dark blue: GP4_1, light blue: GP4_2, yellow: RX0_cam2;
c) experimental site B on day 1-3; dark green: SL_cam1, light green: SL_cam2, red: SL_cam3, purple: PJ740, blue GP7_2, yellow: X3000_1, orange: X3000_2;
d) experimental site D on day 1-4; dark green: SL_cam7, red: SL_cam8, dark blue: GP7_1, yellow: RX0_cam1

Trajectories The trajectory extraction was performed with the pedestrian tracking software PeTrack [17, 18] for cameras indicated in Sec. 3.1 to 3.7. Cameras operated with the Simplylive system produced frame drops, double and black frames. The reason could not be reproduced unequivocally. These artifacts were detected and treated before continuing with trajectory extraction. Black frames were detected by applying a binary filter on the grey-scale frames of the video and checking if all pixels were black. Duplicated

frames were detected by computing the difference between each frame with the previous one in greyscale. On these differences, DBSCAN [19, 20] was used to detect clusters with camera-based parameters. Each frame which did not belong to a cluster was considered to be a duplication of the previous one. Afterward, the videos were reencoded with ffmpeg skipping these erroneous frames. Before exporting the trajectories from PeTrack, the results of the tracking were used to further improve the output data to interpolate the movement between dropped frames. For this, the displacement of each pedestrian in a frame was computed using the Lucas-Kanade method [21, 22]. Computing the ratio between these displacements and the average displacement of the previous frame gave the number of missing frames.
To implement the mapping from pixel to real world coordinates two types of calibration [23] had to be performed. Intrinsic calibration was performed to take into account the distortion of the lenses and internal hardware combinations. Extrinsic calibration was performed to create a transformation map between the camera and real world coordinate system and was performed every morning with a ranging pole and attached levelling unit. The resulting mean re-projection error for all calibration points for all days and cameras was 1.1 cm with a standard deviation of 0.6 cm and a maximum error of 2.2 cm. However, values differ greatly depending on the camera. The values for the individual cameras are shown in the appendix in Tab. 20.
For cameras used for code reading, recognition in the software PeTrack was performed with the code marker method using Aruco Code dictionary dict_6X6_1000 [5]. All other cameras' recognition was performed using the multicolor marker method within PeTrack. After the automatic extraction of trajectories, all runs were manually corrected. To handle the perspective distortion of the cameras for a correct head position in space, the individual heights of each person were accounted for and if a code could not be read a default height of 1.75 m was applied. The different camera views of each experimental area were combined into one single dataset by linear interpolation from the trajectory of one camera view to the trajectory of the other camera view in the overlap region.

4.3. Electrodermal Activity

Ambulatory sensors (EDA Move4) from the Movisens company [24] were used for measuring electrodermal activity. A total of 28 sensors were used, which were activated every morning and their data saved every evening. The EDA Move recorded electrodermal activity using the exosomatic method at a constant voltage of 0.5 V. The measurement range is 2 - 100 micro Siemens and the sampling frequency is 32 Hz.
The sensor was attached to the non-dominant hand of the subjects using a wristband. There were two cables attached to the wristband. These cables connected the two measurement electrodes to the sensor. The electrodes were structural non-woven electrodes with special gel/solid gel and a diameter of 55 mm, which was cut to size if necessary. The electrodes were glued to the palm of the hand below the little finger so that the gel surfaces of the electrodes did not overlap. If the electrodes did not hold well, they were fixed with leukotape. The EDA sensors were always attached by the experimenters and worn for a maximum of one hour. Between different subjects, the sensors were not read.

The separation of the data was done in the aftermath by cutting up the individual experiment blocks. The sensor number and the subject number for the day were noted and thus the data of the sensor and the remaining data of the subjects could be linked. EDA data was recorded in runs listed in Tab. 9.

4.4. Heart Rate Variability

Movisens ambulatory sensors (ECG Move4) [25] were used for heart rate measurements. A total of 28 sensors were used, which were activated every morning and their data saved every evening. The ECG Move records the heart rate with a resolution of 12 bit. The input range is 560 mV (CM), ± mV (DM) and 3 db bandwidth from 1.6 - 33 Hz. The sampling rate is 1024 Hz. In addition to the ECG sensor, the ECG Move contains a number of other sensors. These include a 3D-acceleration sensor, which records with 64 Hz and has a measuring range of ± 16 g, and a rotation rate sensor with a measuring range of ± 2000 dps and a resolution of 70 mdps, with an output rate of 64 Hz. It also has a pressure sensor with a range of 300 - 1100 hPa at a resolution of 0.03 hPa, a sampling rate of 8 Hz and a temperature sensor that measures ambient temperature at a frequency of 1 Hz.
The sensor was placed below the chest using disposable electrodes. The electrodes contained a highly conductive wet gel and a high quality Ag/AgCl sensor. They had a decentred connection to reduce motion artifacts. The ECG sensors were frequently attached by the subjects themselves. Between different subjects, the sensors were not read. The separation of the data was performed by cutting up the individual experimental blocks. The sensor number and subject number for the day were noted and thus the sensor data and the rest of the subject data could be linked. Heart rate data was recorded in runs listed in Tab. 10.

4.5. Pressure

During the bottleneck experiments on day 4 (Sec. 3.7), two pressure sensors from Tekscan (Pressure Mapping Sensor 5400N [26]) were employed to estimate normal forces within a crowd. Each sensor consists of 1768 measurement cells covering an area of 57.8 cm ×

Table 9 Experiment runs in which EDA sensors were used. Experimental configurations of runs are shown in the appendix.

day	Tiny Box Experiment	Oval Experiment	Personal Space Experiment
1	1 – 85	–	–
2	86 –170	–	–
3	171 – 204	–	–
4	–	single_file_gender_2_6, single_file_gender_2_11, single_file_gender_random_2_6, single_file_gender_random_2_11	4C1010, 4C1020, 4C1030, 4C1040, 4C2010, 4C2020, 4C2030, 4C2040

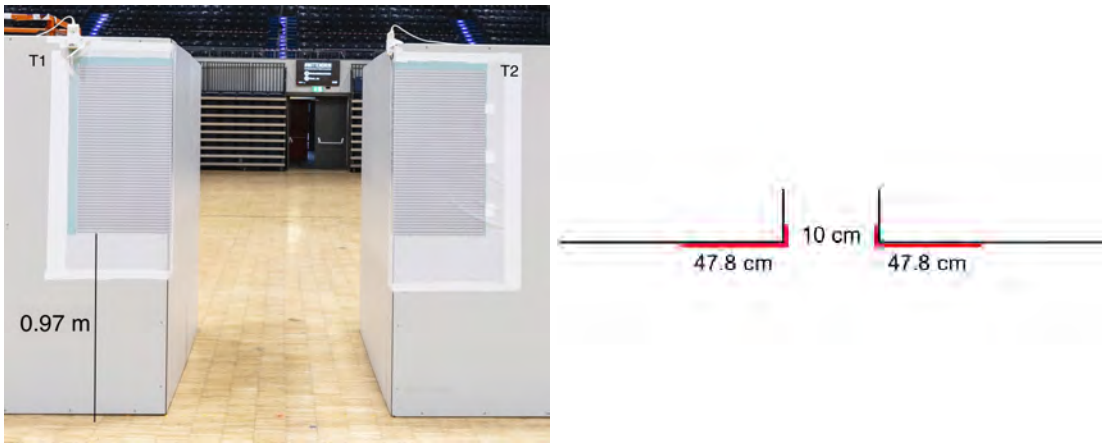
Table 10 Experiment runs in which HRV sensors were used. Experimental configurations of runs are shown in the appendix.

day	Tiny Box Experiment	Crowd Management Experiment	Oval Experiment	Personal Space Experiment
1	1 – 85	–	–	–
2	86 –170	–	–	–
3	171 – 204	3C070, 3C080, 3C081, 3C090, 3C100, 3C101, 3C110, 3C120, 3C121	–	–
4	–	–	single_file_gender_2_6, single_file_gender_2_11, single_file_gender_random_2_6, single_file_gender_random_2_11	4C1010, 4C1020, 4C1030, 4C1040, 4C2010, 4C2020, 4C2030, 4C2040

88.4 cm. Before the actual data recording, the sensors must be calibrated. For this purpose, the sensor was placed horizontally on a table and successively loaded with 10 kg, 20 kg, 30 kg, 40 kg, 50 kg, 95 kg, 110 kg, or 120 kg in total. Corresponding pressure values were measured with a sensitivity of S-40 and used for a multi-point calibration.

On either side of the bottleneck, a pressure sensor was attached vertically at a height of 0.97 m for the lower edge (Fig. 15 a). The short side of the sensor was bent around the corner to place 10 cm of the measurement area inside the bottleneck and 47.8 cm in front of it (Fig. 15 b). Teflon foil was spread over the pressure sensors to reduce shear forces and ensure a secure attachment. Each sensor was connected to a laptop recording pressure with the I-Scan software using a sampling rate of 60 fps.
Furthermore, two participants were equipped with flexible pressure sensors on their body, each with two upper arm sensors and one sensor for the back. Xsensor LX210:50.50.05 [27] has 2500 measuring cells providing pressure measurement on an area of 25.4 cm $\times$ 25.4 cm on the participant's back. The arm sensor (Xsensor LX210:25.50.05 [28]) covers an area of 12.7 cm $\times$ 25.4 cm with 1250 measuring cells. All sensors were calibrated in advance by the manufacturer resulting in a pressure range of 0.14 Ncm^{-2} – 10.3 Ncm^{-2}.

For easy wearing, the three pressure sensors were tucked into designated pockets of a specific T-shirt (Fig. 16) and connected to a tablet. The tablet, which was carried in the chest pocket throughout the experiments, used the Software Xsensor Pro V8 to capture pressure at a sampling rate of 25 fps. In order to receive as much pressure as possible at the central part of the back, the volunteers who wore the shirts were 1.91 m and 2.04 m tall. Unfortunately, no pressure data from the Xsensor sensors in the T-shirts were recorded during the experiments.



(a) (b)

Figure 15 Attachment of the pressure sensors to the walls of the bottleneck with a) front view and b) top view.

Figure 16 Wearable T-shirts with pockets for the pressure sensors. a) Back view of the T-shirt. Pressure sensors can be stored in the pockets for the left arm, right arm and the back. b) Participant during an experiment. The tablet is stored in the chest pocket.

4.6. 3D-Motion Capturing

We used the 3D motion capturing (MoCap) system MVN Link by Xsens to track the full body motion of a person in the crowd [29]. While optical MoCap Systems need a free line of sight between the tracking points on the body and a set of cameras, the Xsens MoCap system uses inertial measurement units (IMU) as sensors. These IMUs measure the acceleration, the angular rate and the magnetic field strength and a line of sight between the body and a camera is not necessary. Therefore, it is possible to capture the full body motion even in dense crowds.

Each MVN Link suit (Fig. 17) is equipped with 17 IMU sensors on predefined independently moving body segments. The measurement can be triggered manually and the recorded data is stored locally on a body-pack in the suit. Thus, the measurement is self-contained and the data can be downloaded afterwards.

Figure 17 The Xsens MVN Link lycra suit (left) and the associated IMU sensors (right) (reproduced Fig. 2 and 13 from [30]).

After doing a calibration procedure and taking detailed body dimension measurements, the MVN Analyze software then calculates the full body motion based on a biomechanical model from the measured data set. The processed data includes the orientation, position, velocity, acceleration, angular velocity and angular acceleration of each body segment as well as the angles of joints and the location of the centre of mass. The data can be exported either as xml file or as biomechanical c3d file.

Because the IMU based motion capturing is self-sufficient and based on relative measurements only, the absolute positioning in space suffers from a drift which can accumulate over time. The head trajectories extracted from camera recordings, however, have a small positioning error. Therefore, we used a hybrid tracking algorithm [31] to combine both data sets. In particular, that means that the position of the biomechanical model was shifted and rotated to match the head position and orientation of the camera trajectories.

On all days, we equipped 20 people with an Xsens MVN Link Motion Capturing system. On experiment days 1-3, these persons were part of the red group (Fig. 2), and on day 4 they took part on experiment site D, namely the bottleneck experiment. 3D motion capturing data were therefore recorded in runs listed in Tab. 11.

4.7. Mood-Buttons

In order to be able to classify the mood of the test subjects over the course of the day in the individual experiments, we installed simple mood button terminals (Happy-or-not [32]). The terminals consist of four smiley-faced buttons with a sign saying “how did you feel in the last run?” (Fig. 18) that participants were invited to press after every run. The system saved a time stamp for each pressed button.
The terminals were attached to man-rails and placed so that participants passed them after each run. Care was taken to ensure that the grids were positioned in such a way that the walking path was affected as little as possible and no backlog was created. Participants were actively asked to press a button after each run. In the Train Platform Experiments,

Table 11 Experiment runs in which participants took part, that were equipped with MoCap suits. Experimental configurations of runs are shown in the appendix.

day	Train Platform Experiment	Crowd Management Experiment	Boarding and Alighting Experiment	Bottleneck Experiment
1	1B110, 1B120, 1B130	1C030, 1C040, SOLO_REF11, 1C100, 1C110	D1_3_* , D1_6_*	–
2	2B110, 2B120, 2B130, 2B131	2C040, 2C050, SOLO_REF21, 2C110, 2C120, 2C130	D2_3_* , D2_6_*	–
3	3B110, 3B120, 3B130, 3B131	3C030, 3C040, SOLO_REF31, 3C090, 3C100, 3C101	D3_3_* , D3_6_*	–
4	–	–	–	4D000 – 4D340

Figure 18 Terminal showing Mood Buttons placed in some experiments to compare the well-being of the participants between the experimental runs. The question on top translates as “How did you feel in the last run?” from German.

the terminal was placed in the corridor leading participants from the area where they filled out questionnaires back to the waiting area in front of the experiment. In the Crowd Management Experiments, the terminal was positioned 15 m after passing the entry gate on the way back to the line-up area. In the Boarding and Alighting Experiments, the terminal was placed next to the waiting area (behind the train car for runs marked as ‘reversedirection’). In the Bottleneck Experiments, one terminal was placed at each side

of the bottleneck. Participants passed the terminal on their way back to the line-up area, regardless of whether they turned right or left after passing the finish line. No mood buttons were placed in the Tiny House, Oval or Personal Space Experiments.

5. Summary and Discussion

This paper presents pedestrian experiments conducted as part of the CroMa project aimed at increasing the robustness and efficiency of transport infrastructure. Even though the planning and execution of large-scale experiments requires far-reaching planning and organizational steps that go far beyond the scientific content, experiments under laboratory conditions offer the opportunity to control factors and can therefore be worth the effort involved.
This publication provides an overview of the individual experiments carried out as well as descriptions of sensor techniques applied, as the contents and goals of the experiments were planned and evaluated by different disciplines and had to be coordinated and combined with each other. Furthermore, it presents the context in which the individual experimental runs and experimental sites were intertwined. The results of the scientific analyses will be published in subsequent content papers.

Even though the experiments took place during a global pandemic, the questionnaire results as well as the evaluation of well-being during the experiments (mean value of mood buttons over all days) show that the overall concept of communication, hygiene and safety measures as well as the slow acclimatization to density (queuing, measurement course, waiting area, icebreaker) led to the participants feeling confident. As a result, they felt good and the thought of a potential infection seemed to have no meaningful influence on their actions. This is consistent with the impressions of the organizers regarding the mood of the subjects during the experiments.

For each of the conducted experiments, the goal of the study is described along with which parameters were varied, how participants were approached and which dimensions the experimental areas and geometries had. The description is supplemented by impressions of the experiments given through sketches and snapshots.
In the chapters about the sensors, the technical specifications are listed. Furthermore, it is documented how the sensors were synchronized with each other, how many of the sensors were used, with which settings they were operated and which basic processing steps were carried out if necessary. For each sensor there is an overview of the runs in which the sensors were used. For each experiment, a link to the data archive is given under which the respective complete data will be made freely available after publication of the respective content paper.

Acknowledgements We thank all staff members of Forschungszentrum Jülich, University of Wuppertal, Ruhr-Universität Bochum and D.LIVE for their valuable help during the experimental

days, without whom it would not have been possible to fulfil all tasks and ensure a smooth process on all days.

Ethical Review The application of ethical approval for the experiments “Crowd Management”, “Single-File”, “Personal-Space”, “Train Platform” and “Boarding and Alighting” were submitted by A. Sieben to the German Psychological Society (DGPs, the Society) and approved in December 2019 (file reference SiebenAnna2019-10-22VA). The “Bottleneck” experiment was submitted to the ethical review committee of the University of Wuppertal (German: Bergische Universität Wuppertal) by A. Seyfried and was approved in January 2020 (file reference MS/BBL 191213 Seyfried).

Funding The experiments were financially supported by the German Federal Ministry of Education and Research (BMBF) within the project CroMa (Crowd Management in Verkehrsinfrastrukturen / Crowd Management in transport infrastructures) under grant number 13N14530 to 13N14533 and by the European Union’s Horizon 2020 research and innovation program within the project CrowdDNA under grant agreement number 899739.

Author Contributions Juliane Adrian: technical responsibility 3D-motion capturing system, scientific content planning bottleneck experiment, software combination of trajectories, data curation (3D-motion capturing system, manual correction trajectories, combination of trajectories), writing (original draft chapter 4.6) / Maik Boltes: supervision, technical planning camera, data curation camera, responsible for daily briefing and adherence of safety measures, scientific content planning bottleneck experiment, writing (original draft chapter 1, review and editing) / Ann Katrin Boomers: coordinating and technical realization of experiments, technical planning camera, data curation (camera, processing to trajectories, manual correction trajectories, combination of trajectories), scientific content planning bottleneck experiment, writing (original draft chapter 2 - 4.2, 4.7, 5) / Mira Beermann: technical responsibility EDA/HRV sensors, data curation EDA/HRV, scientific content planning tiny box experiment, boarding-alighting experiment and single-file experiment, writing (original draft chapter 4.3 + 4.4) / Mohcine Chraibi: scientific content planning single-file / Sina Feldmann: technical responsibility pressure sensors, data curation (pressure sensors, manual correction trajectories), scientific content planning bottleneck, writing (original draft chapter 4.5) / Frank Fiedrich: scientific content planning visual inspection of density / Niklas Frings: technical support data collection visual inspection of density / Arne Graf: technical support construction and testing camera system / Alica Kandler: technical responsibility camera and time synchronization, data curation (camera, processing to trajectories), writing (original draft chapter 4.1 + 4.2) / Deniz Kilic: software recruiting process / Krisztina Konya: scientific content planning train platform experiment, data curation (manual correction trajectories), writing (review and editing) / Mira Küpper: scientific content planning train platform experiment and boarding-alighting experiment, data curation (manual correction trajectories), writing (review and editing) / Andreas Lotter: scientific content planning visual inspection of density / Helena Lügering: scientific content planning bottleneck experiment, data curation (manual correction trajectories) / Francesca Müller: scientific content planning visual inspection of density / Sarah Paetzke: scientific content planning single-file experiment, data curation (manual correction trajectories) / Anna-Katharina Raytarowski: testing pressure sensor system / Olga Sablik: scientific content planning crowd management experiment, data curation (manual correction trajectories), writing (review and editing) / Tobias Schrödter: technical support construction / Armin Seyfried: supervision, scientific content

planning all experiments, writing (review and editing) / Anna Sieben: supervision, scientific content planning all experiments, writing (review and editing) / Ezel Üsten: scientific content planning crowd management experiment (interruption), data curation (HRV sensors, manual correction trajectories) /

References

[1] CroMa Project: Website CroMa Project. URL https://www.croma-projekt.de/de

[2] CrowdDNA Project: Website CrowdDNA Project. URL https://crowddna.eu/

[3] Forschungszentrum Jülich: Pedestrian dynamics data archive. Pedestrian Dynamics Data Archive (2022). doi:10.34735/ped.da

[4] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Experiment outline and participant statistics for experiments within the CroMa project. Pedestrian Dynamics Data Archive (2022). doi:10.34735/PED.2021.2

[5] Garrido-Jurado, S., Muñoz-Salinas, R., Madrid-Cuevas, F., Medina-Carnicer, R.: Generation of fiducial marker dictionaries using Mixed Integer Linear Programming. Pattern Recognition **51**, 481–491 (2016). doi:10.1016/j.patcog.2015.09.023

[6] Robert Koch Institut: 7-day incidence Germany (2021). URL https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Situationsberichte/COVID-19-Trends/COVID-19-Trends.html?__blob=publicationFile#/home

[7] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Train Platform Experiments. Pedestrian Dynamics Data Archive (2022). URL http://ped.fz-juelich.de/da/2021train_platform

[8] Düsseldorf, F.: Merkblatt der feuerwehr düsseldorf - einschätzen von personendichten bei veranstaltungen im freien (2020). URL https://www.duesseldorf.de/fileadmin/Amt37/feuerwehr/dokudb/37_233/200120_Merkblatt_Feuerwehr_Duesseldorf_Einschaetzen_von_Personendichten_bei_Veranstaltungen.pdf

[9] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Crowd Management Experiment. Pedestrian Dynamics Data Archive (2022). URL http://ped.fz-juelich.de/da/2021crowd_management

[10] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Oval Experiment: Single File Motion. Pedestrian Dynamics Data Archive (2022). URL http://ped.fz-juelich.de/da/2021oval

[11] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Personal Space Experiment. Pedestrian Dynamics Data Archive (2022). URL http://ped.fz-juelich.de/da/2021personal_space

[12] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Boarding and Alighting Experiment. Pedestrian Dynamics Data Archive (2022). URL http://ped.fz-juelich.de/da/2021boarding_alighting

[13] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Tiny Box Experiment. Pedestrian Dynamics Data Archive (2022). URL https://ped.fz-juelich.de/da/doku.php?id=tiny_box

[14] Forschungszentrum Jülich, Bergische Universität Wuppertal, Ruhr-Universität Bochum: Bottleneck Experiment. Pedestrian Dynamics Data Archive (2022). URL http://ped.fz-juelich.de/da/2021bottleneck

[15] Tentacle Sync GmbH: Tentacle sync E - operating manual v1.0. URL https://tentaclesync.com/files/documents/Tentacle_Sync_E_Operating_Manual_ENG.pdf

[16] Rosendahl Studiotechnik GmbH: Instruction Manual Rosendahl nanosyncs HD. URL https://rosendahl-studiotechnik.com/nanosyncs_hd_20.pdf

[17] Boltes, M., Adrian, J., Boomers, A.K., Brualla, R.M., Graf, A., Häger, P., Hillebrand, D., Kilic, D., Lieberenz, P., Salden, D., Schrödter, T.: PeTrack CroMa (2022-03-01). doi:10.5281/zenodo.6320753

[18] Boltes, M., Seyfried, A.: Collecting pedestrian trajectories. Neurocomputing, Special Issue on Behaviours in Video **100**, 127–133 (2013). doi:10.1016/j.neucom.2012.01.036

[19] Ester, M., Kriegel, H.P., Sander, J., Xu, X.: A density-based algorithm for discovering clusters in large spatial databases with noise. In: Proceedings of the Second International Conference on Knowledge Discovery and Data Mining, KDD'96, p. 226–231. AAAI Press (1996)

[20] Schubert, E., Sander, J., Ester, M., Kriegel, H.P., Xu, X.: DBSCAN revisited, revisited: Why and how you should (still) use DBSCAN. ACM Transactions on Database Systems (TODS) **42**(3), 1–21 (2017)

[21] Lucas, B.D., Kanade, T.: An iterative image registration technique with an application to stereo vision. In: Proceedings of the 7th International Joint Conference on Artificial Intelligence - Volume 2, IJCAI'81, pp. 674–679. Morgan Kaufmann Publishers Inc. (1981)

[22] Lucas, B.D.: Generalized image matching by the method of differences (1984)

[23] Boltes, M., Seyfried, A., Steffen, B., Schadschneider, A.: Automatic extraction of pedestrian trajectories from video recordings. In: Klingsch, W.W.F., Rogsch, C., Schadschneider, A., Schreckenberg, M. (eds.) Pedestrian and Evacuation Dynamics 2008, pp. 43–54. Springer Berlin Heidelberg (2010). doi:10.1007/978-3-642-04504-2_3

[24] Movisens EdaMove4 UserManual: User Manual EdaMove4. URL https://docs.movisens.com/Sensors/EdaMove4/#welcome

[25] Movisens EcgMove4 UserManual: EcgMove 4 — movisens Docs. URL https://docs.movisens.com/Sensors/EcgMove4/

[26] Tekscan PMS5400N: Datasheet: Tekscan Pressure Mapping Sensor 5400N. URL https://www.tekscan.com/sites/default/files/resources/IDL-Pressure-Mapping-Sensor-5400N-Datasheet_0.pdf

[27] Xsensor LX210:50.50.05: Datasheet: Xsensor SENSORS LX210:50.50.05. URL https://www.xsensor.de/wp-content/uploads/2015/11/LX210_50_50_05-2500-Sensoren-508mm-Aufl%C3%B6sung-Gr%C3%B6sse-25x25cm-Messbereich-014-11Ncm2-Anwendung-Sitze_Rollst%C3%BChle.pdf

[28] Xsensor LX210:25.50.05: Datasheet: Xsensor SENSORS LX210:25.50.05. URL https://www.xsensor.de/wp-content/uploads/2016/09/Katalog-Industrie.pdf

[29] Schepers, M., Giuberti, M., Bellusci, G.: Xsens MVN: Consistent Tracking of Human Motion Using Inertial Sensing (2018). doi:10.13140/RG.2.2.22099.07205

[30] Xsens: MVN User Manual, Revision Z, 20 04 2022. URL https://www.xsens.com/hubfs/MVN_User_Manual.pdf

[31] Boltes, M., Adrian, J., Raytarowski, A.K.: A Hybrid Tracking System of Full-Body Motion Inside Crowds. Sensors **21**(6), 2108 (2021-03-17). doi:10.3390/s21062108

[32] HappyOrNot: Smiley terminal – happyornot – feedbacksystem. URL https://www.happy-or-not.com/de/losung/smiley-terminal/

A. Appendices

A.1. Test Person Sample: Statistics per Day

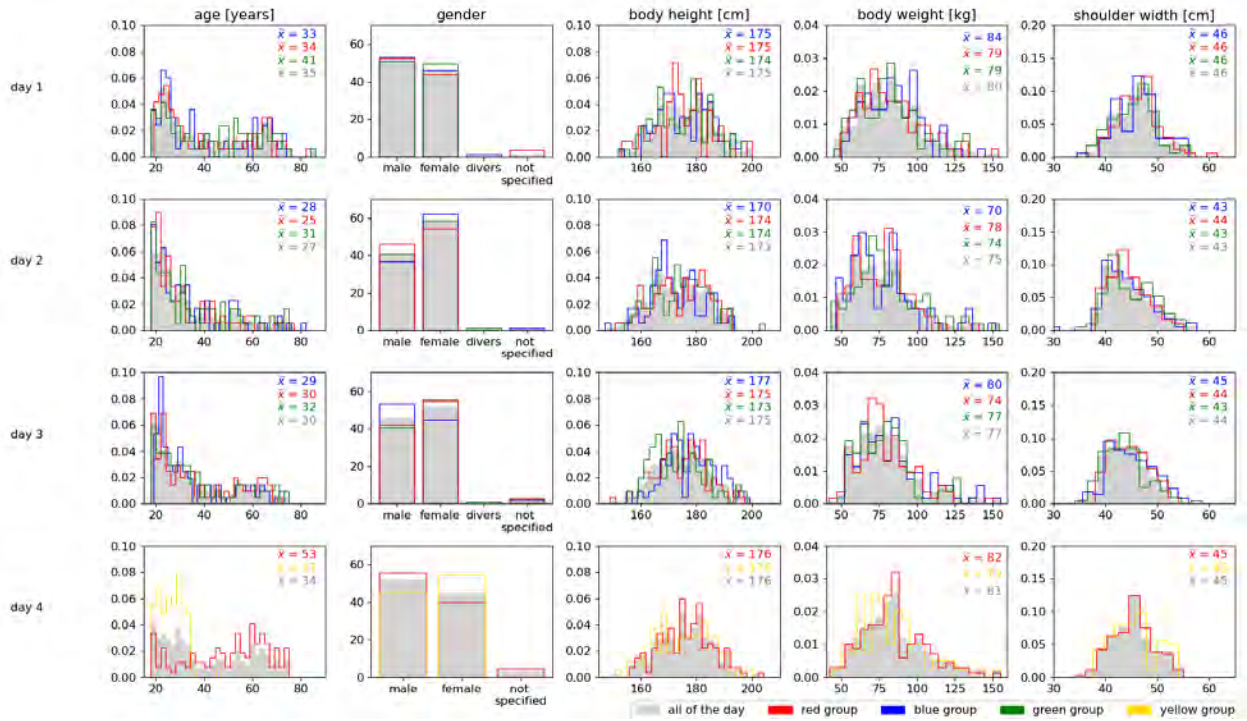


Figure 19 Panel of different histograms showing demographic data of the participants for each day. Row one refers to data of participants on day 1, row 2 to day 2, row 3 to day 3 and row 4 to day 4. Column 1 shows age, column 2 gender, column 3 body height, column 4 body weight and column 5 shoulder width. Data shown in grey includes data from all participants of the respective day, data in green data of participants belonging to the green experimental group and data in red, blue and yellow to data of participants belonging to experimental group of the respective color accordingly. Respective Medians are shown in the same color as the data.

A.2. Covid-Related Questionnaire Data

Table 12 Descriptive statistics of Covid-related questionnaire data.

	N	Min.	Max.	Mean value M	Standard deviation
I found it...					
...uncomfortable to be in a crowd during the experiments.	992	1	7	2,61	1,748
...uncomfortable because of crowding.	937	1	7	3,37	2,148
...uncomfortable because of Covid infection concerns.	940	1	7	2,45	1,879
...uncomfortable because of infection concerns with other illness.	940	1	7	2,19	1,693
...uncomfortable because of unclear instructions.	938	1	7	2,34	1,679
...uncomfortable because of physical exertion.	946	1	7	3,49	2,068
...uncomfortable because of stress caused by the experimenter.	940	1	7	1,80	1,378
...uncomfortable because of being around many people.	941	1	7	2,92	1,975
I have often thought about Covid.	999	1	7	2,20	1,690
I have often worried about catching Covid.	997	1	7	1,98	1,559
I would have behaved differently before the pandemic.	996	1	7	2,69	1,959
I have also been in crowds elsewhere since the pandemic started.	994	1	7	4,02	2,361

A.3. Experimental Configurations Train Platform Experiments

Table 13 Table showing experimental runs performed within the scope of the Train Platform Experiments (Sec. 3.1). The names of the experiments are given together with the colour of the group that participated in the respective runs as well as varied parameters.

		run name (short)	run name (descriptive)	no. of participants	setup 1: building constructions [none (-); wall; house; marked areas]	setup 2: stairs present at beginning of run [yes; no]	inflow participants	waiting time on platform [mm:ss]	induced anonymity [none (-); anonym; group identity]	special announcements [none (-); no speaking; speaking allowed]	questionnaire [yes; no]
day 1		1B010	ano_no-speak_small	10	-	yes	all at once	05:00	anonym	no speaking	yes
		1B020	ano_speak_small	10	-	yes	all at once	05:00	anonym	speaking allowed	yes
		1B030	ano_no-speak_large	50	-	yes	all at once	05:00	anonym	no speaking	yes
		1B040	ano_speak_large	50	-	yes	all at once	05:00	anonym	speaking allowed	yes
		1B050	blank_Aa	40	-	no	every 2-3 sec	02:00	-	-	-
		1B060	blank_Ab	40	-	no	every 2-3 sec	04:00	-	-	-
		1B070	blank_Ba	85	-	no	every 2-3 sec	02:00	-	-	yes
		1B080	wall_Aa	40	wall	no	every 2-3 sec	02:00	-	-	yes
		1B090	wall_Ab	35	wall	no	every 2-3 sec	04:00	-	-	yes
		1B100	wall_Ba	83	wall	no	every 2-3 sec	02:00	-	-	-
		1B110	house_Aa	40	house	no	every 2-3 sec	02:00	-	-	yes
		1B120	house_Ab	38	house	no	every 2-3 sec	04:00	-	-	yes
		1B130	house_Ba	82	house	no	every 2-3 sec	02:00	-	-	-
		1B140	SI_no-speak_small	10	-	yes	all at once	05:00	group identity	no speaking	yes
		1B150	SI_speak_small	10	-	yes	all at once	05:00	group identity	speaking allowed	yes
		1B160	SI_no-speak_large	50	-	yes	all at once	05:00	group identity	no speaking	yes
		1B170	SI_speak_large	50	-	yes	all at once	05:00	group identity	speaking allowed	yes
		1B180	blank_Aa_inflow10	40	-	no	groups of 10	02:00	-	-	-
		1B190	blank_Ab_inflow10	40	-	no	groups of 10	04:00	-	-	-
		1B200	blank_Ba_inflow10	82	-	no	groups of 10	02:00	-	-	yes
day 2		2B010	ano_no-speak_small	10	-	yes	all at once	05:00	anonym	no speaking	yes
		2B020	ano_speak_small	10	-	yes	all at once	05:00	anonym	speaking allowed	yes
		2B030	ano_no-speak_large	50	-	yes	all at once	05:00	anonym	no speaking	yes
		2B040	ano_speak_large	50	-	yes	all at once	05:00	anonym	speaking allowed	yes
		2B050	blank_Aa	40	-	no	every 2-3 sec	02:00	-	-	-
		2B060	blank_Ab	40	-	no	every 2-3 sec	04:00	-	-	-
		2B070	blank_Ba	85	-	no	every 2-3 sec	02:00	-	-	yes
		2B071	blank_C	145	-	no	every 2-3 sec	02:00	-	-	-
		2B080	wall_Aa	40	wall	no	every 2-3 sec	02:00	-	-	yes
		2B090	wall_Ab	40	wall	no	every 2-3 sec	04:00	-	-	yes
		2B100	wall_Ba	87	wall	no	every 2-3 sec	02:00	-	-	-
		2B110	house_Aa	40	house	no	every 2-3 sec	02:00	-	-	yes
		2B120	house_Ab	40	house	no	every 2-3 sec	04:00	-	-	yes
		2B130	house_Ba	87	house	no	every 2-3 sec	02:00	-	-	-
		2B131	house_C	147	house	no	every 2-3 sec	02:00	-	-	-
		2B140	SI_no-speak_small	10	-	yes	all at once	05:00	group identity	no speaking	yes
		2B150	SI_speak_small	10	-	yes	all at once	05:00	group identity	speaking allowed	yes
		2B160	SI_no-speak_large	50	-	yes	all at once	05:00	group identity	no speaking	yes
		2B170	SI_speak_large	50	-	yes	all at once	05:00	group identity	speaking allowed	yes
		2B180	blank_Aa_inflow10	50	-	no	groups of 10	02:00	-	-	-
		2B190	blank_Ab_inflow10	40	-	no	groups of 10	04:00	-	-	-
		2B200	blank_Ba_inflow10	89	-	no	groups of 10	02:00	-	-	yes

Table 13 continued from previous page

	run name (short)	run name (descriptive)	no. of participants	setup 1: building constructions [none (-); wall; house; marked areas]	setup 2: stairs present at beginning of run [yes; no]	inflow participants	waiting time on platform [mm:ss]	induced anonymity [none (-); anonym; group identity]	special announcements [none (-); no speaking; speaking allowed]	questionnaire [yes; no]
day 3	3B010	ano_no-speak_small	10	-	yes	all at once	05:00	anonym	no speaking	yes
	3B020	ano_speak_small	10	-	yes	all at once	05:00	anonym	speaking allowed	yes
	3B030	ano_no-speak_large	50	-	yes	all at once	05:00	anonym	no speaking	yes
	3B040	ano_speak_large	50	-	yes	all at once	05:00	anonym	speaking allowed	yes
	3B050	blank_Aa	40	-	no	every 2-3 sec	02:00	-	-	-
	3B060	blank_Ab	40	-	no	every 2-3 sec	04:00	-	-	-
	3B070	blank_Ba	102	-	no	groups of 20 every 2-3 sec	02:00	-	-	yes
	3B071	blank_C	180	-	no	every 2-3 sec	02:00	-	'red-group-train' first, 'green-group-train' second	-
	3B080	wall_Aa	40	wall	no	every 2-3 sec	02:00	-	-	-
	3B090	wall_Ab	40	wall	no	every 2-3 sec	04:00	-	-	-
	3B100	wall_Ba	104	wall	no	groups of 20 every 2-3 sec	02:00	-	-	yes
	3B110	house_Aa	40	house	no	every 2-3 sec	02:00	-	-	-
	3B120	house_Ab	40	house	no	every 2-3 sec	04:00	-	-	-
	3B130	house_Ba	101	house	no	every 2-3 sec	02:00	-	-	-
	3B131	house_C	180	house	no	groups of 20 every 2-3 sec	02:00	-	'blue-group-train' first, 'red-group-train' second	yes
	3B140	SI_no-speak_small	10	-	yes	all at once	05:00	group identity	no speaking	yes
	3B150	SI_speak_small	10	-	yes	all at once	05:00	group identity	speaking allowed	yes
	3B160	SI_no-speak_large	50	-	yes	all at once	05:00	group identity	no speaking	yes
	3B170	SI_speak_large	50	-	yes	all at once	05:00	group identity	speaking allowed	yes
	3B180	blank_Aa_inflow10	60	-	no	groups of 10	02:00	-	-	-
	3B190	blank_Ab_inflow10	40	-	no	groups of 10	04:00	-	Track change, right train first	-
	3B200	blank_Ba_inflow10	107	-	no	groups of 10	02:00	-	-	yes

A.4. Experimental Configurations Crowd Management Experiments

Table 14 Table showing experimental runs performed within the scope of the Crowd Management Experiments (Sec. 3.2). The names of the experiments are given together with the colour of the group that participated in the respective runs as well as varied parameters.

		run name (short)	run name (descriptive)	no. of participants	Setup 1: structure grid [straight; small bend; 90° bend]	no. of open gateways [1; 3]	Setup 2: signposting [none (-); lines; signs]	motivation [low; high]	norm specification [none (-); 70%;85% ; 95%; 100%]	special announcement	questionnaire [yes; no]
day 1		1C010	entry3_ lines_ nM	tba	straight	3	lines	low	-		yes
		1C020	entry3_lines_hM		straight	3	lines	high	-		yes
		1C030	entry3_signs_nM		straight	3	signs	low	-		yes
		1C040	entry1_norm95_nM		straight	1	signs	low	95%		yes
		SOLO_REF11	SOLO_REF		straight						no
		1C050	entry3_blank_nM		straight	3	-	low	-		yes
		1C060	entry1_blank_nM		straight	1	-	low	-		yes
		1C070	entry1_norm85_nM		straight	1	-	low	85%		yes
		1C080	entry3_bendSmall_nM		small bend	3	-	low	-		yes
		1C090	entry3_bendSmall_hM		small bend	3	-	high	-		yes
		1C100	entry3_straight_nM		straight	3	-	low	-		yes
		1C110	entry3_straight_hM		straight	3	-	high	-		yes
		1C120	entry3_signs_nM		straight	3	signs	low	-		yes
		1C130	entry3_signs_hM		straight	3	signs	high	-		yes
		SOLO_REF12	SOLO_REF		straight						no
day 2		2C010	entry3_blank_nM		straight	3	-	low	-		yes
		2C020	entry1_blank_nM		straight	1	-	low	-		yes
		2C030	entry1_norm85_nM		straight	1	-	low	85%		yes
		2C040	entry3_bendSmall_nM		small bend	3	-	low	-		yes
		2C050	entry3_bendSmall_hM		small bend	3	-	high	-		yes
		SOLO_REF21	SOLO_REF		small bend						no
		2C060	entry3_blank_hM		straight	3	-	high	-		yes
		2C070	entry1_blank_hM		straight	1	-	high	-		yes
		2C080	entry1_norm85_hM		straight	1	-	high	85%		yes
		2C090	entry3_straight_nM		straight	3	-	low	-		yes
		2C100	entry3_straight_hM		straight	3	-	high	-		yes
		2C110	entry3_signs_hM		straight	3	signs	high	-		yes
		2C120	entry1_blank_hM		straight	1	-	high	-		yes
		2C130	entry1_norm70_nM		straight	1	-	low	70%		yes
		2C140	entry3_blank_hM		straight	?	-	high	-		yes
		2C150	entry1_norm70_nM		straight	?	-	low	70%		yes
		SOLO_REF22	SOLO_REF		straight						no

Table 14 continued from previous page

		run name (short)	run name (descriptive)	no. of participants	Setup 1: structure grid [straight; small bend; 90° bend]	no. of open gateways [1; 3]	Setup 2: signposting [none (-); lines; signs]	motivation [low; high]	norm specification [none (-); 70%;85% ; 95%; 100%]	special announcement	questionnaire [yes; no]
		3C010	entry3_bend90_lines_nM		90° bend	3	lines	low	-		yes
		3C020	entry3_bend90_lines_hM		90° bend	3	lines	low	-		yes
		3C021	entry3_bend90_lines_hM		90° bend	3	lines	high	-		no
		3C030	entry3_bend90_nM		90° bend	3	-	low	-		yes
		3C040	entry3_bend90_hM		90° bend	3	-	high	-		yes
		SOLO_REF31	SOLO_REF		90° bend						no
		3C050	entry3_bend90_nM		90° bend	3	-	low	-		yes
		3C060	entry3_bend90_hM		90° bend	3	-	low	-		yes
		3C061	entry3_bend90_hM		90° bend	3	-	high	-		no
day 3		3C070	entry1_bend90_nI_nM		90° bend	1	-	low	-		yes
		3C080	entry1_bend90_wI_nM		90° bend	1	-	low	-		yes
		3C081	entry1_bend90_slow_hM		90° bend	1	-	high	-		no
		3C090	entry1_bend90_nI_hM		90° bend	1	-	low	-	nI, inflow side	yes
		3C100	entry1_bend90_wI_hM		90° bend	1	-	low	-	wI, side	yes
		3C101	entry1_bend90_slow_nM		90° bend	1	-	high	-	slow, inflow side	no
		3C110	entry1_bend90_nI_nM		90° bend	1	-	low	-	nI, inflow	yes
		3C120	entry1_bend90_wI_hM		90° bend	1	-	high	-	wI, straight inflow	yes
		3C121	entry3_bend90_slow_hM		90° bend	1	-	high	-	slow, straight inflow	no
		SOLO_REF_32	SOLO_REF		90° bend						no

A.5. Experimental Configurations Oval Experiments

Table 15 Table showing experimental runs performed within the scope of the Oval Experiments (Sec. 3.3). The names of the experiments are given as well as varied parameters.

Run no.	No. of peds oval 1 (left in camera)	No. of peds oval 2 (right in camera)	run name oval 1	run name oval 2
female/male				
1	40	35	single_file_gender_female_1_1	single_file_gender_male_2_1
2	36	31	single_file_gender_female_1_2	single_file_gender_male_2_2
3	32	27	single_file_gender_female_1_3	single_file_gender_male_2_3
4	24	19	single_file_gender_female_1_4	single_file_gender_male_2_4
5	20	15	single_file_gender_female_1_5	single_file_gender_male_2_5
6	20	20	single_file_gender_female_1_6	single_file_gender_male_2_6
7	16	16	single_file_gender_female_1_7	single_file_gender_male_2_7
8	8	8	single_file_gender_female_1_8	single_file_gender_male_2_8
9	4	8	single_file_gender_female_1_9	single_file_gender_male_2_9
10	0	4		single_file_gender_male_2_10
gender alternating				
1	4	4	single_file_gender_1_1	single_file_gender_2_1
2	4	4	single_file_gender_1_2	single_file_gender_2_2
3	4	4	single_file_gender_1_3	single_file_gender_2_3
4	4	8	single_file_gender_1_4	single_file_gender_2_4
5	4	4	single_file_gender_1_5	single_file_gender_2_5
6	8	4	single_file_gender_1_6	single_file_gender_2_6
7	8	8	single_file_gender_1_7	single_file_gender_2_7
8	16	16	single_file_gender_1_8	single_file_gender_2_8
9	20	20	single_file_gender_1_9	single_file_gender_2_9
10	24	0	single_file_gender_1_10	
11	24	16	single_file_gender_1_11	single_file_gender_2_10
12	32	8	single_file_gender_1_12	single_file_gender_2_11
13	36	0	single_file_gender_1_13	
14	40	0	single_file_gender_1_14	
gender random order				
1	4	4	single_file_gender_random_1_1	single_file_gender_random_2_1
2	4	4	single_file_gender_random_1_2	single_file_gender_random_2_2
3	4	4	single_file_gender_random_1_3	single_file_gender_random_2_3
4	4	8	single_file_gender_random_1_4	single_file_gender_random_2_4
5	4	4	single_file_gender_random_1_5	single_file_gender_random_2_5
6	8	4	single_file_gender_random_1_6	single_file_gender_random_2_6
7	8	8	single_file_gender_random_1_7	single_file_gender_random_2_7
8	16	16	single_file_gender_random_1_8	single_file_gender_random_2_8
9	20	20	single_file_gender_random_1_9	single_file_gender_random_2_9
10	24	0	single_file_gender_random_1_10	
11	24	16	single_file_gender_random_1_11	single_file_gender_random_2_10
12	32	8	single_file_gender_random_1_12	single_file_gender_random_2_11
13	36	0	single_file_gender_random_1_13	
14	40	0	single_file_gender_random_1_14	

A.6. Experimental Configurations Personal-Space Experiments

Table 16 Table showing experimental runs performed within the scope of the Personal Space Experiments (Sec. 3.4). The names of the experiments are given as well as the IDs of the "standing" participants.

run name	no. of standing people	no. of walking people	Code ID of standing people
4C1010	7	10	770, 710, 775, 785, 884, 897, 957
4C1020	7	10	731, 735, 784, 793, 859, 959, 960
4C1030	7	10	670, 713, 714, 718, 837, 945, 963
4C1040	7	10	645, 657, 669, 901, 902, 903, 953
4C2010	7	10	673, 711, 738, 783, 801, 857, 942
4C2020	7	10	666, 766, 789, 835, 843, 880, 946
4C2030	7	10	649, 708, 761, 771, 773, 889, 900
4C2040	7	10	737, 844, 847, 850, 854, 940, 941

A.7. Experimental Configurations Boarding And Alighting Experiments

Table 17 Table showing experimental runs performed within the scope of the Boarding and Alighting Experiments (Sec. 3.5). The Names of the experiments are given together with the colour of the group that participated in the respective runs as well as varied parameters.

		run name	N_total [number of participants]	N_in [number of participants boarding]	N_train [number of participants staying in train]	N_out [number of participants alighting]	luggage_in [none, backpack, trolley, buggy, mix]	luggage_out [none, backpack, trolley, buggy, mix]	norm [none, 70, 80, 100]	cooperation [none, work together]	line-up [none, throng, corridor, 45°]	groups [none, pairs, groups of 3, groups of 5]	motivation [none, hurry, pushing, 50%/100% distracted]
		D1_1_d_4_1	30	10,10,10	0,10,20	0,0,10	–	–	–	–	–	–	–
		D1_1_d_4_2	50	10,10,20	10,20,20	0,10,10	–	–	–	–	–	–	–
		D1_1_d_4_3	60	10, 20, 10	20,20,30	10,10,10	–	–	–	–	–	–	–
		D1_1_d_4_4	50	20,10,10	20,30,30	10,10,20	–	–	–	–	–	–	–
		D1_1_d_4_5	50	10,10,20	30,30,20	10,20,10	–	–	–	–	–	–	–
		D1_1_d_4_6	40	10,20,10	30,20,30	20,10,10	–	–	–	–	–	–	–
		D1_1_d_4_7	40	20,10,20	20,30,30	10,10,20	–	–	–	–	–	–	–
		D1_1_d_4_8	60	10,20,10	30,30,30	10,20,10	–	–	–	–	–	–	–
		D1_1_d_4_9	50	20,10,20	30,30,30	20,10,20	–	–	–	–	–	–	–
		D1_1_d_4_10	60	10,20,0	30,30,30	10,20,10	–	–	–	–	–	–	–
		D1_1_d_4_11	30	20,0,0	30,30,0	20,10,20	–	–	–	–	–	–	–
		D1_1_d_4_12K	20	20,0,0	0,20,0	0,0,20	–	–	–	–	–	–	–
		D1_1_d_4_13K	40	40,0,0	0,40,0	0,0,40	–	–	–	–	–	–	–
		D1_2_20-20_10-00_1	40	20	0	20	10 backpacks	0 backpacks	–	–	–	–	–
		D1_2_10-20_05-10_1	30	10	0	20	5 backpacks	10 backpacks	–	–	–	–	–
		D1_2_20-10_10-05	30	20	0	10	10 backpacks	5 backpacks	–	–	–	–	–
		D1_2_20-20_05-10_1	40	20	0	20	5 backpacks	10 backpacks	–	–	–	–	–
		D1_2_10-20_10-05	30	10	0	20	10 backpacks	5 backpacks	–	–	–	–	–
		D1_2_20-20_00-05	40	20	0	20	–	5 backpacks	–	–	–	–	–
		D1_2_10-20_10-00	30	10	0	20	10 backpacks	–	–	–	–	–	–
		D1_2_20-10_00-10	30	20	0	10	–	10 backpacks	–	–	–	–	–
		D1_2_20-20_10-00_2	40	20	0	20	10 backpacks	–	–	–	–	–	–
		D1_2_10-20_00-10_1	30	10	0	20	–	10 backpacks	–	–	–	–	–
		D1_2_20-10_10-00	30	20	0	10	10 backpacks	–	–	–	–	–	–
		D1_2_20-20_05-10_2	40	20	0	20	5 backpacks	10 backpacks	–	–	–	–	–
		D1_2_20-20_10-05	40	20	0	20	10 backpacks	5 backpacks	–	–	–	–	–
		D1_2_10-20_00-10_2	30	10	0	20	–	10 backpacks	–	–	–	–	–
		D1_3_20-00_blank_1	20	20	0	0	–	–	–	–	–	–	–
		D1_3_20-20_blank_1	40	20	0	20	–	–	–	–	–	–	–
		D1_3_10-20_blank_1	30	10	0	20	–	–	–	–	–	–	–
		D1_3_00-10_blank	10	0	0	10	–	–	–	–	–	–	–
		D1_3_20-00_blank_2	20	20	0	0	–	–	–	–	–	–	–
		D1_3_20-20_blank_2	40	20	0	20	–	–	–	–	–	–	–
		D1_3_10-20_blank_2	30	10	0	20	–	–	–	–	–	–	–
		D1_3_20-10_blank	30	20	0	10	–	–	–	–	–	–	–
		D1_3_00-20_blank	20	0	0	20	–	–	–	–	–	–	–
		D1_3_20-20_norm100_1	40	20	0	20	–	–	100	–	–	–	–
		D1_3_20-20_norm100_2	40	20	0	20	–	–	100	–	–	–	–
		D1_3_20-20_norm80_1	40	20	0	20	–	–	80	–	–	–	–
		D1_3_20-20_norm80_2	40	20	0	20	–	–	80	–	–	–	–
		D1_3_20-20_norm70_1	40	20	0	20	–	–	70	–	–	–	–
day 1		D1_3_20-20_norm70_2	40	20	0	20	–	–	70	–	–	–	–
		D1_4_30-30_distraction	60	30	0	30	–	–	–	–	–	–	100% distracted
		D1_4_20-10_K-03-00	30	20	0	10	3 trolleys	–	–	–	–	–	–
		D1_4_20-20_K-02-03	40	20	0	20	2 trolleys	3 trolleys	–	–	–	–	–
		D1_4_10-20_K-03-02	30	10	0	20	3 trolleys	2 trolleys	–	–	–	–	–

Table 17 continued from previous page

run name	N_total [number of participants]	N_in [number of participants boarding]	N_train [number of participants staying in train]	N_out [number of participants alighting]	luggage_in [none, backpack, trolley, buggy, mix]	luggage_out [none, backpack, trolley, buggy, mix]	norm [none, 70, 80, 100]	cooperation [none, work together]	line-up [none, throng, corridor, 45°]	groups [none, pairs, groups of 3, groups of 5]	motivation [none, hurry, pushing, 50%/100% distracted]
D1_4_20-10_K-02-03	30	20	0	10	2 trolleys	3 trolleys	–	–	–	–	–
D1_4_30-30_cooperation	60	30	0	30	–	–	–	work together	–	–	–
D1_4_30-30_norm70_1	60	30	0	30	–	–	70	–	–	–	–
D1_4_30-30_norm70_2	60	30	0	30	–	–	70	–	–	–	–
D1_5_20-00_00-00	20	20	0	0	–	–	–	–	–	–	–
D1_5_20-20_C-01-00	40	20	0	20	1 buggy	–	–	–	–	–	–
D1_5_10-20_C-00-01	30	10	0	20	–	1 buggy	–	–	–	–	–
D1_5_20-10_C-01-00	30	20	0	10	1 buggy	–	–	–	–	–	–
D1_5_00-20_C-00-01	20	0	0	20	–	1 buggy	–	–	–	–	–
D1_5_20-20_pairs	40	20	0	20	–	–	–	–	–	pairs	–
D1_5_20-20_3s	40	20	0	20	–	–	–	–	–	groups of 3	–
D1_5_20-20_pairs5s	40	20	0	20	–	–	–	–	–	pairs, groups of 5	–
D1_5_20-20_pairs3s	40	20	0	20	–	–	–	–	–	pairs, groups of 3	–
D1_5_20-20_pairs3s5s	40	20	0	20	–	–	–	–	–	pairs, groups of 3 and 5	–
D1_5_30-30_distraction	60	30	0	30	–	–	–	–	–	–	100% distracted
D1_5_20-00_M-06-00	20	20	0	0	6 mixed	–	–	–	–	–	–
D1_5_20-20_M-05-06	40	20	0	20	5 mixed	6 mixed	–	–	–	–	–
D1_5_10-20_M-07-05	30	10	0	20	7 mixed	5 mixed	–	–	–	–	–
D1_5_20-10_M-09-07	30	20	0	10	9 mixed	7 mixed	–	–	–	–	–
D1_5_20-20_M-07-09	40	20	0	20	7 mixed	9 mixed	–	–	–	–	–
D1_5_00-20_M-00-07	20	0	0	20	–	7 mixed	–	–	–	–	–
D1_6_20-20_cooperation	40	20	0	20	–	–	–	work together	–	–	–
D1_6_17-17_cooperation34	34	17	0	17	–	–	–	work together	–	–	–
D1_6_20-00_throng	20	20	0	0	–	–	–	–	throng	–	–
D1_6_20-20_throng	40	20	0	20	–	–	–	–	throng	–	–
D1_6_10-20_throng	30	10	0	20	–	–	–	–	throng	–	–
D1_6_20-10_throng	30	20	0	10	–	–	–	–	throng	–	–
D1_6_20-00_45angle	20	20	0	0	–	–	–	–	45°	–	–
D1_6_20-20_45angle	40	20	0	20	–	–	–	–	45°	–	–
D1_6_10-20_45angle	30	10	0	20	–	–	–	–	45°	–	–
D1_6_20-10_45angle	30	20	0	10	–	–	–	–	45°	–	–
D1_6_20-00_corridor	20	20	0	0	–	–	–	–	corridor	–	–
D1_6_20-20_corridor	40	20	0	20	–	–	–	–	corridor	–	–
D1_6_10-20_corridor	30	10	0	20	–	–	–	–	corridor	–	–
D1_6_20-10_corridor	30	20	0	10	–	–	–	–	corridor	–	–
D2_1_d_4_1	30	10,10,10	0,10,20	0,0,10	–	–	–	–	–	–	–
D2_1_d_4_2	30	20,20,30	20,40,40	0,20,10	–	–	–	–	–	–	–
D2_1_d_4_3	50	10,20,10	20,20,30	10,10,10	–	–	–	–	–	–	–
D2_1_d_4_4	50	20,10,10	20,30,30	10,10,20	–	–	–	–	–	–	–
D2_1_d_4_5	50	10,10,20	30,30,20	10,20,10	–	–	–	–	–	–	–
D2_1_d_4_6	40	10,20,10	30,20,30	20,10,10	–	–	–	–	–	–	–
D2_1_d_4_7	40	20,10,20	20,30,30	10,10,20	–	–	–	–	–	–	–
D2_1_d_4_8	60	10,20,10	30,30,30	10,20,10	–	–	–	–	–	–	–
D2_1_d_4_9	50	20,10,20	30,30,30	20,10,20	–	–	–	–	–	–	–
D2_1_d_4_10	60	10,20,0	30,30,30	10,20,10	–	–	–	–	–	–	–
D2_1_d_4_11K	20	20,0,0	0,20,0	0,0,20	–	–	–	–	–	–	–
D2_1_d_4_12K	40	40,0,0	0,40,0	0,0,40	–	–	–	–	–	–	–
D2_1_d_6_13K	60	60,0,0	0,60,0	0,0,60	–	–	–	–	–	–	–
D2_1_d_6_1	60	20,20,20	0,20,40	0,0,20	–	–	–	–	–	–	–
D2_1_d_6_2	60	20,20,30	20,40,40	0,20,10	–	–	–	–	–	–	–

Table 17 continued from previous page

run name	N_total [number of participants]	N_in [number of participants boarding]	N_train [number of participants staying in train]	N_out [number of participants alighting]	luggage_in [none, backpack, trolley, buggy, mix]	luggage_out [none, backpack, trolley, buggy, mix]	norm [none, 70, 80, 100]	cooperation [none, work together]	line-up [none, throng, corridor, 45°]	groups [none, pairs, groups of 3, groups of 5]	motivation [none, hurry, pushing, 50%/100% distracted]
D2_1_d_6_3	80	20,20,20	0,20,40	0,0,20	–	–	–	–	–	–	–
D2_1_d_6_4	80	30,20,20	40,40,50	20,20,20	–	–	–	–	–	–	–
D2_1_d_6_5	80	20,20,20	50,50,40	20,30,20	–	–	–	–	–	–	–
D2_1_d_6_6	70	20,30,20	50,40,50	30,20,20	–	–	–	–	–	–	–
D2_1_d_6_7	70	20,30,20	50,40,50	30,20,20	–	–	–	–	–	–	–
D2_1_d_6_8	90	20,30,20	50,50,50	20,30,20	–	–	–	–	–	–	–
D2_1_d_6_9	80	30,20,30	50,50,50	30,20,30	–	–	–	–	–	–	–
D2_1_d_6_10	90	20,30,0	50,50,50	20,30,20	–	–	–	–	–	–	–
D2_1_d_6_11	50	0	0	50	–	–	–	–	–	–	–
D2_2_20-00_00-00	20	20	0	0	–	–	–	–	–	–	–
D2_2_20-20_10-00	40	20	0	20	10 backpacks	–	–	–	–	–	–
D2_2_10-20_05-10	30	10	0	20	5 backpacks	10 backpacks	–	–	–	–	–
D2_2_20-10_10-05	30	20	0	10	10 backpacks	5 backpacks	–	–	–	–	–
D2_2_20-20_05-10	40	20	0	20	5 backpacks	10 backpacks	–	–	–	–	–
D2_2_10-20_10-05	30	10	0	20	10 backpacks	5 backpacks	–	–	–	–	–
D2_2_20-10_05-10_1	30	20	0	10	5 backpacks	10 backpacks	–	–	–	–	–
D2_2_20-20_10-05	40	20	0	20	10 backpacks	5 backpacks	–	–	–	–	–
D2_2_10-20_00-10	30	10	0	20	–	10 backpacks	–	–	–	–	–
D2_2_20-10_10-00	30	20	0	10	10 backpacks	–	–	–	–	–	–
D2_2_20-20_00-10	40	20	0	20	–	10 backpacks	–	–	–	–	–
D2_2_10-20_10-00	30	10	0	20	10 backpacks	–	–	–	–	–	–
D2_2_20-10_05-10_2	30	20	0	10	5 backpacks	10 backpacks	–	–	–	–	–
D2_2_00-20_00-05	20	0	0	20	–	5 backpacks	–	–	–	–	–
D2_2_20-00_00-00_S	20	20	0	0	–	–	–	–	–	–	hurry
D2_2_20-20_09-00_S	40	20	0	20	10 backpacks	–	–	–	–	–	hurry
D2_2_10-20_05-09_S	30	10	0	20	5 backpacks	10 backpacks	–	–	–	–	hurry
D2_2_20-10_10-05_S	30	20	0	10	10 backpacks	5 backpacks	–	–	–	–	hurry
D2_2_20-20_05-10_S_1	40	20	0	20	5 backpacks	10 backpacks	–	–	–	–	hurry
D2_2_10-20_10-05_S	30	10	0	20	10 backpacks	5 backpacks	–	–	–	–	hurry
D2_2_20-10_05-10_S	30	20	0	10	5 backpacks	10 backpacks	–	–	–	–	hurry
D2_2_20-20_10-05_S	40	20	0	20	10 backpacks	5 backpacks	–	–	–	–	hurry
D2_2_10-20_00-10_S	30	10	0	20	–	10 backpacks	–	–	–	–	hurry
D2_2_20-10_10-00_S	30	20	0	10	10 backpacks	–	–	–	–	–	hurry
D2_2_20-20_00-10_S	40	20	0	20	–	10 backpacks	–	–	–	–	hurry
D2_2_10-20_10-00_S	30	10	0	20	10 backpacks	–	–	–	–	–	hurry
D2_2_20-10_05-10_S_2	30	20	0	10	5 backpacks	10 backpacks	–	–	–	–	hurry
D2_2_00-20_00-05_S	20	0	0	20	–	5 backpacks	–	–	–	–	hurry
D2_2_20-20_norm70_1	40	20	0	20	–	–	70	–	–	–	–
D2_2_20-20_norm70_2	40	20	0	20	–	–	70	–	–	–	–
D2_3_20-00_blank	20	20	0	0	–	–	–	–	–	–	–
D2_3_20-20_blank	40	20	0	20	–	–	–	–	–	–	–
D2_3_10-20_blank	30	10	0	20	–	–	–	–	–	–	–
D2_3_20-10_blank	30	20	0	10	–	–	–	–	–	–	–
D2_3_00-20_blank	20	0	0	20	–	–	–	–	–	–	–
D2_3_30-00_blank	30	30	0	0	–	–	–	–	–	–	–
D2_3_30-30_blank	60	30	0	30	–	–	–	–	–	–	–
D2_3_00-30_blank	30	0	0	30	–	–	–	–	–	–	–
D2_3_20-00_distraction	20	20	0	0	–	–	–	–	–	–	100% distracted boarding
D2_3_20-20_distraction	40	20	0	20	–	–	–	–	–	–	100% distracted
D2_3_20-20_distraction50in	40	20	0	20	–	–	–	–	–	–	50% distracted boarding 100% distracted alighting

Table 17 continued from previous page

		run name	N_total [number of participants]	N_in [number of participants boarding]	N_train [number of participants staying in train]	N_out [number of participants alighting]	luggage_in [none, backpack, trolley, buggy, mix]	luggage_out [none, backpack, trolley, buggy, mix]	norm [none, 70, 80, 100]	cooperation [none, work together]	line-up [none, throng, corridor, 45°]	groups [none, pairs, groups of 3, groups of 5]	motivation [none, hurry, pushing, 50%/100% distracted]
		D2_3_20-20_distraction50	40	20	0	20	–	–	–	–	–	–	50% distracted
		D2_3_00-20_distraction50out	20	0	0	20	–	–	–	–	–	–	50% distracted alighting
		D2_3_20-20_norm100_1	40	20	0	20	–	–	100	–	–	–	–
		D2_3_20-20_norm100_2	40	20	0	20	–	–	100	–	–	–	–
		D2_3_20-20_norm80_1	40	20	0	20	–	–	80	–	–	–	–
		D2_3_20-20_norm80_2	40	20	0	20	–	–	80	–	–	–	–
day 2		D2_3_50-50_blank	50	50	0	50	–	–	–	–	–	–	–
		D2_4_30-30_distraction	60	30	0	30	–	–	–	–	–	–	100% distracted
		D2_4_20-00_K-05-00	20	20	0	0	5 trolleys	–	–	–	–	–	–
		D2_4_20-20_K-00-05	40	20	0	20	–	5 trolleys	–	–	–	–	–
		D2_4_10-20_K-05-00	30	10	0	20	5 trolleys	–	–	–	–	–	–
		D2_4_20-10_K-00-05	30	20	0	10	–	5 trolleys	–	–	–	–	–
		D2_4_20-20_K-05-00	40	20	0	20	5 trolleys	–	–	–	–	–	–
		D2_4_10-20_K-00-05	30	10	0	20	–	5 trolleys	–	–	–	–	–
		D2_4_20-10_K-05-00	30	20	0	10	5 trolleys	–	–	–	–	–	–
		D2_4_00-20_K-00-05	20	0	0	20	–	5 trolleys	–	–	–	–	–
		D2_4_30-30_cooperation	60	30	0	30	–	–	–	work together	–	–	–
		D2_4_30-00_norm70_1	60	30	0	30	–	–	70	–	–	–	–
		D2_4_30-30_norm70_2	60	30	0	30	–	–	70	–	–	–	–
		D2_5_20-00_00-00	20	20	0	0	–	–	–	–	–	–	–
		D2_5_20-20_C-01-00	40	20	0	20	1 buggy	–	–	–	–	–	–
		D2_5_10-20_C-00-01	30	10	0	20	–	1 buggy	–	–	–	–	–
		D2_5_20-10_C-01-00	30	20	0	10	1 buggy	–	–	–	–	–	–
		D2_5_00-20_C-00-01	20	0	0	20	–	1 buggy	–	–	–	–	–
		D2_5_20-20_pairs	40	20	0	20	–	–	–	–	–	pairs	–
		D2_5_20-20_3s	40	20	0	20	–	–	–	–	–	groups of 3	–
		D2_5_20-20_pairs5s	40	20	0	20	–	–	–	–	–	pairs, groups of 5	–
		D2_5_20-20_pairs3s	40	20	0	20	–	–	–	–	–	pairs, groups of 3	–
		D2_5_20-20_pairs3s5s	40	20	0	20	–	–	–	–	–	pairs, groups of 3 and 5	–
		D2_5_20-00_M-06-00	20	20	0	0	6 mixed	–	–	–	–	–	–
		D2_5_20-20_M-05-06	40	20	0	20	5 mixed	6 mixed	–	–	–	–	–
		D2_5_10-20_M-07-05	30	10	0	20	7 mixed	5 mixed	–	–	–	–	–
		D2_5_20-10_M-07-07	30	20	0	10	7 mixed	7 mixed	–	–	–	–	–
		D2_5_20-20_M-06-07	40	20	0	20	6 mixed	7 mixed	–	–	–	–	–
		D2_5_00-20_M-00-06	20	0	0	20	–	6 mixed	–	–	–	–	–
		D2_5_30-00_push	30	30	0	0	–	–	–	–	–	–	pushing boarding
		D2_5_30-30_push	60	30	0	30	–	–	–	–	–	–	pushing boarding
		D2_5_20-30_push	50	20	0	30	–	–	–	–	–	–	pushing boarding
		D2_6_20-20_cooperation20	40	20	0	20	–	–	–	work together	–	–	–
		D2_6_12-00_cooperation12	12	12	0	0	–	–	–	work together	–	–	–
		D2_6_20-00_throng	20	20	0	0	–	–	–	–	throng	–	–
		D2_6_20-20_throng	40	20	0	20	–	–	–	–	throng	–	–
		D2_6_10-20_throng	30	10	0	20	–	–	–	–	throng	–	–
		D2_6_20-10_throng	30	20	0	10	–	–	–	–	throng	–	–
		D2_6_20-00_45angle	20	20	0	0	–	–	–	–	45°	–	–
		D2_6_20-20_45angle	40	20	0	20	–	–	–	–	45°	–	–
		D2_6_10-20_45angle	30	10	0	20	–	–	–	–	45°	–	–
		D2_6_20-10_45angle	30	20	0	10	–	–	–	–	45°	–	–
		D2_6_20-00_corridor	20	20	0	0	–	–	–	–	corridor	–	–

Table 17 continued from previous page

run name	N_total [number of participants]	N_in [number of participants boarding]	N_train [number of participants staying in train]	N_out [number of participants alighting]	luggage_in [none, backpack, trolley, buggy, mix]	luggage_out [none, backpack, trolley, buggy, mix]	norm [none, 70, 80, 100]	cooperation [none, work together]	line-up [none, throng, corridor, 45°]	groups [none, pairs, groups of 3, groups of 5]	motivation [none, hurry, pushing, 50%/100% distracted]
D2_6_20-20_corridor	40	20	0	20	–	–	–	–	corridor	–	–
D2_6_10-20_corridor	30	10	0	20	–	–	–	–	corridor	–	–
D2_6_20-10_corridor	30	20	0	10	–	–	–	–	corridor	–	–
D2_6_30-00_throng	30	30	0	0	–	–	–	–	throng	–	–
D2_6_30-30_throng	60	30	0	30	–	–	–	–	throng	–	–
D3_1_blank_30-30_1	30	30	0	0	–	–	–	–	–	–	–
D3_1_blank_30-30_2	60	30	0	30	–	–	–	–	–	–	–
D3_1_distraction_20-20_1	20	20	0	0	–	–	–	–	–	–	100% distracted boarding
D3_1_distraction_20-20_2	40	20	0	20	–	–	–	–	–	–	100% distracted
D3_1_distraction_10-20	30	10	0	20	–	–	–	–	–	–	100% distracted
D3_1_distraction_20-10	30	20	0	10	–	–	–	–	–	–	100% distracted
D3_1_norm100_30-30_1	30	30	0	0	–	–	100	–	–	–	–
D3_1_norm100_30-30_2	60	30	0	30	–	–	100	–	–	–	–
D3_1_norm100_30-30_3	60	30	0	30	–	–	100	–	–	–	–
D3_1_norm80_30-30_1	60	30	0	30	–	–	80	–	–	–	–
D3_1_norm80_30-30_2	60	30	0	30	–	–	80	–	–	–	–
D3_1_throng_30-30_1	30	30	0	0	–	–	–	–	throng	–	–
D3_1_throng_30-30_2	60	30	0	30	–	–	–	–	throng	–	–
D3_2_blank_30-30_1	30	30	0	0	–	–	–	–	–	–	–
D3_2_blank_30-30_2	60	30	0	30	–	–	–	–	–	–	–
D3_2_distraction_20-20_1	20	20	0	0	–	–	–	–	–	–	100% distracted boarding
D3_2_distraction_20-20_2	40	20	0	20	–	–	–	–	–	–	100% distracted
D3_2_distraction_10-20	30	10	0	20	–	–	–	–	–	–	100% distracted
D3_2_distraction_20-10	30	20	0	10	–	–	–	–	–	–	100% distracted
D3_2_norm100_30-30_1	30	30	0	0	–	–	100	–	–	–	–
D3_2_norm100_30-30_2	60	30	0	30	–	–	100	–	–	–	–
D3_2_norm100_30-30_3	60	30	0	30	–	–	100	–	–	–	–
D3_2_norm80_30-30_1	60	30	0	30	–	–	80	–	–	–	–
D3_2_norm80_30-30_2	60	30	0	30	–	–	80	–	–	–	–
D3_2_throng_30-30_1	30	30	0	0	–	–	–	–	throng	–	–
D3_2_throng_30-30_2	60	30	0	30	–	–	–	–	throng	–	–
D3_2_throng_30-30_3	60	30	0	30	–	–	–	–	throng	–	–
D3_2_throng_30-30_4	60	30	0	30	–	–	–	–	throng	–	–
D3_3_d_4_1	20	30	10,10,10	0,10,20	0,0,10	–	–	–	–	–	–
D3_3_d_4_2	30	20,20,30	20,40,40	0,20,10	–	–	–	–	–	–	–
D3_3_d_4_3	50	10,20,10	20,20,30	10,10,10	–	–	–	–	–	–	–
D3_3_d_4_4	50	20,10,10	20,30,30	10,10,20	–	–	–	–	–	–	–
D3_3_d_4_5	50	10,10,20	30,30,20	10,20,10	–	–	–	–	–	–	–
D3_3_d_4_6	40	10,20,10	30,20,30	20,10,10	–	–	–	–	–	–	–
D3_3_d_4_7	40	20,10,20	20,30,30	10,10,20	–	–	–	–	–	–	–
D3_3_d_4_8	60	10,20,10	30,30,30	10,20,10	–	–	–	–	–	–	–
D3_3_d_4_9	50	20,10,20	30,30,30	20,10,20	–	–	–	–	–	–	–
D3_3_d_4_10	60	10,20,0	30,30,30	10,20,10	–	–	–	–	–	–	–
D3_3_d_4_11K	20	20,0,0	0,20,0	0,0,20	–	–	–	–	–	–	–
D3_3_d_4_12K	40	40,0,0	0,40,0	0,0,40	–	–	–	–	–	–	–
D3_3_d_6_1	40	20,20,20	0,20,40	0,0,20	–	–	–	–	–	–	–
D3_3_d_6_2	60	20,20,30	20,40,40	0,20,10	–	–	–	–	–	–	–
D3_3_d_6_3	80	20,20,20	0,20,40	0,0,20	–	–	–	–	–	–	–
D3_3_d_6_4	80	30,20,20	40,40,50	20,20,20	–	–	–	–	–	–	–
D3_3_d_6_5	80	20,20,20	50,50,40	20,30,20	–	–	–	–	–	–	–
D3_3_d_6_6	70	20,30,20	50,40,50	30,20,20	–	–	–	–	–	–	–
D3_3_d_6_7	70	20,30,20	50,40,50	30,20,20	–	–	–	–	–	–	–

Table 17 continued from previous page

		run name	N_total [number of participants]	N_in [number of participants boarding]	N_train [number of participants staying in train]	N_out [number of participants alighting]	luggage_in [none, backpack, trolley, buggy, mix]	luggage_out [none, backpack, trolley, buggy, mix]	norm [none, 70, 80, 100]	cooperation [none, work together]	line-up [none, throng, corridor, 45°]	groups [none, pairs, groups of 3, groups of 5]	motivation [none, hurry, pushing, 50%/100% distracted]
		D3_3_d_6_8	90	20,30,20	50,50,50	20,30,20	–	–	–	–	–	–	–
		D3_3_d_6_9	80	30,20,30	50,50,50	30,20,30	–	–	–	–	–	–	–
		D3_3_d_6_10	90	20,30,0	50,50,50	20,30,20	–	–	–	–	–	–	–
day 3		D3_3_d_6_11K	60	60,0,0	0,60,0	0,0,60	–	–	–	–	–	–	–
		D3_4_cooperation_30-30	60	30	0	30	–	–	–	work together	–	–	–
		D3_4_pairs_30-30_1	30	30	0	0	–	–	–	–	–	–	–
		D3_4_pairs_30-30_2	60	30	0	30	–	–	–	–	–	pairs	–
		D3_4_3s_30-30	60	30	0	30	–	–	–	–	–	groups of 3	–
		D3_4_pairs5s_30-30	60	30	0	30	–	–	–	–	–	pairs, groups of 5	–
		D3_4_delay_35-00	35	35	0	0	–	–	–	–	–	–	pushing
		D3_4_20_20_10-00	40	20	0	20	10 backpacks	–	–	–	–	–	–
		D3_4_10-20_05-10	30	10	0	20	5 backpacks	10 backpacks	–	–	–	–	–
		D3_4_20-10_10-05	30	20	0	10	10 backpacks	5 backpacks	–	–	–	–	–
		D3_4_20-20_05-10	40	20	0	20	5 backpacks	10 backpacks	–	–	–	–	–
		D3_4_10-20_10-05	30	10	0	20	10 backpacks	5 backpacks	–	–	–	–	–
		D3_4_20-10_05-10_1	30	20	0	10	5 backpacks	10 backpacks	–	–	–	–	–
		D3_4_20-20_10-05	40	20	0	20	10 backpacks	5 backpacks	–	–	–	–	–
		D3_4_10-20_00-10	30	10	0	20	–	10 backpacks	–	–	–	–	–
		D3_4_20-10_10-00	30	20	0	10	10 backpacks	–	–	–	–	–	–
		D3_4_20-20_00-10	40	20	0	20	–	10 backpacks	–	–	–	–	–
		D3_4_10-20_10-00	30	10	0	20	10 backpacks	–	–	–	–	–	–
		D3_4_20-10_05-10_2	30	20	0	10	5 backpacks	10 backpacks	–	–	–	–	–
		D3_5_cooperation_20-20_1	40	20	0	20	–	–	–	work together	–	–	–
		D3_5_cooperation_20-20_2	40	20	0	20	–	–	–	work together	–	–	–
		D3_5_pairs3s_30-30_1	30	30	0	0	–	–	–	–	–	–	–
		D3_5_pairs3s_30-30_2	60	30	0	30	–	–	–	–	–	pairs, groups of 3	–
		D3_5_pairs3s5s_30-30	60	30	0	30	–	–	–	–	–	pairs, groups of 3 and 5	–
		D3_5_pairs_30-30	60	30	0	30	–	–	–	–	–	pairs	–
		D3_5_delay_35-00	35	35	0	0	–	–	–	–	–	–	pushing
		D3_5_reversedirection_20-00	20	20	0	0	–	–	–	–	–	–	–
		D3_5_reversedirection_20-20_1	40	20	0	20	–	–	–	–	–	–	–
		D3_5_reversedirection_10-20_1	30	10	0	20	–	–	–	–	–	–	–
		D3_5_reversedirection_20-10	30	20	0	10	–	–	–	–	–	–	–
		D3_5_reversedirection_20-20_2	40	20	0	20	–	–	–	–	–	–	–
		D3_5_reversedirection_20-20_3	40	20	0	20	–	–	–	–	–	–	–
		D3_5_reversedirection_10-20_2	30	10	0	20	–	–	–	–	–	–	–
		D3_5_blank_20-10	30	20	0	10	–	–	–	–	–	–	–
		D3_5_blank_30-30_1	30	30	0	0	–	–	–	–	–	–	–
		D3_5_blank_30-30_2	60	30	0	30	–	–	–	–	–	–	–
		D3_6_3s_30-00	30	30	0	0	–	–	–	–	–	–	–
		D3_6_3s_30-30	60	30	0	30	–	–	–	–	–	groups of 3	–
		D3_6_pairs5s_30-30	60	30	0	30	–	–	–	–	–	pairs, groups of 5	–
		D3_6_pairs3s_30-30	60	30	0	30	–	–	–	–	–	pairs, groups of 3	–
		D3_6_pairs3s5s_30-30	60	30	0	30	–	–	–	–	–	pairs, groups of 3 and 5	–
		D3_6_norm80_20-20_1	20	20	0	0	–	–	80	–	–	–	–
		D3_6_norm80_20-20_2	40	20	0	20	–	–	80	–	–	–	–

Table 17 continued from previous page

run name	N_total [number of participants]	N_in [number of participants boarding]	N_train [number of participants staying in train]	N_out [number of participants alighting]	luggage_in [none, backpack, trolley, buggy, mix]	luggage_out [none, backpack, trolley, buggy, mix]	norm [none, 70, 80, 100]	cooperation [none, work together]	line-up [none, throng, corridor, 45°]	groups [none, pairs, groups of 3, groups of 5]	motivation [none, hurry, pushing, 50%/100% distracted]
D3_6_norm80_30-30_1	30	30	0	0	–	–	80	–	–	–	–
D3_6_norm80_30-30_2	60	30	0	30	–	–	80	–	–	–	–
D3_6_delay_35-00	35	35	0	0	–	–	–	–	–	–	pushing
D3_6_distraction20_20-00	20	20	0	0	–	–	–	–	–	–	50% distracted
D3_6_distraction20_20-20	40	20	0	20	–	–	–	–	–	–	boarding 50% distracted
D3_6_reversedirection_20-20_1	20	20	0	0	–	–	–	–	–	–	–
D3_6_reversedirection_20-20_2	40	20	0	20	–	–	–	–	–	–	–
D3_6_reversedirection_10-20	30	10	0	20	–	–	–	–	–	–	–
D3_6_reversedirection_20-10	30	20	0	10	–	–	–	–	–	–	–
D3_6_reversedirection_30-00	30	30	0	0	–	–	–	–	–	–	–
D3_6_reversedirection_30-30	60	30	0	30	–	–	–	–	–	–	–
D3_6_allitems_30-00_13-00	30	30	0	0	13 mixed	–	–	–	–	–	–
D3_6_allitems_30-30_13-13	60	30	0	30	13 mixed	13 mixed	–	–	–	–	–

A.8. Experimental Configurations Tiny Box Experiments

Table 18 Table showing experimental runs performed within the scope of the Tiny Box Experiments (Sec. 3.6). The colour of the group that participants belonged to is given as well as varied parameters.

	run no	no. of people in box	id numbers	box no. [1,2,3,4]	special announcement [speaking allowed / prohibited]	waiting time [minutes]
	1	2	1, 8	1	speaking allowed	5
	2	2	2, 7	2	speaking allowed	5
	3	2	3, 6	3	speaking allowed	5
	4	2	4, 5	4	speaking allowed	5
	5	1	3	1	speaking allowed	5
	6	1	4	2	speaking allowed	5
	7	1	5	3	speaking allowed	5
	8	1	6	4	speaking allowed	5
	9	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking allowed	5
	10	6	1, 2, 3, 4, 5, 6	1	speaking allowed	5
	11	1	7	2	speaking allowed	5
	12	1	8	3	speaking allowed	5
	13	1	1	1	speaking allowed	5
	14	1	2	2	speaking allowed	5
	15	6	3, 4, 5, 6, 7, 8	3	speaking allowed	5
	16	4	1, 2, 3, 4	2	speaking allowed	5
	17	4	5, 6, 7, 8	4	speaking allowed	5
	18	6	1, 2, 3, 4, 5, 6	1	speaking allowed	5
	19	1	7	2	speaking allowed	5
	20	1	8	3	speaking allowed	5
	21	1	1	1	speaking allowed	5
	22	1	2	2	speaking allowed	5
	23	6	3, 4, 5, 6, 7, 8	3	speaking allowed	5
	24	4	1, 2, 3, 4	2	speaking allowed	5
	25	4	5, 6, 7, 8	4	speaking allowed	5
	26	2	1, 8	1	speaking allowed	5
	27	2	2, 7	2	speaking allowed	5
	28	2	3, 6	3	speaking allowed	5
	29	2	4, 5	4	speaking allowed	5
	30	1	3	1	speaking allowed	5
	31	1	4	2	speaking allowed	5
	32	1	5	3	speaking allowed	5
	33	1	6	4	speaking allowed	5
	34	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking allowed	5
	35	1	1	1	speaking allowed	5
	36	1	2	2	speaking allowed	5
	37	6	3, 4, 5, 6, 7, 8	3	speaking allowed	5
	38	4	1, 2, 3, 4	2	speaking allowed	5
	39	4	5, 6, 7, 8	4	speaking allowed	5
	40	2	1, 8	1	speaking allowed	5
	41	2	2, 7	2	speaking allowed	5
	42	2	3, 6	3	speaking allowed	5
	43	2	4, 5	4	speaking allowed	5
	44	1	3	1	speaking allowed	5
	45	1	4	2	speaking allowed	5
	46	1	5	3	speaking allowed	5
	47	1	6	4	speaking allowed	5
	48	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking allowed	5
	49	6	1, 2, 3, 4, 5, 6	1	speaking allowed	5
	50	1	7	2	speaking allowed	5
day 1	51	1	8	3	speaking allowed	5
	52	4	1, 2, 3, 4	2	speaking allowed	5
	53	4	5, 6, 7, 8	4	speaking allowed	5
	54	2	1, 8	1	speaking allowed	5
	55	2	2, 7	2	speaking allowed	5
	56	2	3, 6	3	speaking allowed	5
	57	2	4, 5	4	speaking allowed	5
	58	1	3	1	speaking allowed	5
	59	1	4	2	speaking allowed	5
	60	1	5	3	speaking allowed	5
	61	1	6	4	speaking allowed	5
	62	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking allowed	5
	63	6	1, 2, 3, 4, 5, 6	1	speaking allowed	5
	64	1	7	2	speaking allowed	5
	65	1	8	3	speaking allowed	5
	66	1	1	1	speaking allowed	5
	67	1	2	2	speaking allowed	5
	68	6	3, 4, 5, 6, 7, 8	3	speaking allowed	5

Table 18 continued from previous page

	run no	no. of people in box	id numbers	box no. [1,2,3,4]	special announcement [speaking allowed / prohibited]	waiting time [minutes]
	69	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking allowed	5
	70	6	1, 2, 3, 4, 5, 6	1	speaking allowed	5
	71	1	7	2	speaking allowed	5
	72	1	8	3	speaking allowed	5
	73	1	1	1	speaking allowed	5
	74	1	2	2	speaking allowed	5
	75	6	3, 4, 5, 6, 7, 8	3	speaking allowed	5
	76	4	1, 2, 3, 4	2	speaking allowed	5
	77	4	5, 6, 7, 8	4	speaking allowed	5
	78	2	1, 8	1	speaking allowed	5
	79	2	2, 7	2	speaking allowed	5
	80	2	3, 6	3	speaking allowed	5
	81	2	4, 5	4	speaking allowed	5
	82	1	3	1	speaking allowed	5
	83	1	4	2	speaking allowed	5
	84	1	5	3	speaking allowed	5
	85	1	6	4	speaking allowed	5
	86	2	1, 8	1	speaking prohibited	5
	87	2	2, 7	2	speaking prohibited	5
	88	2	3, 6	3	speaking prohibited	5
	89	2	4, 5	4	speaking prohibited	5
	90	1	3	1	speaking prohibited	5
	91	1	4	2	speaking prohibited	5
	92	1	5	3	speaking prohibited	5
	93	1	6	4	speaking prohibited	5
	94	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking prohibited	5
	95	6	1, 2, 3, 4, 5, 6	1	speaking prohibited	5
	96	1	7	2	speaking prohibited	5
	97	1	8	3	speaking prohibited	5
	98	6	1	1	speaking prohibited	5
	99	1	2	2	speaking prohibited	5
	100	1	3, 4, 5, 6, 7, 8	3	speaking prohibited	5
	101	4	1, 2, 3, 4	2	speaking prohibited	5
	102	4	5, 6, 7, 8	4	speaking prohibited	5
	103	6	1, 2, 3, 4, 5, 6	1	speaking prohibited	5
	104	1	7	2	speaking prohibited	5
	105	1	8	3	speaking prohibited	5
	106	1	1	1	speaking prohibited	5
	107	1	2	2	speaking prohibited	5
	108	6	3, 4, 5, 6, 7, 8	3	speaking prohibited	5
	109	4	1, 2, 3, 4	2	speaking prohibited	5
	110	4	5, 6, 7, 8	4	speaking prohibited	5
	111	2	1, 8	1	speaking prohibited	5
	112	2	2, 7	2	speaking prohibited	5
	113	2	3, 6	3	speaking prohibited	5
	114	2	4, 5	4	speaking prohibited	5
	115	1	3	1	speaking prohibited	5
	116	1	4	2	speaking prohibited	5
	117	1	5	3	speaking prohibited	5
	118	1	6	4	speaking prohibited	5
	119	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking prohibited	5
	120	1	1	1	speaking prohibited	5
	121	1	2	2	speaking prohibited	5
	122	6	3, 4, 5, 6, 7, 8	3	speaking prohibited	5
	123	4	1, 2, 3, 4	2	speaking prohibited	5
	124	4	5, 6, 7, 8	4	speaking prohibited	5
	125	2	1, 8	1	speaking prohibited	5
	126	2	2, 7	2	speaking prohibited	5
	127	2	3, 6	3	speaking prohibited	5
	128	2	4, 5	4	speaking prohibited	5
	129	1	3	1	speaking prohibited	5
	130	1	4	2	speaking prohibited	5
	131	1	5	3	speaking prohibited	5
	132	1	6	4	speaking prohibited	5
	133	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking prohibited	5
	134	6	1, 2, 3, 4, 5, 6	1	speaking prohibited	5
	135	1	7	2	speaking prohibited	5
day 2	136	1	8	3	speaking prohibited	5
	137	4	1, 2, 3, 4	2	speaking prohibited	5
	138	4	5, 6, 7, 8	4	speaking prohibited	5
	139	2	1, 8	1	speaking prohibited	5
	140	2	2, 7	2	speaking prohibited	5
	141	2	3, 6	3	speaking prohibited	5
	142	2	4, 5	4	speaking prohibited	5
	143	1	3	1	speaking prohibited	5
	144	1	4	2	speaking prohibited	5
	145	1	5	3	speaking prohibited	5
	146	1	6	4	speaking prohibited	5
	147	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking prohibited	5
	148	6	1, 2, 3, 4, 5, 6	1	speaking prohibited	5
	149	1	7	2	speaking prohibited	5
	150	1	8	3	speaking prohibited	5
	151	1	1	1	speaking prohibited	5
	152	1	2	2	speaking prohibited	5
	153	6	3, 4, 5, 6, 7, 8	3	speaking prohibited	5

Table 18 continued from previous page

	run no	no. of people in box	id numbers	box no. [1,2,3,4]	special announcement [speaking allowed / prohibited]	waiting time [minutes]
	154	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking prohibited	5
	155	6	1, 2, 3, 4, 5, 6	1	speaking prohibited	5
	156	1	7	2	speaking prohibited	5
	157	1	8	3	speaking prohibited	5
	158	1	1	1	speaking prohibited	5
	159	1	2	2	speaking prohibited	5
	160	6	3, 4, 5, 6, 7, 8	3	speaking prohibited	5
	161	4	1, 2, 3, 4	2	speaking prohibited	5
	162	4	5, 6, 7, 8	4	speaking prohibited	5
	163	2	1, 8	1	speaking prohibited	5
	164	2	2, 7	2	speaking prohibited	5
	165	2	3, 6	3	speaking prohibited	5
	166	2	4, 5	4	speaking prohibited	5
	167	1	3	1	speaking prohibited	5
	168	1	4	2	speaking prohibited	5
	169	1	5	3	speaking prohibited	5
	170	1	6	4	speaking prohibited	5
	171	2	1, 8	1	speaking allowed	5
	172	2	2, 7	2	speaking allowed	5
	173	2	3, 6	3	speaking allowed	5
	174	2	4, 5	4	speaking allowed	5
	175	1	3	1	speaking allowed	5
	176	1	4	2	speaking allowed	5
	177	1	5	3	speaking allowed	5
	178	1	6	4	speaking allowed	5
	179	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking allowed	5
	180	6	1, 2, 3, 4, 5, 6	1	speaking allowed	5
	181	1	7	2	speaking allowed	5
	182	1	8	3	speaking allowed	5
	183	6	1	1	speaking allowed	5
	184	1	2	2	speaking allowed	5
	185	1	3, 4, 5, 6, 7, 8	3	speaking allowed	5
	186	4	1, 2, 3, 4	2	speaking allowed	5
	187	4	5, 6, 7, 8	4	speaking allowed	5
day 3	188	2	1, 8	1	speaking prohibited	5
	189	2	2, 7	2	speaking prohibited	5
	190	2	3, 6	3	speaking prohibited	5
	191	2	4, 5	4	speaking prohibited	5
	192	1	3	1	speaking prohibited	5
	193	1	4	2	speaking prohibited	5
	194	1	5	3	speaking prohibited	5
	195	1	6	4	speaking prohibited	5
	196	8	1, 2, 3, 4, 5, 6, 7, 8	1	speaking prohibited	5
	197	6	1, 2, 3, 4, 5, 6	1	speaking prohibited	5
	198	1	7	2	speaking prohibited	5
	199	1	8	3	speaking prohibited	5
	200	6	1	1	speaking prohibited	5
	201	1	2	2	speaking prohibited	5
	202	1	3, 4, 5, 6, 7, 8	3	speaking prohibited	5
	203	4	1, 2, 3, 4	2	speaking prohibited	5
	204	4	5, 6, 7, 8	4	speaking prohibited	5

A.9. Experimental Configurations Bottleneck Experiments.

Table 19 Table showing experimental runs performed within the scope of the Bottleneck Experiments (Sec. 3.7). The names of the experiments are given as well as varied parameters.

run name (short)	run name (descriptive) [width_length_motivation_addition]	no. of participants	width [m]	length [m]	motivation [h0: normal; h1: hurry; h2: full commitment; he: normal-hurry]	line-up	special announcement
4D000	test01	136	1.2	2.0	h0	2 m semi-circle	explanation h0
4D001	test02	136	1.2	2.0	h1	2 m semi-circle	explanation h1
4D002	test03	136	1.2	2.0	h2	directly at bottleneck	explanation h2, abort signal
4D010	w120_l200_h0	136	1.2	2.0	h0	2 m semi-circle	-
4D020	w120_l200_h1	136	1.2	2.0	h1	2 m semi-circle	-
4D030	w080_l200_h0	161	0.8	2.0	h0	2 m semi-circle	-
4D040	w080_l200_h1	160	0.8	2.0	h1	2 m semi-circle	-
4D050	w160_l021_h0	125	1.6	0.2	h0	2 m semi-circle	-
4D060	w160_l021_h1	129	1.6	0.2	h1	2 m semi-circle	-
4D070	w120_l021_h0	153	1.2	0.2	h0	2 m semi-circle	-
4D080	w120_l021_h1	129	1.2	0.2	h1	2 m semi-circle	-
4D090	w100_l021_h0	152	1.0	0.2	h0	2 m semi-circle	-
4D100	w100_l021_h1	131	1.0	0.2	h1	2 m semi-circle	-
4D110	w080_l021_h0	132	0.8	0.2	h0	2 m semi-circle	mix up: first row queue behind
4D120	w080_l021_h1	132	0.8	0.2	h1	2 m semi-circle	-
4D130	w080_l021_h2	129	0.8	0.2	h2	directly at bottleneck	-
4D140	w080_l021_h1_AoO15	2 at a time total: 122	0.8	0.2	h1	4 m semi-circle positions: 0°, 180°	-
4D150	w080_l021_h1_AoO13	2 at a time total: 152	0.8	0.2	h1	4 m semi-circle positions: 0°, 90°	-
4D170	w080_l021_h1_AoO135	3 at a time total: 75	0.8	0.2	h1	4 m semi-circle positions: 0°, 90°, 180°	-
4D171	w080_l021_h1_AoO125	3 at a time total: 57	0.8	0.2	h1	4 m semi-circle positions: 0°, 45°, 180°	-
4D172	w080_l021_h1_AoO1245	4 at a time total: 116	0.8	0.2	h1	4 m semi-circle positions: 0°, 45°, 135°, 180°	-
4D173	w080_l021_h1_AoO12345	5 at a time total: 115	0.8	0.2	h1	4 m semi-circle positions: 0°, 45°, 90°, 135°, 180°	-
4D180	w070_l021_h1_interrupt	150	0.7	0.2	h1	2 m semi-circle	interruption: technical, questionnaire
4D200	w070_l021_h0	168	0.7	0.2	h0	2 m semi-circle	-
4D210	w070_l021_h1	169	0.7	0.2	h1	2 m semi-circle	questionnaire
4D181	w070_l021_h1_interrupt	164	0.7	0.2	h1	2 m semi-circle	interruption: technical
4D220	w070_l021_h2_025	25	0.7	0.2	h2	directly at bottleneck	-
4D230	w070_l021_h2_050	51	0.7	0.2	h2	directly at bottleneck	-
4D240	w070_l021_h2_075	77	0.7	0.2	h2	directly at bottleneck	-
4D250	w070_l021_h2_100	94	0.7	0.2	h2	directly at bottleneck	abort signal
4D251	w070_l021_h2_100	96	0.7	0.2	h2	directly at bottleneck	-
4D280	w070_l021_h1_push	158	0.7	0.2	h1	2 m semi-circle	20% active pushing, questionnaire, abort signal
4D281	w070_l021_h0	167	0.7	0.2	h0	-	no announced run / without 'go' signal
4D290	w070_l021_he_slow	201	0.7	0.2	he	2 m semi-circle	20% actively slowing down
4D291	w070_l021_he	168	0.7	0.2	he	2 m semi-circle	-
4D300	w060_l021_h0	187	0.6	0.2	h0	2 m semi-circle	
4D310	w060_l021_he	191	0.6	0.2	he	2 m semi-circle	
4D320	w060_l021_he_interrupt	101	0.6	0.2	he	2 m semi-circle	interruption: information, questionnaire
4D330	w060_l021_he_interrupt	91	0.6	0.2	he	2 m semi-circle	interruption: information, questionnaire
4D340	w060_l021_h2	53	0.6	0.2	h2	directly at bottleneck	

A.10. Reprojection Error Camera

Table 20 Table showing the reprojection errors for the calibration points for each camera and day in the persons' default height.

day	area	camera	reprojection error at default height		
			average / cm	std. dev / cm	max / cm
1	B	SL_cam1	0.99	0.42	2.03
1	B	SL_cam2	1.01	0.64	3.28
1	B	SL_cam3	0.46	0.16	0.67
1	C	SL_cam4	0.98	0.5	1.59
1	C	SL_cam5	1.21	0.66	2.88
1	C	SL_cam6	0.51	0.25	0.92
1	D	SL_cam7	3.15	1.8	8.03
1	D	SL_cam8	0.62	0.49	1.54
2	B	SL_cam1	0.99	0.53	2.32
2	B	SL_cam2	0.96	0.47	2.19
2	B	SL_cam3	0.48	0.19	0.68
2	C	SL_cam4	0.98	0.5	1.59
2	C	SL_cam5	1.21	0.66	2.88
2	C	SL_cam6	0.51	0.25	0.92
2	D	SL_cam7	1.51	0.88	2.74
2	D	SL_cam8	0.47	0.42	1.18
3	B	SL_cam1	0.99	0.53	2.32
3	B	SL_cam2	0.96	0.47	2.19
3	B	SL_cam3	0.48	0.19	0.68
3	C	SL_cam4	0.98	0.5	1.59
3	C	SL_cam5	1.21	0.66	2.88
3	C	SL_cam6	0.55	0.26	0.81
3	D	SL_cam7	1.51	0.88	2.74
3	D	SL_cam8	0.47	0.42	1.18
4	C	SL_cam4	1.21	0.67	2.79
4	C	SL_cam5	1.5	0.73	2.85
4	C	SL_cam6	0.6	0.25	1.05
4	C	RX0_cam2	1.35	0.5	2.33
4	D	GP7_1	3.66	2.1	7.47
4	D	RX0_cam1	0.45	0.23	0.81