Results of the NSCR Curfew Study
(pre-print, version 1)

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Note that these are preliminary results from a not yet peer-reviewed study in progress. The final results will be available at osf.io/7ek9d. The study was partly financed by ZonMw (grant number: 50-56300-98-603) and the Municipality of Amsterdam. It was conducted independently by the authors. We would like to thank Laura Hendriks for her contribution to coding the footage.

Summary
Drawing on video footage from municipal public space cameras in Amsterdam, we investigated behavioral compliance with a curfew installed as a Covid-19 mitigating measurement in a period of lockdown. Based on the existing studies of the effect of curfews on aggregated transmission patterns (Baunez et al. 2020; Haug et al. 2021; Huber and Langen 2020), we expected that the curfew would lead to lower numbers of people on the street. Utilizing the curfew as a natural experimental situation, we compared the number of people on the street, six hours before the start time of the curfew (15:00 to 21:00) and six hours after the curfew start time (21:00 to 03:00), across four days before and three days during the curfew. Data ($N = 995$) were analyzed with a difference-in-difference (DID) approach (Wing et al. 2018). All statistical results were run using negative binomial regression (appropriate for estimating overdispersed count data), specified with robust standard errors.

The key results were as follows: With the introduction of the curfew, the number of people on the street in the period 21:00 to 03:00 decreased, suggesting that people complied with the measurement. Adding to this finding, at least one-third of the people observed during the curfew were visually evaluated to have a legitimate reason to be on the street (e.g., dog walking, bike delivery service). The negative effect of the curfew on movement was relatively small in magnitude, suggesting that this measure may only have a limited effect in a situation where society is already under lockdown. Finally, we found some, albeit fragile, evidence that the curfew was followed by a slight increase in the number of people in the period 15:00 to 21:00. Although this should be interpreted with caution, this result indicates some displacement effect, by which people chose to go outside in the hours before the curfew now that they cannot go outside after 21.00. We discuss the potential implications of these findings for transmission risks in the light of epidemiological literature suggesting that outdoor behavior involves a low Covid-19 transmission risk.

Background
For the first time since the Second World War, the Dutch government installed a curfew on Saturday 23 January, 2021, in an attempt to mitigate the spread of Covid-19. In the period between 21:00 and 04:30, citizens were enforced to stay inside their homes, with only a few exceptions allowing outside

behavior. The Dutch government presented it as an “extraordinary restrictive measurement” (Rijksoverheid, 2020) installed with the purpose of limiting people’s movements outside their homes, particularly the inclination to visit friends and family in their home. In doing so, the government referred to studies from other countries indicating the potential effect of curfews on limiting transmission risks. Indeed, evidence from France, Germany, and Switzerland (Huber and Langen 2020; Baunez et al. 2020), as well as international comparisons (Haug et al. 2021), suggest that curfews may limit transmission risks.

However, a limitation of the available evidence is that the installment of a mitigating measure is no guarantee of behavioral compliance (Hoeben et al. 2020). As such, little is known about whether and how people actually comply with curfew measures. Here, we address this behavioral question by investigating whether the number of people on the streets of Amsterdam changed after the introduction of the curfew. We also report on the observable activities that we could assess from the footage indicating whether people were on the street for legitimate reasons during the curfew hours. While these findings do not say anything about the mitigating effects of the curfew on Covid-19, they do offer valuable insights into the behavioral consequences of the curfew measure, which is assumed in epidemiological studies and intended by governmental agencies.

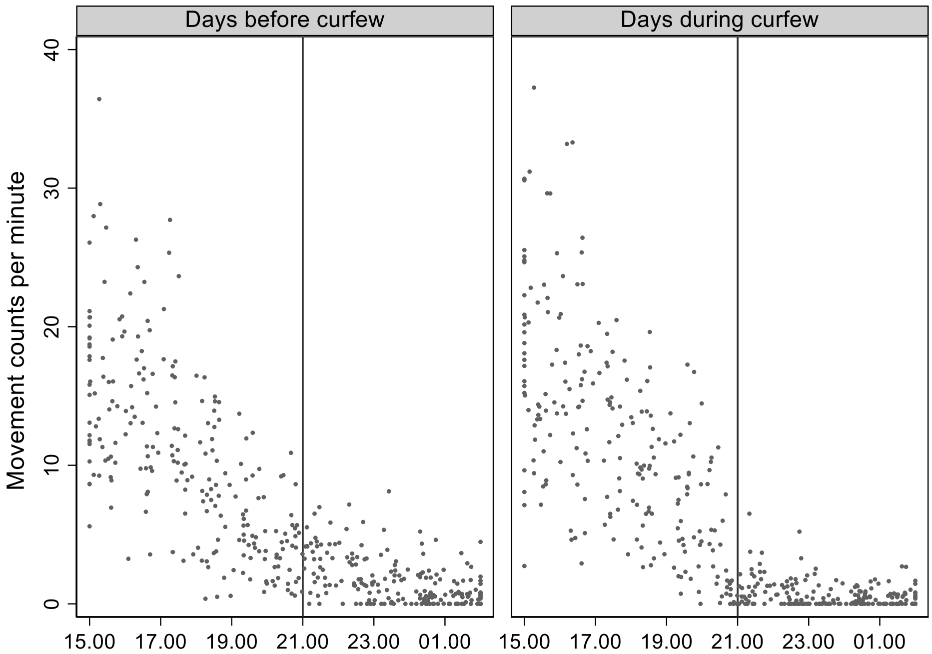
Methods

The data comprised video footage of everyday public behavior captured by three security cameras in Amsterdam (the Netherlands) that were assessed as relatively busy during the lockdown (i.e., Leidsestraat, Javaplein, and Bijlmerplein). Data were recorded Saturdays and Tuesdays, January 7, 9, 14, 16, 21, 23, 28, and 30, 2021. With the permission of the Dutch Public Prosecutor, we obtained data from the Amsterdam police, and the research was approved by the Ethics Committee for Legal and Criminological Research (CERCO) at Vrije Universiteit Amsterdam. To document the effect of the curfew on crowding, we sampled 995 time points (at every 15th minutes for each camera for all days) in which we counted the number of people (pedestrians and cyclists) passing through the street for one minute in both directions. In total, we counted 6342 individuals across the included time points. When people were observed on the streets after 21:00 on curfew nights, we also recorded in what activity they were involved. Categories included police patrolling, delivery service, dog walking, regular cyclists, and regular walkers, with the last two categories defined as no direct observable legitimate purpose on the street. Note that we most likely underestimate the proportion of people with a legitimate purpose, given that people are allowed to transport themselves to and from work, and this activity type cannot be visually distinguished from regular cyclists and walkers. Finally, we note that the sample size was determined from what was practically feasible to code within the timeframe of the study, while keeping in mind that a sample size of around 1000 offers sufficient statistical power for most estimation scenarios (assessed with G*power, see Erdfelder et al. 1996).

Results

Figure 1 visualizes the level of movement across time points, with separate graphs for the days before and during the curfew. The overall pattern of the two graphs was similar: the level of movement was highest in the afternoon and decreased throughout the evening and night hours. On the other hand, it is noteworthy that this decreasing trend unfolded in a “linear” manner in the days before the curfew, while the trend appeared more “L-shaped” in the days during the curfew—with a sharper fall before the starting hour of the curfew (i.e., indicated by the vertical line). This indicates that people comply with the curfew by returning home and indoor when the clock nears 21:00. In line with this interpretation, it is also noteworthy that the movement level was lower in hours during the curfew than in the same hours before the curfew was implemented. Taken together, this offers visual evidence that the curfew has the intended effect of reducing the number of people moving in and throughout public space.

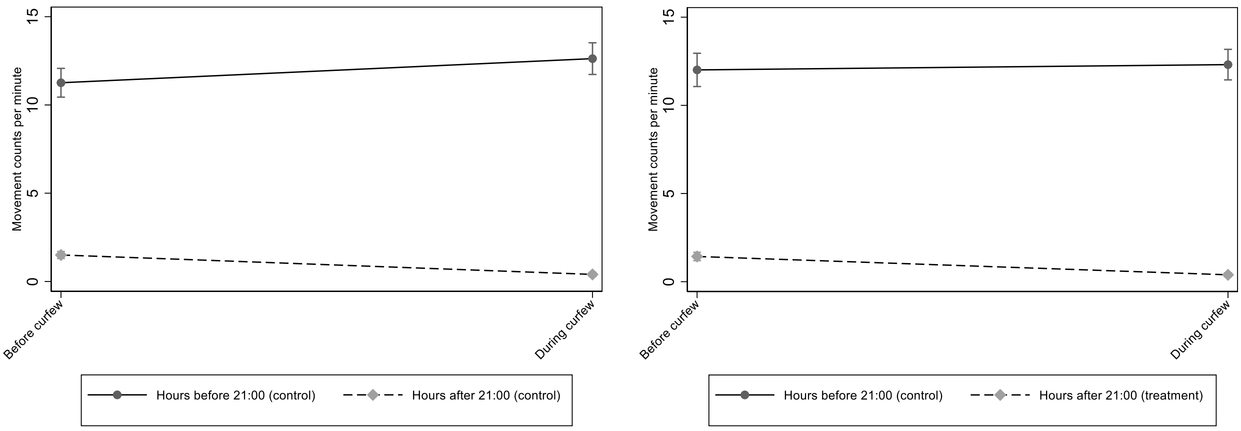
Figure 1. Movement counts across the observed hours, for days before and during the curfew.



A total of 87 persons were on the street after 21:00 on the days the curfew was installed, with 31 (36%) of these persons having an apparent legitimate purpose for being outside, such as walking the dog (6 persons) or delivering food (23 persons). The remaining 64% did not have a visually identifiable legitimate purpose; the majority of these persons were walking or cycling by (59%), and 6% (5 persons) walked together with someone who was walking the dog, which is not allowed according to the rules of the curfew.

Next, we statistically tested the effect of the curfew on movement using a difference-in-difference model, see Table 1 (left panel). This analysis suggested that the ‘control’ hours before 21:00 and the ‘treatment’ hours after 21:00 changed differently after the implementation of the curfew (DID-estimator = -1.43, $p < .001$). That is, the movement level was reduced in the hours after 21:00, while the model indicated an increasing trend in the hours before the 21:00. These results statistically verify the visual pattern presented in Figure 1. However, it should be stressed that the effect sizes are modest in magnitude, depicted by relatively flat regression slopes. For example, the curfew was only followed by a reduction of post-21:00 from 1.5 to 0.40 persons per minute. In line with this modest effect, we did not find that the days before and during the curfew had different movement levels (B = 0.02, p = .801), suggesting that the curfew did not alter the overall movement level in public space to a statistically significant degree.

Table 1. Difference-in-difference regression analyses of movement counts per minute, with (left panel) and without (right panel) the second Saturday included



Given that the increasing trend of the control hours is a somewhat surprising and perhaps controversial result, we further evaluated its robustness. Figure 2 presents the estimates of the treatment and control hours across the seven days included in the study (with the vertical line indicating the first curfew date). Here, it should be noted that the treatment and control hours do not follow 'parallel trends' in the days leading up to the curfew—i.e., a fundamental assumption for the validity of difference-in-difference analysis (Wing et al. 2018). The non-parallel trends seem to be related to the low movement count in the hours before 21:00 on the second Saturday, which possibly reflects that the weather was unusually bad this day between 15:00 and 24:00 (with snowfall, which is atypical in the Netherlands). As such, rather than an effect of the curfew, the increasing trend we saw in Table 1 with respect to the control hours may simply be due to this Saturday having an unusually low movement level. In line with this interpretation, the slope of the control hours was attenuated and only showed a trivial positive trend if the "outlier" Saturday was excluded from the analysis (i.e., the predicted movement counts per minute barely increased from 12.0 to 12.3), see Figure 1 (right panel). Note, however, that the DID-estimator remained statistically significant after this exclusion (DID-estimator = -1.32, p = .001.

Study limitations

One limitation of the current study is that we examine behavioral compliance, not an effect on transmission. Whether the observed behavioral effects will eventually mitigate the transmissions is difficult to determine, but there are reasons to question the extent to which this is likely to happen. Here, it should be kept in mind that the magnitude of the estimated behavioral effect is relatively modest, reflecting the circumstance that the level of activity in society was already at a minimum due to the nation-wide lockdown in operation. The already relatively modest behavioral effect of the curfew is only plausible to have a limited by-product effect on Covid-19 transmissions. Another limitation of our study is that we do not know where people go when they move outside, including whether their movements are related to risk behaviors (e.g., visiting friends or family). Adding to this, one may question whether the authorities should be concerned about movements outside at all, given the emerging evidence that Covid-19 has a low transmission risk in outdoor settings (Weed and Foad 2020).

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