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Visualizing ventilation in the bus: Addressing risk perception in public transport passengers

Anna Helfers [a,b,*], Natalie Schneider [a], Johanna Koch [a], Lea Fouckhardt [a], Carsten Sommer [a]

[a] *Transportation Planning and Traffic Systems, Faculty of Civil and Environmental Engineering, University of Kassel, Mönchebergstr. 7, 34127 Kassel, Germany*

[b] *Developmental Psychology, Institute of Psychology, Faculty of Human Sciences, University of Kassel, Holländische Str. 36 – 38, 34127 Kassel, Germany*

A R T I C L E I N F O

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Intervention
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A B S T R A C T

Background: This study evaluated the effectiveness of a communicative intervention in addressing passengers' increased risk perception of getting infected with COVID-19 in public buses and thereby improving travel-related well-being after the pandemic.
Method: A pre-registered quasi-experimental field-study (N = 306) was conducted in two public bus line bundles. The intervention consisted of visualizing the fresh air supply in the bus via tinsel garlands.
Findings: The intervention successfully increased passengers' awareness of fresh air supply in the bus (in the intervention group as compared to the control group; d = 0.25). However, this awareness did neither reduce passengers' risk perception, nor did it increase their subjective well-being in the bus. An explorative analysis identified crowding, and general COVID-19 risk perception as major predictors of risk perception on-board.
Conclusion: The study revealed first-hand, real-time insights in bus passengers' risk perception, travel well-being and their major predictors during the out fading COVID-19 pandemic.

1. Introduction

Developing a resilient and sustainable transportation system plays a major role for the economy, environment, and health in cities worldwide (Resolution adopted by the General Assembly on 25 September, 2015, 2015/Transforming our world: the 2030 Agenda for Sustainable Development). Convincing people to shift from private vehicles to public transport by installing a culture in which people perceive public transport as an efficient, cost effective and safe transport system is an important first step to addressing this challenge (Dahim, 2021).

Interfering with this aim, the COVID-19 pandemic has, however, caused an increased feeling of risk in public transport in the last years: The basic function of public transport to efficiently moving many people at small space became a major factor of concern for health during the COVID-19 pandemic. As there was limited knowledge on the transmission risk in public transport vehicles and effective mitigation measures in the beginning of the COVID-19 pandemic, (health) authorities advised the public to retain from the use of public transport (Tirachini & Cats, 2020). These warnings resulted in an increased public risk perception of getting infected with

* Corresponding author.
E-mail address: a.helfers@uni-kassel.de (A. Helfers).

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COVID-19 in public transport (Finbom et al., 2020; Helfers et al., 2022), which was associated with reduced well-being in public transport (Gnerre et al., 2022) and with declines in passenger numbers (Haghani et al., 2022; Palma et al., 2022). Reversing this trend is a major challenge for public transport associations, authorities, and operators after the COVID-19 pandemic. Addressing this challenge, public perceptions of public transport must be re-defined to be perceived as a safe and comfortable travel-mode.

This study developed and evaluated a communicative intervention (i.e., visualizing fresh air supply in public buses) aiming to address the increased risk perception of getting infected with COVID-19 in public transport passengers. Fostering the risk perception of ongoing passengers of public transport could contribute to potentially win them as multipliers in (re-) establishing a positive image of public transport as a safe space after the pandemic in the public (Helfers et al., 2022). This will be important as, for instance, Kumar and Sinha (2022) showed that safety perceptions, together with travel duration, frequency and comfort, play a major role in the perceived utility and willingness to pay for (and accordingly use) public transportation.

This study contributes to the literature in several ways: It developed an applicable communicative solution to reduce passengers' COVID-19 related risk perception and increasing their well-being on-board of a public bus and tested it in the field. Prior insights on risk perception and well-being of public transport passengers were mostly derived from survey studies (for an overview see here: Wang & Gao, 2022) and often focused on other aspects than health. Expanding this methodology, this study provides firsthand on-board data of passengers' experiences during a ride in the out fading COVID-19 pandemic. There is a general lack of methodologically sound evaluations of the impact of communicative interventions in the field which this study seeks to overcome by realizing a quasi-experimental design in the field. Finally, the study provides insights from the field on predictors of risk perception and well-being of passengers in pandemic or epidemic settings.

1.1. Literature review

In the following sections, a brief introduction to the relevance of ventilation and fresh air supply in public transport will be provided: The concepts of risk perception and travel-related subjective well-being will be defined, and an overview over their main determinants as derived from prior research will be given. It will be outlined how communicative interventions could play a significant role in reducing passengers' risk perception and thereby reinstalling travel-related well-being in public transportation in the aftermath of the COVID-19 pandemic.

1.1.1. Fresh air supply and the COVID-19 infection risk in public transport

Ventilation systems are central to reducing the risk of COVID-19 transmission during bus rides (Fouckhardt et al., 2023 Moreno et al., 2021; Zhou & Koutsopoulos, 2021). Ventilation systems in public buses are designed to exchange air with fresh air every few minutes (e.g. Hartmann & Kriegel, 2020; Eberspächer; Mercedes-Benz Buses, 2022) and public transportation personnel were instructed to maximize ventilation since the early stages of the pandemic (Steichele-biskup, 2020). The use of personal protective equipment, such as masks, further diminished the risk of getting infected with COVID-19 while using public transport (Ku et al., 2021; Tirachini & Cats, 2020). These effective risk mitigation measures in public transport, contribute to public transport being a rather safe travel mode, even during pandemic or epidemic phases (Charite Research Organisation CRO, 2021).

1.1.2. Risk perception of getting infected in public transportation

For an appropriate management of post-pandemic public transport systems, it is important to keep in mind that the subjective perception of transport passengers does not always correspond with the state-of-the-art knowledge or "objectively" quantified attributes of public transport. For instance "perceived accessibility" was found to differ from "objective estimations of accessibility" (Lukina et al., 2021), showing that it is important to focus on passengers' perceptions in addition to objective evaluations of public transportation, too.

Risk perceptions refer to people's evaluations of threats they are or might be exposed to in a specific situation (Rohrmann, 2008). Risk perceptions are based on a complex interplay of individuals' risk related beliefs, for instance regarding the quantitative dimension (i.e., the likelihood of getting infected with COVID-19 during the ride), the qualitative dimension (i.e., the severity of getting infected with COVID-19), and the epistemic dimension (i.e., the strength of beliefs regarding the prior questions) of risk (Bieber, 2018).

An increased risk perception for public transport was reported during the COVID-19 pandemic (Finbom et al., 2020; Helfers et al., 2022; Schneider et al., 2022; Shibayama et al., 2021). Helfers et al. (2022) and Schneider et al. (2022) investigated individuals' risk perception on using public transport during the COVID-19 pandemic by means of a panel survey. In the survey, risk perception was operationalized as passengers accumulated evaluation of "getting infected with COVID-19 in public buses" or "trams". The survey revealed an increased risk perception of getting infected with COVID-19 in public transportation as compared to comparable day-to-day situations (e.g., "going to the grocery store"). Passengers who kept on using public transportation during the COVID-19 pandemic reported a slightly lower risk perception than those who reduced their use or dropped out of public transport (Helfers et al., 2022). However, they still perceived this space as a rather risky environment and higher as compared to many other situations (Helfers et al., 2022). Addressing the increased risk perception of getting infected with COVID-19 in public transport will therefore be important for ongoing passengers as well as for the broader public.

The survey of Helfers et al. (2022) furthermore revealed that ongoing users of public transportation during the COVID-19 pandemic had distinct preferences of which risk mitigation measures taken in public transport they perceived as important to feel safe during the ride within the ongoing pandemic: The top-most important measures for passengers to feel safe in public transport in 2022 were fresh air supply via "maximal ventilation" together with "mandatory mask wearing" (Schneider et al., 2022), which is in line with the scientific state-of-the-art knowledge on the most effective risk mitigation measures in public transport (Fouckhardt et al., 2023).

Despite these measures were present in German public transportation at the time of the survey, risk perception for public transportation was however still increased in 2022 (Schneider et al., 2022) which indicated a need and a starting point for communication. In particular public buses were appraised as most risky travel mode of getting infected (Barbieri et al., 2021) and may therefore profit from communicative interventions

An intervention that visualized ventilation systems which are normally not directly perceivable for passengers in a public bus was developed. It was expected that increasing passengers' salience of fresh air supply via the ventilation systems in the bus would reduce their risk perception during the specific ride and for public buses in general.

Several predictors of risk perception during the COVID-19 pandemic were already known from former survey studies and considered as control variables in our study: On a *situational level*, travel duration (Lucchesi et al., 2022), the behavior of other passengers (Fellesson & Friman, 2011; Haghani et al., 2022; Noor et al., 2014; Rehman et al., 2020; Stradling et al., 2007; Susilo & Cats, 2014; van Lierop et al., 2018), other participants' compliance to mask wearing (Haghani et al., 2022; Helfers et al., 2022; Kłos-Adamkiewicz & Gutowski, 2022; Shelat et al., 2022; Sun et al., 2022), and crowded vehicles (Lucchesi et al., 2022; Shelat et al., 2022; Sun et al., 2022) had been found to influence risk perception. On a *personal level*, the perceived risk of getting infected with COVID-19 was found to be typically influenced by age and gender with older passengers feeling safer on-board (Böcker et al., 2023) and women feeling less safe (Böcker et al., 2023), health status (i.e. risk-group), socio-economic factors (Tagini et al., 2021), and the general risk perception towards COVID-19 (Haghani et al., 2022). The effect of using personal protective equipment, such as the effect of using an FFP2 face mask, had, to our knowledge, not been investigated yet, but as FFP2 masks are very effective in mitigating the risk of an infection with COVID-19, it was assumed that wearing FFP2 masks in contrast to surgery masks would make a difference in peoples' risk perception. Being vaccinated was found to have a minor impact on risk concern (Haghani et al., 2022).

1.1.3. *Subjective well-being in public transportation*

Subjective well-being constitutes a direct measure of passengers' travel-related satisfaction, including cognitive and affective judgments of the journey (De Vos et al., 2015; Gao et al., 2017; Wang & Gao, 2022). In the transportation domain it can be conceptualized as a short-term outcome of the experiences made during a single journey and also as a long-term outcome of these experiences accumulated (Mokhtarian, 2019).

Already before the COVID-19 pandemic, public transport passengers were identified as having the lowest levels of well-being among all other transport mode users: Subjective well-being of passengers was found to be lower as compared to active travelers (Friman et al., 2017; Gatersleben & Uzzell, 2007; Zhu & Fan, 2018), and as compared to users of private vehicles (De Vos et al., 2016; Friman et al., 2017). Especially using public buses was found negatively related to travel-related subjective well-being (Handy & Thigpen, 2019; Kruijf et al., 2019; Mokhtarian et al., 2015; St-Louis et al., 2014). Risk perception was identified as an important determinant of travel satisfaction and travel-related well-being for public transport passengers (Budiono, 2009; Figler et al., 2011; Lyons et al., 2008; Nathanail, 2008; Rehman et al., 2020; Shiwakoti et al., 2019; Stradling et al., 2007; van Lierop & El-Geneidy, 2016).

During the COVID-19 pandemic, public transport passengers reported a feeling of inconvenience, negative emotions, stress, and anxiety (DLR Transport, 2022; Meena, 2020). Safety concerns (Dong et al., 2021; Sun et al., 2022) and an increased risk perception (Gnerre et al., 2022) regarding COVID-19 were negatively related with subjective well-being. It was therefore expected that decreasing passengers' risk perception in public buses (via the intervention) would result in increased well-being during the ride.

From prior research several determinants were known from before the COVID-19 pandemic and therefore considered as potential covariates: The most important *situational determinants* of subjective well-being in public transportation were on-board comfort (dell'Olio et al., 2011; Fellesson & Friman, 2011; Noor et al., 2014; Rehman et al., 2020; Susilo & Cats, 2014; van Lierop et al., 2018), the occupation of the vehicle (Cox et al., 2006; Kumagai et al., 2021; Lundberg, 1976; Mahudin and Cox, 2011; Mohd Mahudin et al., 2012; Stradling et al., 2007; Tirachini et al., 2013), travel duration (Budiono, 2009; Ettema et al., 2012; Ettema et al., 2011; Morris & Guerra, 2015; St-Louis et al., 2014; Wener et al., 2003; Zhu & Fan, 2018) and the behavior of other passengers (Stradling et al., 2007). The most important determinants on a *personal level* were age, with older passengers and middle aged passengers being less satisfied than younger passengers, (Esmailpour et al., 2022; Ingvardson & Nielsen, 2019) and gender, with female passengers being less satisfied than males (Esmailpour et al., 2022).

1.1.4. *How to address the increased risk perception in public transport?*

The task of risk communication is to offer information that brings the subjective risk perception more in line with the objective risk assessment (i.e., the scientific expert model) (Atman et al., 1994; Bostrom et al., 1994). Therefore, information to fill knowledge gaps, to restructure risk related belief structures, or to correct false beliefs must be provided. The communicative intervention presented in this study addressed passengers' salience of the fresh air supply in public buses by visualizing the active ventilation with tinsel garlands at the ventilation outlets, supported by information.

As negative experiences and risk perception are often more salient in peoples' minds than positive experiences due to the human tendency of loss aversion (Kahneman & Tversky, 1979), it is important to enable passengers to make new, and very salient positive experiences in public transport. The fresh air supply via the ventilation systems in public transportation is typically not directly experienceable for passengers, as the ventilation systems are construed so that passengers are not directly exposed to the stream of fresh air for reasons of comfort (Ausschuss für Kraftfahrwesen [Committee for Motor Vehicles], 2018). Even though fresh air supply is turned to a maximum it is therefore likely that this might not be recognized by passengers. To provoke risk related belief change it was therefore assumed to be helpful for passengers to actively consider this factor and integrate the active ventilation into their situational belief model of the risk in public transport.

In the presence of prior risk beliefs, simply providing persuasive informational signals is often not enough. Instead, belief change requires signals that trigger active and elaborative processing to actively reconsider and potentially replace false beliefs (e.g.; Markant et al., 2022). Here, visualizations can play a significant role. Visualizations are engaging and interactive and therefore stimulate deeper elaboration and learning (e.g., Markant et al., 2022; Rapp, 2005), which makes them more memorable and easy to integrating into existing mental model (e.g., Bateman et al., 2010; Houts et al., 2006). When being exposed to visualizations, perceivers draw inferences themselves (Johnson-Laird, 1995, 1983; Schnotz & Kürschner, 2008) which might be helpful in preventing backfiring effects that sometimes arise in health communication (Markant et al., 2022; Morgan, 2002).

1.2. Hypotheses

Based on the considerations above, the following hypotheses were formulated.

Hypothesis 1: The visualization of fresh air reduces the situational perception of the risk of getting infected with COVID-19 during the stay in the bus. In the quasi-experiment, participants in the intervention condition are expected to report lower risk perception of "getting infected with COVID-19 in this bus" as compared to participants in the control group.

Hypothesis 2: The visualization of fresh air reduces the general perception of the risk of getting infected with COVID-19 during the stay in buses in general. In the quasi-experiment, participants in the intervention condition are expected to report lower risk perception of "getting infected with COVID-19 in buses in general" as compared to participants in the control group.

Hypothesis 3: The visualization of fresh air increases the situational subjective well-being during the stay in the bus. In the quasi-experiment, participants in the intervention condition are expected to report higher subjective well-being "during the ride in this bus" as compared to participants in the control group.

2. Methods

2.1. Study design

The intervention was evaluated using a quasi-experiment (i.e., participants were not randomly assigned to the selected bus lines, but it was taken care to select two comparable bus line bundles). We realized a one-factorial between-subjects design with the factor *intervention* (intervention vs. control condition) and the dependent variables *risk perception in this bus*, *risk perception in buses in general*,

Table 1
Sociodemographic Characteristics of Participants.

	Frequency (%)
Age [in years]	
Min	18
Max	86
M (*SD*)	296; 42.68 ± 19.13
median	41.5
Gender	
Male	114 (38.38 %)
Female	183 (61.62 %)
Nonbinary	0 (0 %)
No answer	9 (2.94 %)
Occupation	
Employed	147 (50.17 %)
Not employed	15 (5.12 %)
Retired	54 (18.43 %)
Student	33 (11.26 %)
Scholar or Trainee	36 (12.29 %)
Care work	8 (2.73 %)
No answer	13 (4.25 %)
Ticket	
Single or short trip ticket	45 (14.85 %)
Day-Ticket, Group ticket	61 (20.13 %)
Weekly/monthly pass without subscription	59 (19.47 %)
Annual/monthly pass with subscription	47 (15.51 %)
Semester/School/Seniors Ticket	71 (23.43 %)
Other	20 (6.60 %)
No answer	3 (0.98 %)
Reason for travel	
Doing groceries	50 (16.56 %)
Commuting	140 (46.36 %)
Leisure activities	34 (11.26 %)
Just to leave the house	3 (0.99 %)
Care work	50 (16.56 %)
Other private duties	11 (3.64 %)
No answer	4 (1.31 %)

Note. $N = 306$.

and *subjective well-being in the bus*. To account for potential prior differences between the two conditions, situational and personal control variables (see Table 2) were assessed and systematically explored before testing the hypotheses (see Results).

2.1.1. *Intervention: Visualization of fresh air*

The salience of the ventilation was quasi-experimentally manipulated. In the intervention condition, the ventilation was visualized within the bus by means of tinsel garlands, supported by posters and signs at the ceiling-mounted grab handles (the material can be inspected in the supplementary material on OSF). A total of ten approximately 30 cm long glittering tinsel garlands were attached to the ceiling at the outlets of the ventilation system. When the ventilation was switched on, a typical "fluttering movement" was created, which is associated with air movement. The posters contained information about the supply of fresh air in the bus. They were printed in DIN A3 format and placed at four distinct positions in the bus. One poster faced outwards next to the front door, the second behind the driver's position towards the passenger compartment. The third poster was attached on the side window in the multifunctional area, and the last poster was placed on a partition next to the rear door and oriented towards the rear passenger compartment. As a third element, seven to eight hanging signs were attached to the buses' grab handles in the multi-functional area of the buses. The signs contained the same information referring to the fresh air supply in the bus as the poster. In the control group, there was no communication of the ventilation in the bus. However, on both bus line bundles the driving personnel were instructed to turn the ventilation to the maximum, keep windows closed and to open doors at every stop.

2.1.2. *Risk perception*

The outcome variable risk perception was assessed with the items "How high do you estimate the risk of becoming infected with COVID-19 <u>in this moment in this bus</u>?" (*situational risk perception*) and "How high do you estimate the risk of becoming infected with COVID-19 <u>in buses in general</u>?" (*risk perception for buses in general*). Participants evaluated the items on a five-point Likert scale ranging

Table 2
Operationalization of the Situational and Personal Control Variables.

Situational control variables		
Travel duration	*Approximately how long does your ride on this bus take (in minutes)?*	[in minutes]
	Please evaluate how much the following aspects apply to this bus right now.	
Comfort	*It is comfortable to ride this bus.*	[Five-point Likert scale] 1 (does not apply at all) to 5 (fully applies)
Behavior of other passengers	*My fellow passengers are behaving quietly.*	
Occupation	*This bus is very crowded.*	
Compliance to mask wearing	*Other passengers are compliant with the mask wearing mandate.*	
Personal control variables		
General COVID-Risk perception	*How high do you estimate the risk of infection with COVID-19 in the following situations?* *Doing groceries* *In school* *At work* *When going for a walk* *Meeting friends at home*	[Five-point Likert scale] 1 (very low) to 5 (very high)
Age	*How old are you?*	[in years]
Gender	*What gender are you?*	[Single Choice Item] Male Female Nonbinary
Risk group	*A disease with COVID-19 would be particularly dangerous for me.*	[Single Choice Item] Yes No No answer
Target group reducer	*I use the bus because of the COVID-19 pandemic…….*	[Five-point Likert scale] 3 (much less) to 7 (much more)
	Please rate how much the following aspects apply <u>to you personally right now</u>.	
Vaccination	*I have been vaccinated against COVID-19.*	[Single Choice item] • Yes • No • No Answer
FFP2/3 mask	*I am wearing a surgical mask.* *I wear an FFP2/FFP3 mask (without valve).* *I wear an FFP2/FFP3 mask (with valve).*	

from 1 (very low) to 5 (very high). The two items were selected for the investigation as similar items had been used in prior research conducted during the research project this study was conducted in (Helfers et al., 2022; Schneider et al., 2022) and in further investigations during the COVID-19 pandemic in Germany (DLR Transport, 2022), allowing to compare this studies' findings with prior research.

2.1.3. Subjective well-being

The outcome variable subjective well-being was measured and computed as mean of the two items "I feel comfortable on this bus." and "I like sitting in this bus.", which were evaluated on a five-point Likert scale ranging from 1 (very low) to 5 (very high). These items referred to the hedonic aspect (i.e., the presence of positive affect and the absence of negative affect during while traveling) of experienced travel well-being during the ride (De Vos et al., 2013; Mokhtarian, 2019). The two items were supposed to capture the cognitive and affective aspect of well-being in the bus. The first item was derived from former research on mobility during the COVID-19 pandemic (DLR Verkehr, 2023).

2.1.4. Control variables

Even though it was taken care to select two very comparable bus line bundles, it was assumed that certain relevant determinants of our dependent variables might not be fully balanced between both bus line bundles (i.e., the quasi-experimental conditions). Therefore, situational, and personal control variables as derived from prior research (see Table 2 for an overview), allowing to statistically control for these variables in case they were confounded with the two quasi-experimental conditions.

2.1.5. Manipulation check

As a manipulation check, the item "I recognize fresh air coming into this bus." was evaluated on a five-point Likert scale ranging from 1 (not at all) to 5 (very much). In addition to that, it was assessed which elements of the intervention ("tinsel garlands", "poster", signs on the grab handles ", "none of these") participants in the intervention group had noticed. This last question was not presented in the control group since commuter numbers and commuter matrixes proposed the two districts having no share in passengers.

2.1.6. Socio-demographic

Age, gender, occupation, the ticket participants were traveling with, and their reason for travel was assessed.

2.2. Data collection

The study was preregistered on OSF: https://doi.org/10.17605/OSF.IO/4KNVP.

Written informed consent from each participant was obtained in the beginning of the study. Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements.

Data collection took place in the period from 20th to 30th September 2022 on working days between 8:30 am to 12:30 pm and from 01:30 pm to 06:00 pm. Unlike preregistered, there was indeed school transport service offered in some of the buses. Therefore, data-collection was paused in the school transportation peeks before 8:30 h and from 12:30 pm to 02:30 pm. At the time of the data collection, Germany was at the beginning of the sixth pandemic wave (with raising infection numbers). Mask wearing was mandatory (only) in public transportation in the State of Hesse. The omicron variant BA.5 was dominant (Robert Koch Insitut, 2022). The seven-day incidence in the local district increased from 305.8 to 590.8 and the hospitalization rate in Hessen increased from 3.13 to 6.56 during the sampling period (Robert Koch Insitut, 2023). People in Hessen revealed a moderate affective risk towards COVID-19 (COVID-19 Snapshot Monitoring, 2023). German-wide 76.29 % of the population had received their basic vaccination (62.17 % had received a booster) (Bundesministerium für Gesundheit, 2023).

The quasi-experiment took place in two bus line bundles that were considered comparable in terms of transport function and occupancy rate according to the local public transportation organization. The two bus line bundles where located within one service area next to a medium-sized city of a metropolitan urban region in Germany (Bundesministerium für Digitales und Verkehr [Federal Ministry for Digital and Transport], 2021). In both bus line bundles UV virus filters from Heraeus were installed below the ceiling of the buses. The buses, in which the intervention took place, were midi buses with a capacity of maximum forty passengers. The buses in the control group were standard buses with a higher capacity.

In each bus either one or two of our trained interviewers were present. Our interviewers approached passengers after they had entered the bus and had time to look around: They introduced themselves and the study and invited passengers to take part in the study. Participants required to be at least 18 years old and must not have had participated in the study before. After checking these eligibility criteria, the interviewers handed over the printed questionnaire to the participant. The questionnaire was then completed by the participant during the bus ride. However, if participants had problems to understand the questionnaire, the interviewers helped to translate the questions into simple language and offered a visual analogue scale to explain the concept of the Likert scales (see Supplementary Material on OSF). Participants were not rewarded for their participation.

2.3. Statistical procedure

Before beginning with the data collection, the software program G*Power version 3.1.9.2. (Faul et al., 2007) was applied to conduct an a priori sample size planning for these tests. Our goal was to obtain power of 1- $\beta = 0.95$ to detect a medium effect size of $d = 0.5$ with an alpha error probability of 0.05 in each of. Accounting for a Bonferroni correction for these three tests by entering an alpha error of $a = 0.017$ the application revealed that 117 persons per experimental group were required, resulting in a total target sample size of 234 participants. Assuming that not all participants might complete the full questionnaire, it was attempted to recruit at least 250 participants.

After completion of the data collection, the printed versions of the completed questionnaires were digitalized via Lime-Survey and the dataset was exported to R Version 4.2.1. The two items measuring subjective well-being revealed a good internal consistency (Cronbach's Alpha = 0.84), so the outcome variable subjective well-being was computed as mean of the two items "I feel comfortable on the bus." and "I like sitting in this vehicle.". As the items for general risk perception in the control situations revealed good internal fit (Cronbach's Alpha = 0.70), we computed generalized risk perception as a mean of these items. The dummy coded variable reducer was built and coded with 1 if passengers reported using public transport because of the pandemic "much less frequent" or "less frequent", and with 0 if passengers reported using it "on the same level", "more" or "much more". The dummy coded variable FFP2 mask was build and coded with 1 if passengers reported wearing an FFP2/FFP3 mask without valve or with valve and with 0 if passengers reported wearing a surgical mask.

It was planned to conduct either three one-sided t-tests or ANCOVA's (in case of detecting confounded variables) to test the hypotheses. All tests were conducted on an alpha error probability of 0.05 (and Bonferroni corrected where necessary). This statistical procedure was pre-registered https://doi.org/10.17605/OSF.IO/4KNVP.

3. Results

3.1. Sample

In total, 328 participants took part in the study. Participants without or with a missing informed consent were excluded ($n = 18$), with missing data regarding their experimental condition ($n = 1$), or regarding all three dependent variables ($n = 3$) were excluded. The final sample consisted of 306 participants (intervention group $n = 154$, control group $n = 152$; 183 women, 114 men, 9 with no answer; aged between 18 and 86 years, $M = 42.68$ years, $SD = 19.13$). Participants in the intervention and control group did not differ significantly regarding their socio-demographic data (all $ps > 0.124$). For more socio demographic information see Table 1.

3.2. Manipulation check

Overall, participants' salience of fresh air in the bus ranged from 1 (does not apply at all) to 5 (does fully apply) with $M = 3.12$ ($SD = 1.42$). As expected, participants in the intervention group agreed more strongly ($M = 3.30$; $SD = 1.42$) to the statement "I notice fresh air coming into the bus." as compared to participants in the control group ($M = 2.95$; $SD = 1.40$), $t(286) = 2.16$, $p = .032$, $d = 0.25$. The intervention thus successfully increased the salience of the ventilation system of the bus with a small effect size. The tinsel garlands (46.8 %) and the poster (46.1 %) were noticed most often, followed by the hanging signs on the grab handles (39.6 %), however, 28.8 % of the passengers in the intervention group reported having noticed none of the elements.

3.3. Explorative analysis concerning potentially confounding variables

Before testing the three hypotheses, it was exploratively investigated whether there were any confounding variables in the data. This procedure had been preregistered, as the quasi-experimental design did not allow us full control over the situation and passengers' personal characteristics in both conditions. Therefore, it was tested whether there were any a priori differences between situational or personal control variables in both bus line bundles that potentially could have affected the impact of the intervention on the dependent variables systematically. A summary of the descriptive findings of the situational and personal potential covariates for the full sample can be found in Table 3 and Table 4.

The explorative analysis revealed the following a priori differences between both bus line bundles: Participants in the intervention group reported a shorter travel duration ($M = 17.99$, $SD = 9.48$) than those in the control group ($M = 23.9$, $SD = 18.94$), $t(272) = -3.27$, $p = .001$, $d = -0.40$. They also more strongly agreed to the statement that their fellow passengers behaved calm (intervention: $M = 4.40$, $SD = 1.08$, control: $M = 4.11$, $SD = 1.15$), $t(284) = 2.18$, $p = .030$, $d = 0.26$, and that fellow passengers were compliant to mask wearing (intervention: $M = 4.48$, $SD = 1.06$, control: $M = 3.78$, $SD = 1.36$), $t(293) = 4.92$, $p < .001$, $d = 0.57$. There were no a priori differences between passengers in both groups regarding the other situational control variables (i.e., comfort and occupation) and their

Table 3
Descriptive Findings for Situational Control Variables.

	n	*Min*	*Max*	*M*	*SD*	*Mdn*
Travel duration (in minutes)	274	4	150	20.92	15.21	18
Comfort[†]	283	1	5	3.87	1.08	4
Behavior of fellow passengers [†]	286	1	5	4.26	1.12	5
Occupation[†]	283	1	5	1.99	1.26	1
Compliance to mask wearing (by fellow passengers)[†]	295	1	5	4.13	1.26	5

Note. N = 306.
[†] Evaluated on five-point Likert scales ranging from 1 (does not apply at all) to 5 (fully applies).

Table 4
Descriptive Findings for Personal Control Variables.

	n	*Min*	*Max*	*M*	*SD*	*Mdn*
General COVID-19 Risk perception*	289	1	5	2.53	0.86	2.6
Age (in years)#	296	18	86	42.68	19.13	41.5
	Code	*n (%)*		*Code*	*n (%)*	
Female †	0	114 (38.38 %)		1	183 (61.62 %)	
Risk group †	0	173 (71.78 %)		1	68 (28.22 %)	
Target group reducer †	0	243 (82.09 %)		1	53 (17.91 %)	
Vaccinated †	0	27 (9.61 %)		1	254 (90.39 %)	
FFP2/3 mask †	0	197 (74.06 %)		1	69 (25.94 %)	

Note. N = 306.
* Evaluated on a five-point Likert scale ranging from 1 (very low) to 5 (very high).
† Dummy coded: 1 = yes, 0 = no/NA.
# Evaluated in years.

personal control variables (i.e., general COVID-19 risk perception, age, gender, risk group, target group, vaccination, or FFP2/3 mask) (all *ps* > 0.124).

In a next step, it was checked whether the variables that differed between both bus line bundles were also significantly correlated with any of the dependent variables and therefore represent confounding variables. The analyses revealed that travel duration was significantly correlated with situational risk perception in the bus, $r(255) = 0.16$, $p = .009$, and with risk perception in buses in general, $r(250) = 0.14$, $p = .023$. Hence, travel duration will be treated as a confounding variable for these two dependent variables. For the dependent variable subjective well-being, the behavior of fellow passengers, $r(282) = 0.52$, $p < .001$, and the compliance to mask wearing of other passengers, $r(287) = 0.43$, $p < .001$, were confounding variables.

3.4. Evaluating the effectiveness of the intervention

As the explorative analyses had identified relevant confounding variables, the hypotheses were evaluated controlling for these variables by using three ANCOVAs (Bonferroni corrected $p_{crit} = 0.017$, one-sided testing) instead of t-tests.

Hypothesis 1 – The intervention reduces passengers' risk perception in this bus: In the full sample, the dependent variable risk perception in this bus was evaluated on a range from 1 (very low) to 5 (very high) with M = 2.08 (SD = 1.20). The hypothesis that the intervention reduces risk perception in this bus was tested with an ANCOVA with the independent variable experimental condition, the dependent variable risk perception in this bus, and the control variable travel duration. Only cases without missing values in these variables were considered (n = 257). The analysis revealed no significant effect of the experimental condition on risk perception in this bus, $F(1, 254) = 0.99$, $p = .322$, but a significant and small effect of travel duration, $F(1, 254) = 6.96$, $p = .009$, $\eta^2_{partial} = 0.03$. Hence, after controlling for the confounding variable travel duration, participants in the intervention group expressed no decreased risk perception in this bus, leading to a rejection of hypothesis 1.

Hypothesis 2 – The intervention reduces passengers' risk perception in buses in general: In the full sample, risk perception in buses in general was evaluated on a range from 1 (very low) to 5 (very high) with M = 3.09 (SD = 1.23). The hypothesis that the intervention reduces risk perception for buses in general was tested with an ANCOVA with the independent variable experimental condition, the dependent variable risk perception in buses in general, and the control variable travel duration. Only cases without missing values in these variables were considered (n = 252). The analysis revealed no significant effect of the experimental condition on risk perception for buses in general, $F(1, 249) = 3.38$, $p = .067$, but a significant and small effect of travel duration, $F(1, 249) = 5.26$, $p = .023$, $\eta^2_{partial} = 0.02$. Hence, after controlling for the confounding variable travel duration, participants in the intervention group expressed no decreased risk perception in buses in general, leading to a rejection of hypothesis 2.

Hypothesis 3 – The intervention enhances passengers' well-being in the bus: Subjective well-being during the ride ranged from 1 (does not apply at all) to 5 (does fully apply) with M = 3.87 (SD = 1.09). The hypothesis that the intervention increases subjective well-being during the ride was tested with an ANCOVA with the independent variable experimental group, the dependent variable subjective well-being in the bus, and the control variables behavior of other passengers, and compliance to mask wearing of other passengers. Only cases without missing values in these variables were considered (n = 282). The analysis revealed no significant effect of the experimental condition on subjective well-being, $F(1, 278) = 1.18$, $p = .279$, but a significant and large effect of other passengers' behavior, $F(1, 278) = 103.58$, $p < .001$, $\eta^2_{partial} = 0.27$, and a small effect of their compliance to mask wearing, $F(1, 278) = 9.77$, $p = .002$, $\eta^2_{partial} = 0.03$. Hence, after controlling for the behavior of other passengers and their compliance to mask wearing, participants in the intervention group reported no increased subjective well-being in the bus, leading to a rejection of hypothesis 3.

Repeating these analyses after excluding participants who had not recognized the intervention: As the manipulation check had identified that 28.6 % of the persons in the intervention condition had not recognized any part of the intervention, it was exploratively tested whether the intervention was effective after excluding those persons who had not recognized the intervention ($n = 44$). But also when considering only those people in the intervention group, who had recognized at least one element of the intervention ($n = 110$) in comparison with the control group ($n = 152$), no effect of the intervention on risk perception in this bus ($p = .139$), and in buses in general ($p = .168$), or on subjective well-being was found ($p = .479$).

3.5. The most important predictors of risk perception and subjective well-being

Even though the intervention was not successful in influencing risk perception and subjective well-being in the bus, this study may contribute to the literature by giving more appropriate information about passengers' subjective well-being on-board and its determinants during the COVID-19 pandemic. Therefore, explorative analyses, seeking to identify the most crucial predictors of situational risk perception and subjective well-being during a bus passage on a cross-sectional level will be summarized in the following section. For this approach, all potential covariates of situational risk perception and subjective well-being were considered for an exhaustive multiple regression model analysis. The Bayesian Information Criterion (BIC) is a useful criterion for model selection as it balances model fit with model complexity while also avoiding overfitting and was therefore applied for model selection.

According to the BIC criterion, situational risk perception on-board was predicted most exhaustively by the four predictors crowding in the vehicle, general risk perception of getting infected in buses, general COVID-19 related risk perception, and having reduced ridership during the pandemic, $R^2_{adj} = 0.40$, $F(4, 167) = 29.6$, $p < .001$. Risk perception on-board significantly increased with increasing crowding in the vehicle ($\beta = 0.40$, $p < .001$), with passengers' increasing risk perception towards getting infected in buses ($\beta = 0.30$, $p < .001$), and increasing general risk perception towards COVID-19 ($\beta = 0.26$, $p < .001$). Risk perception was slightly decreased in passengers who had decreased their public transport usage during the pandemic (reducers) ($\beta = -0.17$, $p = .005$) (β represent standardized coefficients).

According to the BIC criterion, passengers' subjective well-being on-board was predicted most exhaustively by the three predictors comfort, compliance to mask wearing of other passengers, and salience of fresh air in the bus, $R^2_{adj} = 0.47$, F(3, 168) = 51.5, p < .001. Subjective well-being increased significantly with increasing comfort ($\beta = 0.47$, $p < .001$), with increasing salience of fresh air ($\beta = 0.30$, $p < .001$) and with increasing compliance to mask wearing by other passengers ($\beta = 0.17$, $p = .005$) (β represent standardized coefficients).

4. Discussion

Although the intervention was successful in increasing passengers' salience of the fresh air supply in the bus, this did not affect their infection risk perception, nor their subjective well-being during the ride. The intervention was thus not sufficient in triggering changes in risk perception or travel well-being in public transportation in the out fading phase of the COVID-19 pandemic.

Even though it had been taken care to create a very salient intervention, 28.6 % of the participants in the bus line with the intervention did not recognize it all. The intervention was thus not as salient as intended, which might have prevented effects of the intervention on risk perception and subjective well-being. Another important reason for the null effect can be found when looking at the descriptive findings of risk perception and well-being: These show that situational risk perception was evaluated "low" to "medium" in both conditions which contradicts former findings that the risk of traveling with buses during the pandemic is commonly perceived as "high" (Helfers et al., 2022; Schneider et al., 2022). These already low levels of situational infection risk in both conditions might have caused a floor effect for risk perception. During the experiment, mask wearing in public transport was still mandatory in Germany and therefore all participants in our study wore face masks. As mask wearing has a major effect on the infection risk (Ku et al., 2021; Tirachini & Cats, 2020), ventilation on-top of the mask mandate might have no additional use for passengers' subjective risk perception. In the same vein, an overall high level in subjective well-being was found in both conditions, which might have caused a ceiling effect for this variable. The selected bus line bundles were evaluated by the participants as quite comfortable and rather empty, with fellow passengers being rather calm and compliant to mask wearing. It is thus possible, that the intervention would be more effective at other timepoints or in other samples, or when being present for a longer time.

The explorative analysis revealed that risk perception on-board was most strongly associated with crowding in the vehicle and by passengers' general pandemic risk perception (comprising their generalized risk of getting infected with COVID-19, their risk perception of getting infected in buses, and whether they had reduced ridership during the pandemic). Other situational cues (such as fresh air supply, the behavior of other passengers, and their compliance to mask wearing) and personal factors (such as being vaccinated or wearing an FFP2 mask), were of minor predictive power for risk perception in the sample. In line with former approaches to belief change (Hoeken, 2001; Yang et al., 2022), personal risk beliefs were very stable and immune to the intervention. Surprisingly, passengers who had reduced their use of buses because of the pandemic revealed even lower risk perception than those who had kept on using it regularly. One possible explanation for this effect is however that captive public transportation passengers perceive higher risk than people who have the choice to adapt their public transportation usage depending on the pandemic stage (Zhao & Gao, 2022).

The explorative analysis furthermore revealed that subjective well-being on-board was rather independent of passengers risk perception, which is in line with Sun et al. (2022). Instead, subjective well-being was most strongly associated with comfort, salience of fresh air, and compliance to mask wearing of other passengers. It is remarkable that the last two factors significantly affected subjective well-being but not risk perception. This indicates that passengers might approve the compliance to mask wearing and the salience of fresh air due to other reasons than risk mitigation. Observing other passengers' non-compliance to mask wearing could for instance be understood as an observed norm violation, causing moral feelings and outrage (Montada, 1993). Furthermore, observing other passengers not complying to the rules might also have caused negative arousal and stress in passengers as disputes about the mask obligation were associated with increased violence in public transportation (e.g. Jenkins, 2023). Providing information on fresh air in turn might be understood more in the sense of a service feature than as a risk mitigation strategy (Beecroft & Pangbourne, 2015; Friman et al., 2017).

4.1. Practical implications for communication in public transport

The findings in principle support the idea that bus passengers could profit from communicating the fresh air supply in terms of well-being. It is therefore recommended to further elaborate on how fresh air supply could be made experienceable for passengers of public transportation. However, it should be taken care that the ventilation itself does not negatively influence passengers' comfort during the ride, as this was the main predictor of passengers' subjective well-being as outlined in this study. It is recommended to conduct pilot tests to identify the most powerful communicative intervention for the ventilation system before evaluating it in the field and before installing it as a standard design feature in vehicles. The tinsel garlands were the element of the intervention in this study that was most often recognized and might constitute a good starting point for further research.

In addition to the need of communicating fresh air supply, this study also outlined further relevant topics to increase passengers' subjective well-being. Perceived comfort was identified as the most important predictor of well-being on-board and should therefore be maximized to increase passengers' well-being. In times of mandatory mask wearing, increased security measurements should be taken so that passengers do not fear that violations of the mask mandate provoke conflicts and become a security concern during the journey. This is in line with the finding that passengers evaluated the control of the mask obligation as an important measure (Schneider et al., 2022). While mask wearing of other passengers was an important predictor for passengers' risk perception, wearing personal protective equipment (i.e., FFP2 masks) themselves did not increase safety perception. This finding indicates further need for communication. In times after mandatory mask wearing, an emphasis in communication should therefore be made on how well wearing FFP2-masks protect oneself – independently of the behavior of other passengers. This might help to make passengers feel well by giving them control over their own infection risk.

An interesting take-away from this study is, that passengers indeed felt rather safe and well during the ride in the bus line bundles selected for this study. This is in line with other findings of Esmailpour et al. (2022) and Rehman et al. (2020) that – when approached in the vehicles – passengers felt quite well in buses during the COVID-19 pandemic. One explanation for this finding is, that the high-risk perception regarding public transportation, as commonly reported in survey studies, could be understood more as an expression of the cumulative risk of using public transportation during the COVID-19 pandemic, than as a judgment of the perceived safety during a single ride. This has important practical implications for communication as it shows that the beliefs underlying cumulative risk perception must be addressed by further attempts than just highlighting passengers' situational safety on-board. State-of-the-art scientific insights on the safety of using public transportation during longer periods within epidemic or pandemic settings could be communicated to address general risk perception of using public transport.

One important side note should be made regarding the training of the personnel in the bus. Our interviewers reported that some bus drivers were not familiar with the functioning of the automatic ventilation. Therefore, an important take away from this study, is that training for the personnel on the ventilation systems is required, not only in terms of the relevance of ventilation for safety but also in terms of practical information on how to use these systems.

4.2. Limitations and Future directions

This study contributes to the research field by delivering first-hand on-board data of determinants of public transportation passengers' risk perception, their well-being during the out fading COVID-19 pandemic. A major effort was made to collect real-time on-board data, and a high number of participants was achieved. As the data was gathered from real passengers of public transport within the field the data is of high ecological quality.

The study is however limited by its focus on a quite comfortable bus line bundle in a medium sized city, to a specific phase of the pandemic with an active mask wearing policy in public transport as well as by the sample consisting of ongoing passengers of public transportation. Former research has identified that this group of ongoing passengers evaluated to risk of getting infected in public transportation lower than persons who avoided public transportation during the pandemic (Helfers et al., 2022), which might have suppressed the effectiveness of the intervention. It would be interesting to elaborate if the intervention is more effective in post-pandemic scenarios where mask wearing in public transportation is not mandatory anymore, in larger cities, and more stressful public transportation situations, or at other stages of insecurity, for instance in the beginning of upcoming, new epidemics, when people still try to build beliefs regarding the safety in public transportation.

Furthermore, field sampling is often limited by certain unpredicted issues, and this was also true for this study. During the sampling, the interviewers in the field reported that it was difficult for participants to relate the survey to their specific bus trip. In conversations about the questionnaire, participants often spoke abstractly about their bus travel in general, such as "The bus is always…" or "Normally the bus is…". In reaction to this, interviewers verbally emphasized that the questions referred to the current bus journey when distributing the questionnaire. Still, it might be that the situational risk perception and subjective well-being measures represent more cumulative experiences in buses in general than what was intended to capture.

The presented intervention focused on risk beliefs concerning the likelihood of an infection with COVID-19. The consequences of an infection (i.e., severity of an infection) naturally stay the same with or without ventilation. As the measure applied in this study captured risk perception as an accumulated evaluation of risk, individuals with an increased risk of a severe condition might still have evaluated the risk as high. Using a more differentiated measure for risk perception (i.e., capturing the dimensions of likelihood, severity, and susceptibility separately) is recommended to address this limitation. Similarly, the concept of well-being would have profited from using an established measure like the satisfaction with travel scale (Ettema et al., 2011) to make the findings better interpretable and generalizable.

An interesting extension of the study would be to communicate the ventilation system to target groups that still avoid public transportation because of the COVID-19 pandemic, for instance by using campaigns outside of the vehicles via videos or animations. It should furthermore be followed up on why compliance to mask wearing of other passengers contributes so much to passengers' subjective well-being. As crowding was shown to determine risk perception, it should furthermore be elaborated what levels of occupation in the vehicle are acceptable during various stages of the pandemic to better target communication strategies.

4.3. Conclusions

Overall, the findings contribute to the understanding of risk perception and subjective well-being in the context of public transportation during a pandemic. Even though the intervention was not effective in decreasing risk perception and increasing subjective well-being, the idea that passengers' salience of fresh air supply is a relevant correlate of subjective well-being during a pandemic of a respiratory disease was supported. In addition to that, situational risk perception was found to be mostly associated with crowding in the vehicle and with general risk perception of getting infected with COVID-19 in public buses and in other situations. Travel well-being was associated more strongly with situational factors as comfort on-board, salience of fresh air and compliance of other passengers to the mask policy. These insights are of direct practical relevance for public transport providers during upcoming pandemic and epidemic situations. By integrating the perspectives of risk perception concerning infectious diseases and travel related well-being with empirical insights from the field, this research extended prior – survey-based research. The study was limited by the specific stage of the pandemic it was realized in, by a quasi-experimental design and by the focus on ongoing users during the pandemic that were quite content with their journey. Future research should continue exploring the factors influencing risk perception and subjective well-being on-board of public transportation. Actionable and practical engaged scholarship is needed to further improve public transport passengers' risk perception and travel well-being during the transformation of transport systems in the upcoming years. Evidence-based practice from the field will play a key role in identifying communication needs in public transport users and non-users, in developing impactful interventions, and avoiding setbacks in the process to installing a sustainable post-pandemic mobility culture.

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Data statement

The data, together with an r markdown document and a codebook can be found on OSF.

CRediT authorship contribution statement

Anna Helfers: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Natalie Schneider:** Conceptualization, Investigation, Methodology, Project administration, Writing – review & editing. **Johanna Koch:** Investigation, Methodology, Validation. **Lea Fouckhardt:** Writing – review & editing. **Carsten Sommer:** Conceptualization, Funding acquisition, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

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

Data availability

The data, together with an r markdown document and a codebook can be found on OSF: https://osf.io/fd4a7/.

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Appendix A. Supplementary material

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