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PAPER

Feasibility Study of Applying Spatial Crowd Smoothing Without Economic Incentives on Ticket Reservation System that Applies Nudges

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SUMMARY In this study, we devise several seat selection screens for a movie theater ticket reservation system that applies nudges to achieve spatial crowd smoothing without relying on economic incentives. We design three types of nudges that achieve the following: (i) render seats in less-crowded areas noticeable; (ii) present social norms; and (iii) suggest seats in less-crowded areas to people who have selected seats in crowded areas. Results of verification experiment show that (ii) the presentation of social norms is generally effective in avoiding congestion regardless of the ticket sales and (ii) the text of the presented social norms is more effective in avoiding congestion when it contains motivational sentences than when it is verbally expressed. Furthermore, the results indicate that (i) rendering seats in less-crowded areas more conspicuous and (iii) suggesting seats in less-crowded areas to those who select seats in more crowded areas may be effective in avoiding congestion, depending on the ticket sales. Consequently, the feasibility of spatial crowd smoothing without relying on economic incentives for the seat selection screen of a ticket reservation system that applies nudges is demonstrated.
key words: *behavioral economics, behavior modification, nudge, spatial crowd smoothing*

1. Introduction

Severe measures (e.g., city lockdowns) have been implemented in many countries worldwide owing to the coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2. Consequently, economic stagnation (e.g., [1]), damage to the tourism business (e.g., [2], [3]), etc. have occurred. However, the development of vaccines (e.g., [4]) and increased vaccination rates (e.g., [5]) have gradually eased restrictions that directly cause economic stagnation. Measures against infectious diseases continue to be implemented in indoor facilities. One such measure is avoiding overcrowding and/or smooth crowds. Examples include online sales of time- and date-specified tickets in aquariums [6] and the promotion of staggered commuting by assigning points [7]. In addition, Holt et al. [8] indicate that the COVID-19 pandemic has increased personal space and discomfort due to close physical proximity to others.

Japan has the largest aging population worldwide. The declining birth rate and aging population are currently causing a decline in the ratio of the working-age population, which is the workforce, and is a major issue in Japan. Automated systems, artificial intelligence (AI), robots, and digital transformations are been introduced to address the shortage of workers. However, as worker will continue into the future, further measures are required. For example, the aforementioned measures for avoiding and leveling congestion to prevent infectious diseases have optimized the allocation and number of facility staff, thus reducing labor costs (e.g., [6]). In other words, crowd avoidance and crowd smoothing measures have resulted in many advantages, including the prevention of infectious diseases, the guarantee of personal space, and the reduction in labor costs. In addition, many facilities currently in operation are designed based on the expected peak demand. However, because crowd smoothing causes a shift in peak demand, fluctuations in the facility and staff utilization rates are reduced. Consequently, excessive labor and capital investments can be reduced. In other words, not only will labor costs be reduced during off-peak periods, but also worker shortage will be eliminated during peak periods.

To realize these benefits, facility users must adapt appropriately to avoid congestion. One method is to adopt "nudging" [9], which allows people to decide without constraint or significantly changing their economic incentives (e.g., [10]–[15]).

Currently, tickets are being purchased regularly for various occasions, such as movie theaters, concert sites, sports games, and bullet trains, by specifying the date, time, and seats in advance. We aim to realize crowd smoothing in facilities using such a ticket reservation system. For example, we designed and verified the feasibility of nudges to realize temporal crowd smoothing using the showtime selection screen of a movie theater ticket reservation system on a smartphone [16]. By realizing temporal crowd smoothing on the show-time selection screen, we can simultaneously equalize the number of people who attend a movie theater over time and disperse the number of people appearing on each screen of a cinema complex when the same movie is being shown. In movie theaters, spatial crowd smoothing can be realized in each screen by intervening the seat selection behavior at the time of ticket purchase. In addition, the authors of [17], [18] reported the increase in the number of people in a facility and the concentration of evacuees at a single exit as factors that increase the time required to complete evacuation during a disaster. In other words, dispersing the

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arrangement of people in a theater can reduce the time required to complete evacuation during a disaster. Therefore, we design several seat selection screens for a movie theater ticket reservation system that applies nudges and verify the feasibility of spatial crowd smoothing. Note that this paper was written based on [19], and new experiments were added to verify the effectiveness.

2. Previous studies pertaining to nudges and status of crowd avoidance efforts

2.1 Previous studies pertaining to nudges

"Nudge" is one of the behavioral economic concepts proposed by Thaler and Sunstein. In [9], a nudge is defined as "any element of the choice architecture that changes people's behavior in a predictable way, without prohibiting choice or significantly changing economic incentives." Representative examples of nudges include a case in which urine is painted with a picture of a fly to reduce cleaning costs by exploiting people's psychological inclination to target the fly, and a case in which an opt-out method of organ donation increases the consent rate for organ donation.

Nudges have been shown to be effective in several other areas. In health promotion, the effectiveness of nudges for encouraging the purchase of healthy foods in online supermarkets [10] as well as an attempt to increase the use of hand sanitizers among hospital visitors through nudges via social norms have been investigated [11]. To enhance online security, researchers have investigated the effects of presenting personalized nudges to strengthen passwords [12] and the effects of using nudges to manipulate display order and change text color to encourage the selection of secure wireless networks [13]. To address environmental issues, researchers have investigated the effectiveness of presenting nudges via social norms to increase payments to achieve higher levels of recycling in homes [14] as well as compared nudges suitable for increasing renewable energy contracts [15].

2.2 Status of crowd avoidance efforts

Crowd visualization and crowd avoidance systems have been investigated. For example, Sato et al. [20] investigated a system to understand and visualize congestion at event sites using Bluetooth low-energy beacons. Sathyamoorthy et al. [21] proposed a system for monitoring the social distance of facility users using a mobile robot equipped with a camera and a light detection and ranging system. Yang et al. [22] proposed a system that monitors social distance in real time using cameras and AI, estimates crowd density, and alerts facility users. However, these systems only visualize congestion and do not instruct facility users to change their behavior; additionally, warnings are not mandatory, which may reduce the acceptance of the system and measures by facility users.

In a previous study [23], we conducted an experiment at the Central Japan International Airport using a system that applies information and communication technology to inform passengers of their baggage statues, such as the current baggage location and the estimated time of return, to maintain social distance in the baggage-claim area.

Attempts have been endeavored to promote crowd avoidance without requiring mandatory nudge-based warnings. Examples include promoting staggered commuting by assigning points [7], easing congestion on buses [24], easing rush-hour congestion on local buses by assigning coupons [25], and realizing sightseeing events that avoid dense traffic [26]. However, these measures rely on economic incentives, such as points or coupons, which impose a high economic burden on those who launch them. Thus, if these measures are discontinued without being sustained, then the incentive to avoid congestion caused by nudges may vanish. Therefore, this study is performed to achieve spatial crowd smoothing for facility users without relying on economic incentives.

2.3 Approaches for crowd smoothing without economic incentives [16]

Two approaches can be considered for crowd smoothing facility users. The first is to realize temporal and spatial crowd smoothing in facilities where users can move unrestrictedly, such as shopping malls, theme parks, and airports, by combining nudges and expanding the perceived range through the acquisition and visualization of congestion conditions. The second is to realize temporal and spatial crowd smoothing by applying nudges to ticket purchase screens at facilities such as movie theaters and bullet trains, where users can specify the time and area during ticket purchase. Unuma et al. [16] analyzed nudges that realize crowd smoothing using the second approach, which can be introduced more easily by policymakers. Specifically, multiple screens were designed for selecting the showtime of a movie theater ticket reservation system on a smartphone that applies nudges, and the feasibility of temporal crowd smoothing for encouraging the selection of available showtime without relying on economic incentives was demonstrated.

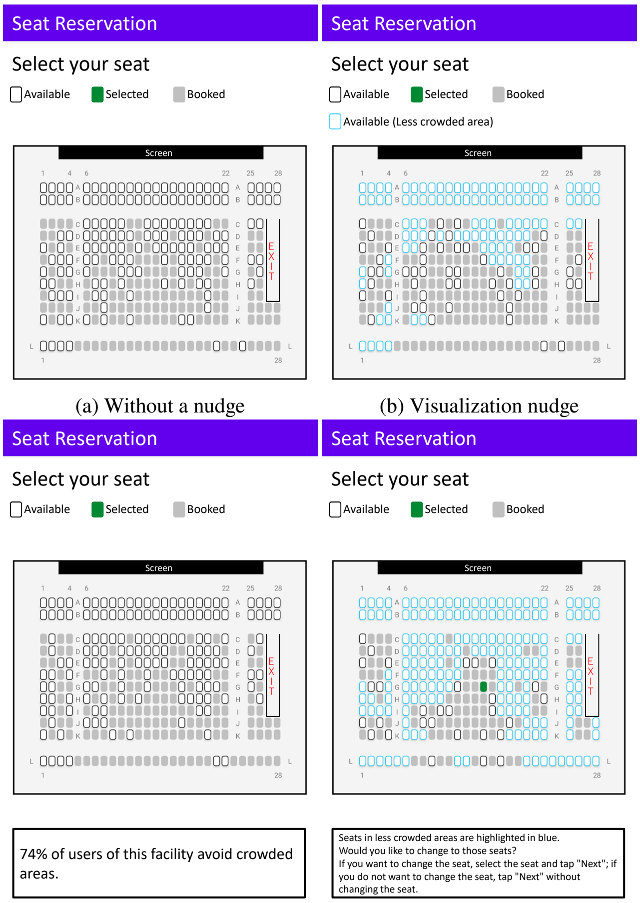
The number of people who visit a movie theater can be equalized over time by encouraging them to select the times when showings are available, thereby avoiding temporal crowding. In addition, when the same movie is shown in multiple theaters during the same period, the number of people present in each theater where the movie is shown can be distributed. This can avoid congestion, as described in Section 1. In addition, the spatial dispersion of people in movie theaters can secure personal space, prevent infectious diseases, and reduce the time required to complete evacuation during a disaster. The dispersion of people in each theater can be achieved by encouraging the avoidance of crowded areas when selecting seats. Therefore, in this study, we designed and verified the feasibility of using nudges for spatial crowd smoothing on the seat selection screen of a movie theater ticket reservation system.

Additionally, spatial crowd smoothing can be achieved by setting an upper limit on the number of seats to be sold, or by increasing the distance between seats. However, the former results in the loss of sales opportunities, whereas the latter incurs additional costs for physical construction. However, the method proposed in this study only promotes spatial crowd smoothing and does not change the total sales. In addition, it requires only a partial modification of the ticket reservation system; therefore, the additional cost of the modification is lower than the cost of the physical construction.

3. Seat selection screen of movie ticket reservation system that achieves spatial crowd smoothing without economic incentives

In this study, we designed three types of seat selection screens based on the concept of nudge, as summarized in [27]. Figure 1 shows a seat selection screen without the application of nudges and the three types of seat selection screens with nudges applied. Figure 1(a) shows the seat selection screen without the application of nudges, i.e., a screen that imitates the seat selection screen of an existing movie theater ticket reservation system on a smartphone. The seat type is displayed at the top of the screen, and the seat status in the theater is confirmed at the center of the screen. In this study, this screen was used as a comparison for the feasibility verification. Figure 1(b) shows a seat selection screen in which "seats in less-crowded areas" are newly defined (details are described in Section 4.1.1) and highlighted with a blue border to clearly indicate the congestion status as well as to apply a nudge (hereinafter referred to as a "visualization nudge") to equalize congestion. Figure 1(c) shows a seat selection screen in which a nudge (hereinafter referred to as a "social norm nudge") is applied to equalize congestion by presenting a social norm where many people avoid seats in congested areas at the bottom of the screen. Figure 1(d) shows a seat selection screen in which a nudge (hereinafter referred to as an "alternative nudge") is applied to a person who selects a seat other than a seat in a "less-crowded area" by presenting a seat in a "less-crowded area" as an alternative proposal to level the congestion.

For the social norm nudge shown in Figure 1(c), we devised four types of social norm sentences to compare two perspectives. The first perspective to be compared is the difference in the effects of social norm nudges based on the different methods by which the normative group (linguistic or numerical) is expressed. Two studies have been conducted to compare the effects of different methods of expressing normative groups. One of them compared the differences in the method by which normative groups are expressed in social norm nudges to encourage tax compliance [28], and the other study compared the differences in the method by which normative groups are expressed in social norm nudges to improve the intention to undergo cancer screening [29]. Hallsworth et al. [28] discovered that numerical expressions were more effective than linguistic expressions, whereas Stoffel et al. [29] discovered the opposite, i.e., linguistic expressions were more effective than numerical expressions. Therefore, to obtain further insights into the differences in the effects of social norms across



(a) Without a nudge (b) Visualization nudge (c) Social norm nudge (d) Alternative nudge

Fig. 1 Diagram of sterilization information provision system.

normative groups, we compared normative groups in terms of the manner by which they are represented. The second perspective to be compared is the difference in the effects of social norm nudges with and without motivational sentences. Mobekk et al. [11] compared the effect of a social norm with a motivational sentence[†] with that of a social norm without a motivational sentence[††] to increase the use of hand sanitizers placed in front of hospital entrances. Mobekk et al. [11] showed that the effects of social norms with and without motivational sentences were comparable. However, we believe that the motivational sentence can be further improved; therefore, we compared the differences in the effects of social norms using a motivational sentence different from that used by Mobekk et al. [11]. Table 1 shows each social norm nudge designed based on the results, and the corresponding sentences are presented.

[†]Expressions in the reference [11]: "Here we use HAND DISINFECTANT ... to protect your relatives."

[††]Expressions in the reference [11]: "Here we use HAND DISINFECTANT"

Table 1 Sentences used in social norm nudges

Nudge	Sentence
Social norm (numerical expression)	74% of users of this facility avoid crowded areas.
Social norm (numerical expression) including motivational sentence	Prevent your friends/family from contracting infectious diseases. 74% of users of this facility avoid crowded areas.
Social norm (linguistic expression)	Many users of this facility avoid crowded areas.
Social norm (linguistic expression) including motivational sentence	Prevent your friends/family from contracting infectious diseases. Many users of this facility avoid crowded areas.

Fig. 2 Example of seat cost calculation.

4. Verification experiment

4.1 Outline of experiment

An experiment was conducted to verify the feasibility of spatial crowd smoothing for the six types of seat selection screens designed in Section 3 that do not rely on economic incentives, as well as for an existing screen (one type; Figure 1(a)) for comparison. The participants were 46 university students aged 18 to 25 (mean: 20.6, standard deviation: 1.83), among which 33 were males and 13 were females. Each participant from the following groups performed the task: no nudge group (group A); one of the groups from the visualization nudge group (group B1)/alternative nudge group (group B2); one of the groups from the social norm (numerical expression) nudge group (group C1)/social norm (numerical expression) nudge with motivational sentences; group (group C2)/social norm (linguistic expression) nudge group (group C3)/social norm (linguistic expression) with motivational sentences (group C4). In this experiment, we assume a situation in which participants plan to see a movie the next day or later and purchase their cinema tickets online the previous day or before[†]. To prevent the participants from being guided by the author's intentions, we did not inform them of the aim of the experiment (i.e., to achieve crowd smoothing). In addition, to avoid participants from realizing the actual aim of the experiment as the experiment progressed, we conducted the experiment in the order A→B1/B2→C1/C2/C3/C4. The participants showed the seat that they wanted to select on each screen. The combination of B1/B2 and C1/C2/C3/C4 groups was randomized. The number of participants who performed the task in each group was 46 in Group A, 23 in Groups B1 and B2, 12 in Groups C1 and C2, and 11 in Groups C3 and C4. The experiment was conducted in July 2022[††].

[†]The authors have confirmed through prior observational experiments on online ticket reservations at existing movie theaters that many seats are reserved one day in advance for films that have just been released or are popular.

[††]This was the period of the infection epidemic known as the 7th Wave in Japan. At that time, surgical masks were not required outdoors, but were worn indoors in principle, and at movie theaters, seats were thinned out for sale, temperature was checked, and hand sanitization was thoroughly enforced.

4.1.1 Definition of "seating cost" and "seat in less-crowded areas"

In this section, we introduce an index known as the "seating cost," which quantifies the degree to which seats around each seat are filled. A pre-survey was conducted to determine the range of surrounding seats to be included in seat cost calculations. Forty-two males and females completed a preliminary questionnaire. In the pre-survey, the respondents were asked to indicate the seats in the vicinity of their own movie theater that they would not like other people to sit in. The range of surrounding seats included in the calculation of the seating cost for each seat was eight seats around each seat (four seats in the front, back, left, and right; and four diagonal seats), which were frequently indicated as seats that the respondents would not like other people to sit on. The voting ratios for each seat (the number of respondents who did not want others to sit on the seat divided by the total number of survey respondents) were 0.671, 0.963, and 0.311 for the front, back, left, right, and diagonal seats, respectively. The cost of each seat was calculated by adding the voting percentages as weights to the eight seats around the target seat that had already been sold. In other words, the higher the seat cost, the more crowded the area around the seat. As an example, we calculated the seat cost of Seat A in Figure 2. Seat A was the seat with a person in the front seat (weight, 0.671), left seat (weight, 0.963), and right diagonal seat (weight, 0.311). Therefore, the cost for Seat A was calculated as $0.671+0.963+0.311=1.945$. For seats facing an aisle or wall, the seat cost was calculated by assuming an unoccupied seat that would have appeared without the aisle or wall.

A "seat in a sparsely populated area" is defined as one with a seating cost less than the median of all seats in a theater. The seats to be highlighted in the visualization nudge (B1) and the seats to be presented as alternatives in the alternatives nudge (B2) are the "seats in less-crowded areas.". In the alternative nudge, the condition for an alternative to be presented is that "seats in less-crowded areas" are not selected; hence, "seats in less-crowded areas" are also used for assessment when an alternative is presented.

4.1.2 Tasks to be performed by participants

The participants were presented with a seat selection screen for each assigned group. Since the effect of the nudge-applied seat selection screen in leveling congestion is expected to vary depending on the number of seats already sold, we performed an evaluation based on the ratios of 0%, 30%, 50%, and 70% of the number of seats sold to the total number of seats in the theater (hereinafter referred to as the "seating ratio"). Hence, the seating ratios of 0%, 30%, 50%, and 70% were evaluated. The participants were instructed to select a seat even when the seating ratio was 0% (i.e., when there are no seats in the theater) to understand their preferred seats. The seating positions in the theater were determined by observing the manner by which the seats were filled during a movie shown in a movie theater and based on the manner by which the seats were filled when the seating ratio was the closest to 30%, 50%, and 70%. In this experiment, because each participant evaluated three different seat selection screens, the evaluations may have been relative. Therefore, the pattern of seat fill at each seating ratio was different for each group.

For participants in Group B2 who selected a seat other than the "seat in a less-crowded area," a seat in a less-crowded area was suggested on the screen shown in Figure 1(d). Participants to whom Figure 1(d) was presented were instructed to decide whether to change their seats, whereas those who decided to change their seats were instructed to select a new seat. Thus, the evaluation index for Group B2 was different from that of the other groups because only the participants in Group B2 were assigned an additional task.

4.1.3 Evaluation index

We used the "crowd avoidance ratio" as an evaluation index for Groups A, B1, C1–C4. The "crowd avoidance ratio" is defined as the percentage of participants who selected a seat with a lower cost than the seat selected at a 0% seating ratio (hereinafter referred to as the "preferred seat") at 30%, 50%, and 70% seating ratio. Therefore, the seats must cost less than the preferred seat at 30%, 50%, and 70% seating ratios. As such, we intentionally filled the eight seats surrounding the preferred seat with a few seats. The number of intentionally filled seats is proportional to the seating ratio. In other words, if the crowd avoidance ratio in the groups to which nudges are applied (groups B1, C1-C4) is higher than that in group A, then the nudges can be assumed to be effective.

The evaluation index for Group B2 was the percentage of participants who changed seats with those who were offered an alternative and the difference between the cost of seats before and after the seat change for all participants who changed seats[†].

[†]Calculated by subtracting the cost of seats before the seat change from the cost of seats after the seat change.

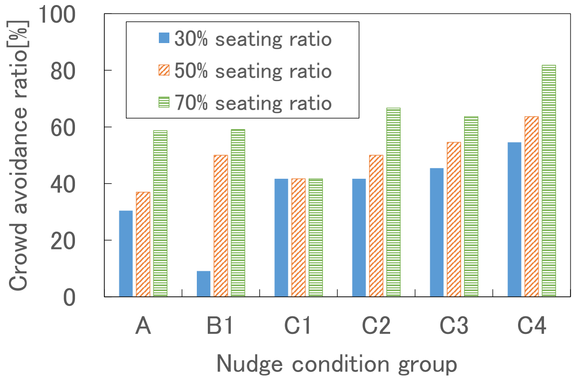


Fig. 3 Percentage of congestion avoidance at each seating ratio.

4.2 Experimental results

Figure 3 shows the crowd avoidance ratio at each seating ratio for groups A, B1, C1–C4. In Group B1, data from 22 participants were used, excluding one participant who provided an incorrect answer. As shown in Figure 3, the crowd avoidance ratios for Groups C2, C3, and C4 were higher than those of Group A at all seating ratios. In other words, C2, C3, and C4 demonstrated the feasibility of crowd smoothing regardless of the seating ratio. The crowd avoidance ratio of Group B1 was higher than that of Group A when the seating ratio was 50%; however, it was similar to that of Group A when the seating ratio was 70% and lower than that of Group A when the seating ratio was 30%. The crowd avoidance ratio of Group C1 was higher than that of Group A at 30% and 50% seating ratios but lower than that of Group A at 70% seating ratio. This indicates that the effects of B1 and C1 on spatial crowd smoothing differ depending on the seating ratio. Comparing the crowd avoidance ratio within groups C1–C4, the crowd avoidance ratio for linguistic expressions was higher than that for numerical expressions when the motivational sentences were included, compared with the case when the motivational sentences were not included.

Table 2 shows the percentage of Group B2 participants who were offered an alternative, the percentage of participants who changed their seats, and the average difference in seat costs before and after the seat change[††] for all participants who changed their seats. As shown in Figure 3, the data from 22 participants were used in Group B2. Based on Table 2, no participant was offered an alternative when the seating ratio was 30%. In the 50% and 70% cases, only a few participants changed their seats after being offered an alternative. In addition, all the participants who changed their seating indicated a decrease in their seating costs prior to the change. These results indicate the possibility of spatial crowd smoothing using alternative nudges.

[††]Calculated by subtracting the seat cost before the seat change from the seat cost after the seat change.

Table 2 Results for alternative nudge

	Seating ratio		
	30%	50%	70%
Percentage of participants for whom an alternative was offered	0%	45.5%	63.6%
Percentage of participants who changed seats among those who were offered an alternative	-	10.0%	14.3%
Mean difference in seat cost before and after seat change for all participants who changed seats	-	-0.982	-1.463

4.3 Discussion

The crowd avoidance ratio of Group B1 was lower than that of group A at the 30% seating ratio because all participants' preferred seats corresponded to seats in less-crowded areas. At the 30% seating ratio of Group B1, all participants' preferred seats were prominently displayed as seats in less-crowded areas because all participants' preferred seats were seats in less-crowded areas. Therefore, even if people appeared around the preferred seat, a sense of security is provided because the seat is located in a sparsely populated area. Therefore, the crowd avoidance ratio in Group B1 was low at a seating ratio of 30% because many participants selected their preferred seats as they were.

Next, the results for the crowd avoidance ratio of Groups C1–C4 were compared. First, the crowd avoidance ratio was higher when motivational sentences were included as compared with when they were not. This suggests that motivational sentences increase the effectiveness of social norms. Furthermore, the crowd avoidance ratio is higher for linguistic expressions than for numerical expressions. The reasons for this are discussed as follows: The social norm presented in this study is that most facility users avoid crowded areas. Therefore, the validity of the social norm can be determined based on the number of seats sold in theaters. In other words, if the theater presents few areas with a high concentration of sold seats, then it implies that many facility users avoid crowded areas and that the social norm is correct. Conversely, if the theater presents many with a high density of seats, then it implies that only a few facility users avoid crowded areas and that the social norms is incorrect. In the case of the linguistic expression, the sentence of the social norm is "many of the users of this facility avoid crowded areas," where the perception of "many" in the text differs from one person to another. Therefore, even if many areas in the theater where seats have been sold are densely packed, i.e., only a few users avoid crowded areas, one may assume that "many" users of the facility avoid crowded areas. Meanwhile, in the case of numerical expression, the text of the social norm would be "74% of the users of the facility avoid crowded areas." The "74%" in the sentence is different from the "many" in the linguistic expression and is not regarded as a numerical range. Therefore, if many areas in the theater where seats have been sold are densely packed, i.e., only a few patrons avoid crowded areas, then the statement "74% of users of this facility avoid crowded areas" may cause a discrepancy between the text of the social norm and the actual filling of sold seats in the theater. A discrepancy will likely occur between the text of the social norm and the actual seats filled in the theater. In other words, linguistic representations are likely to have a higher rate of crowd avoidance than numerical representations owing to the decreased reliability of the text of the social norm (numerical expression) nudge.

At the 70% seating ratio, the crowd avoidance ratio of Group C1 was lower than that of Group A, possibly because the text of the social norm (numerical expression) nudge was particularly unreliable at the 70% seating ratio. At the 70% seating ratio, a discrepancy is likely to occur between the text of the social norm (numerical expression) nudge and the seats sold in the theater, as most of the seats have already been sold. Therefore, the crowd avoidance ratio for Group C1 is likely to be lower than that for Group A only at a seating ratio of 70%.

5. Additional experiments on visualization nudges

5.1 Proposed improvements to visualization nudge

When applying visualization nudges, two aspects of the seat selection screen results can be further improved. The first is the low crowd-avoidance ratio at a seating ratio of 30%, as described in Section 4.3. To improve this, an incentive must be provided to people whose preferred seats are in less-crowded areas to select seats that cost less. Second, at a seating ratio of 50%, the mean seat cost of the seat selected by all participants whose preferred seat was in a less-crowded area among those whose preferred seat not in a less-crowded area was significantly higher than mean seat cost of Group A. To improve this, the difference in congestion (difference in seat cost) around seats within seats in a less-crowded area must be identified visually. To improve these two aspects, we shall further categorize the "seats in less-crowded areas" by the seat cost, i.e., three types of seats will be established based on the seat cost. The three types of seat types are named "available (very less crowed area)," " available (slightly less-crowded area), and "available (highly crowed area)." They are defined in terms of the seat cost, i.e., seats with a seat cost of zero, seats with a seat cost greater than zero but less than the median of the seat costs of all seats, and seats whose cost is greater than or equal to the median cost of all seats, respectively. This improvement in the visualization nudge creates the necessity to avoid congestion unless the seat cost of the preferred seat is zero; additionally, it allows the user to observe the difference in seat cost within seats in less-crowded areas. In other words, this improvement is expected to improve the two aspects above regarding the seat selection screen when the visualization nudge is applied. Hereinafter, the improved visualization nudge is referred to as the improved visualization nudge.

Figure 4 shows the seat selection screen after the improved visualization nudge method was applied. On the seat selection screen with the visualization (before improvement)

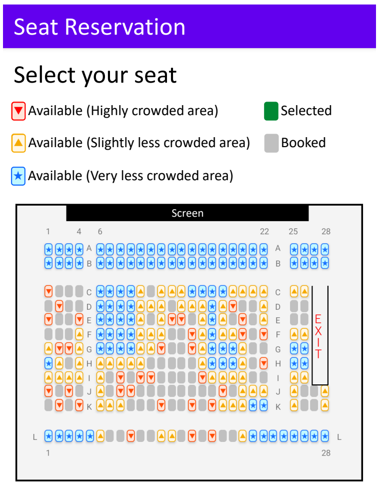


Fig. 4 Seat selection screen after applying improved visualization nudge.

nudge (Figure 1(b)), two types of seats were shown: empty and vacant seats (seats in less-crowded areas). The seat buttons were classified into three types. Specifically, the seat buttons were classified based on the color of the seat button border, the background color, and the symbols on the seat button. The symbols were displayed on the seat buttons using different colors. Blue (instruction), yellow (warning), and red (prohibition) were used for the colors of the border and the symbols on the seat buttons, which are among the safety colors specified by the International Organization for Standardization (ISO) 3864-1 [30] (Japanese Industrial Standard (JIS) Z 9101 [31] in Japan) and ISO 3864-4 [32] (JIS Z 9103 [33] in Japan). Specifically, blue was used for seats with a few people, yellow for seats with slightly fewer people, and red for seats with more people. This color coding is expected to create impressions based on the congestion degree. For the background color, light blue was used for seats in sparsely populated areas, light yellow–red for seats in slightly sparsely populated areas, and light red for seats in populated areas. First, the "★" symbol was used for seats in areas with particularly few people to provide a good impression of seats in less-crowded areas. Next, "▼" was used for seats in areas with many people as the "V" shape is typically perceived as a threat [34], as well as to avoid providing a good impression of the seats in the crowded area. Meanwhile, "▲" was used for seats in slightly less crowded areas such that the seats are perceived better than the seats in crowded areas but not perceived as comparable to seats in less-crowded areas.

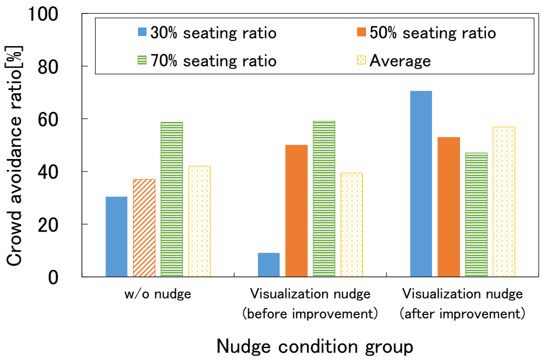
5.2 Outline of Experiment

We investigated the feasibility of spatial crowd smoothing using a seat selection screen applied with the improved visualization nudge presented in Section 5.1. The participants were 17 university students aged 19–24 (mean: 21.8, standard deviation: 1.60), among which 7 were males and 10 were females. An improved visualization nudge group (Group D) was created, and all 17 participants were instructed to evaluate it. The participants were instructed to select a seat at each seating ratio, as described in Section 4.1.2. The evaluation indices were (a) the crowd avoidance ratio, (b) the percentage of participants whose preferred seat was a seat in a less-crowded area among participants whose preferred seat was not a seat in a less-crowded area, and (c) the average seat cost of the seat selected by all participants who selected a seat in a less-crowded area among participants whose preferred seat was a seat in a less-crowded area.

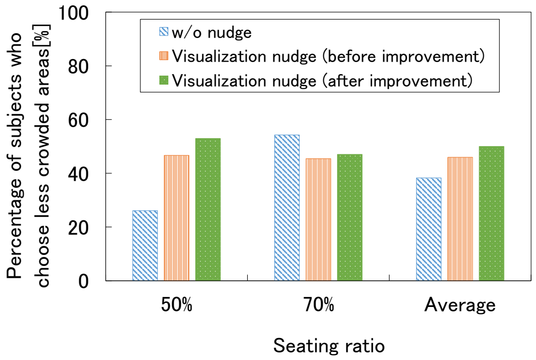
5.3 Experimental results

Figure 5(a) shows the crowd avoidance ratios for Groups D, A, and B1, among which the results for Groups A and B1 were the same as those presented in Section 4.2. The results of Fisher's exact probability test for the crowd avoidance ratio for each nudge condition group in Figure 5(a) show a significant difference between the nudge condition groups only at the 30% seating ratio (significance level $\alpha = 0.05$; 30% seating ratio: $p = 0.0003$; 50% seating ratio: $p = 0.414$; 70% seating ratio: $p = 0.735$; all average seating ratio: $p = 0.125$). Multiple comparisons using the Holm method for the crowd avoidance ratio among the nudge condition groups at the 30% seating ratio showed significant differences between Groups A and D ($p = 0.02$) and between Groups B1 and D ($p = 0.0004$). In other words, at the seating ratio of 30%, the crowd avoidance ratio of Group D was significantly higher than that of Groups A and B1. At the 50% seating ratio, the crowd avoidance ratio of Group D was higher than that of Group A and similar to that of Group B1. The average of the total seating ratio of Group D was higher than that of the other two nudge condition groups. Meanwhile, the crowd avoidance ratio for Group D at 70% seating was lower than that for Groups A and B1.

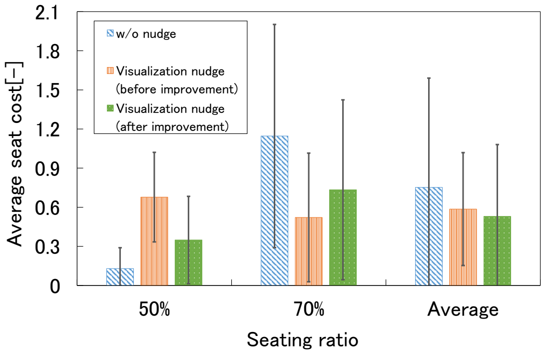
Figure 5(b) shows the percentage of participants whose preferred seat was in a less-crowded area among those whose preferred a seat not in a less-crowded area for Groups A, B1, and D. Figure 5(c) shows the average seating cost of the seats selected by all participants. No result was obtained for the 30% seating ratio because at that ratio, the preferred seats for all participants were those in less-crowded areas. The percentage of participants who selected seats in less-crowded areas among those whose preferred seats not in less-crowded areas, as shown in Figure 5(b), was higher in Group D than in Groups A and B1 at the 50% seating ratio and the mean value of the total seating ratio. As for the mean of the seating cost of all participants who selected a seat in a less-crowded area among participants whose preferred a seat not in a less-crowded area (see Figure 5(c)), the Kruskal–Wallis test results showed a significant difference between each nudge condition group only at the 50% seating ratio (significance level $\alpha = 0.05$; 50% seating: $p = 0.008$; 70% seating: $p = 0.182$; mean between 50% and 70% seating: $p = 0.898$). Multiple comparisons using the Holm method (significance level $\alpha = 0.05$) for the average seating cost at the 50% seating ratio showed a significant difference between Groups A and



(a) Crowd avoidance ratio



(b) Percentage of participants who selected less-crowded areas



(c) Average seat cost

Fig. 5 Results of subsequent experiments.

B1 ($p = 0.006$). For the means of the 50% and 70% seating ratios, the mean of the seating cost in Group D was the lowest.

These results indicate the feasibility of spatial crowd smoothing using a seat selection screen when an improved visualization nudge is applied. In this paper, we discussed the seat selection screen of a movie theater as an example of a ticket reservation system for a facility that allows users to select their own seats. However, ticket reservation systems for other facilities where seats are reserved (e.g., bullet trains, ferries, musicals, etc.) have the same basic mechanism as the movie theaters discussed in this paper, although there are differences in screen layouts and other aspects. Therefore, although there is a possibility that the magnitude of the effect of spatial congestion leveling may differ, the effect of spatial congestion leveling is expected to be similar.

6. Conclusions

In this study, we designed several seat selection screens for a movie theater ticket reservation system that applied nudges to achieve spatial crowd smoothing without relying on economic incentives. The results of validation experiments showed the possibility of crowd smoothing at any seating ratio for the social norm (linguistic expression) nudge, social norm nudge with incentive statements (linguistic expression), and social norm nudge with incentive statements (numerical expression). For alternative nudges, the number of people who changed seats was low, but the seating costs of all those who changed seats decreased compared with those before the seat change. A comparison of the four groups of social normative nudges revealed that linguistic expressions were more effective in avoiding congestion for social normative nudges when they included motivational sentences. These results indicated the feasibility of spatial crowd smoothing without relying on economic incentives in a ticket reservation system that applies nudging.

In future studies, the relationship between the nudge effects obtained in this study and individual characteristics should be investigated more comprehensively. Furthermore, temporal and spatial crowd smoothing in facilities (airports, shopping malls, etc.) where users can move unrestrictedly should be realized.

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