

ORIGINAL ARTICLE

EXPLORING BEHAVIOUR CHANGE SITUATIONS FOR PANDEMIC PREVENTION AND CONTROL IN PUBLIC SPACES IN HEFEI, CHINA

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ABSTRACT

Protective behaviours - such as wearing face masks, ensuring good hygiene, maintaining social distancing, and limiting physical contact - have been acknowledged as effective non-pharmaceutical solutions for pandemic prevention. However, many people often fail to adhere to these behaviour modifications. To better understand the issue, this study explores individuals' behaviour change situations during the COVID-19 pandemic and proposes appropriate design strategies. To collect valuable data for analysis, the researcher utilized three qualitative methods including observation, nominal group technique (NGT), and a user interview. Five facets of the current behaviour change situation were examined in Hefei, China. These include surveillance, publicity and information dissemination, public facilities and auxiliary tools design, people's attitudes towards behaviour change, and their actual behaviour performance. Moreover, the researchers also examined key challenges and design limitations of behaviour change situations, which were ranked based on voting results from three NGT groups. These theoretical findings may provide valuable insights to guide practical designs and policymaking within the domain of pandemic prevention and control.

Keywords: Behaviour Change, Pandemic Prevention and Control, Public Design, Public Health

INTRODUCTION

The current COVID-19 pandemic and its devastating impacts have created an unprecedented global health challenge to all facets of human life. This has, in turn, attracted keen attention from researchers belonging to various research fields^{1,2}. Before the successful development of antiviral medicines and widespread vaccination, non-pharmaceutical interventions have played (and will continue to play) a critical role in limiting the spread of viruses³. Generally, non-pharmaceutical interventions require comprehensive and long-term behaviour modifications in people's daily lives and routines during a pandemic. Since the beginning of the COVID-19 outbreak, various behaviour modification schemes have been consistently emphasised by the World Health Organization (WHO) and enforced by public authorities worldwide - including the Chinese Government⁴. Previous studies have also pointed out the significant role of public behaviour change in pandemic prevention and control⁵⁻⁷.

Although many researchers and public authorities have realised the importance of behaviour modification, its adoption among the public is still lacking. There is still a long way to go to achieve genuinely successful public behaviour change. According to a recent report, individuals in many parts of the world have failed to comply with behaviour change regulations, an observation that may be attributed to two critical reasons: (1) on the one hand, it is challenging to impose

comprehensive surveillance upon large geographical areas and populations - a limitation that may weaken the effects of law enforcement and social control measures, and (2) people's willingness for and attitudes on behaviour change may be undermined by contextual factors such as habits, customs, traditional culture and lifestyles⁸.

Besides, there is a lack of related studies on this topic. Within the field of behavioural science, several studies have been conducted to prompt people's behaviour change under different contexts, such as waste sorting, recycling, smoking cessation, and health treatment promotion⁹⁻¹². However, only a few of them focus on pandemic-related behaviour change, especially within the context of China. Moreover, within the domain of design science, designers have ample opportunities to produce ingenious designs in numerous areas including isolation and disinfecting materials and equipment, medical equipment and service, treatment planning, surveillance, data analysis, forecasting, and others¹³. Current designs are mostly focused on developing intelligent facilities and tools - such as disinfection robots, portable isolation devices, and thermal infrared cameras - that play crucial roles in improving healthcare, communication, transportation, and hospitality during a pandemic^{14,15}.

However, these designs rarely consider how to foster people's behaviour change through design interventions. Therefore, design research that

aims to encourage individual behaviour change during a pandemic is both necessary and meaningful.

The concept of "designing for behavioural change" refers to the use of design methods to change individuals' behavioural patterns to encourage desirable practices¹⁶. In previous studies, the role of design as a method to intentionally change behaviour has grown in importance, especially in the sub-field of sustainable design¹⁷. In effect, a growing number of studies have incorporated theoretical explorations of design-led approaches for behaviour change. As Wendel (2020) mentioned, there are currently many tools in the design community - from user-centred design to design thinking - that can guide human behaviour change¹⁸. For instance, Lilley (2009) outlined three roles that design can play in promoting sustainable behaviour change¹⁹.

Michie et al. (2011), on the other hand, proposed a "behaviour change wheel" integrating 19 prestigious frameworks of behaviour change, through which researchers can produce corresponding strategies for behaviour interventions²⁰. Meanwhile, Mummah et al. (2017) introduced an IDEAS design framework comprising 10 phases to help researchers efficiently generate behavioural strategies and health interventions²¹. In addition, Wendel (2020) forwarded a "DECIDE" model that provided a detailed depiction of the "design for behaviour change" process¹⁸.

The power of design in pandemic prevention has also been emphasised by previous scholars. Numerous scholars have proposed the concept of "Prevention through Design" (PtB), aiming to address pandemic-related issues from design perspectives, as well as "Design for X" (where X = pandemic)^{22,23}. During the past pandemics - and the current COVID-19 one - practical designs have played significant roles in transportation, protection, inspection, diagnosis, and disinfection^{24,25}. Several researchers have attempted to improve the existing urban infrastructure and propose corresponding design strategies to address pandemic situations¹⁴. Besides that, design schemes aiming to disseminate information and knowledge for pandemic prevention have also emerged in various forms, including smartphone applications, posters, publicity boards and others.

For instance, Gaspar et al. (2020) designed a mobile game named "COVID-19-Did You Know" to deliver health education content and promote preventive behaviours through gamification strategies²⁶. In Colombia, Borzenkova et al. (2021) integrated cultural and gamified elements into poster designs for pandemic-related information dissemination²⁷. Overall, it may be observed that most existing studies concentrate on developing and producing critical products with complete

functionality and usability to cope with a pandemic. However, only a few of them have considered fostering people's behaviour change through design interventions. Therefore, this research strives to investigate the current behaviour change situation for pandemic prevention and control in Hefei, China, and explore how to promote individual behaviour change through design interventions.

METHODS

Observation

An observation technique was employed as a qualitative method to examine the existing situation of behaviour change during pandemics in public spaces in Hefei, China. "Observation" is a type of conscious notice and detailed examination of people's behaviour in a natural circumstance²⁸. The researcher selected dozens of public areas in Hefei to conduct the observation. These areas include subway stations, public transportation nodes, supermarkets, restaurants, and administrative offices. The observation at each place generally lasted for half an hour. To ensure the reliability and validity of data, the researcher used smartphones to record the results.

User interview

Moreover, the researcher conducted a structured user interview to gain informative data. Informants with related knowledge backgrounds were invited for the interview. Due to time and distance limitations, the researcher conducted the interview virtually through a social media platform and phone calls. Snowball sampling was employed to select suitable informants. Snowball sampling is a non-profitable sampling technique during which existing subjects recruit future subjects from their acquaintances, analogous to a snowball continuously becoming bigger as it rolls downhill²⁹.

For the data analysis, the researcher utilized a thematic analysis (TA) based on a coding strategy using the Nvivo 12 plus software. The coding and theme identification process is data-driven - rather than influenced by participants' interpretations - to reduce subjectivity and to ensure the trustworthiness of the results. The results were then coded for synthesis to produce unitive themes. Finally, a series of themes were generated for analysis.

Nominal group technique

A nominal group technique (NGT) was employed to identify people's perceived barriers and current design limitations of pandemic-related behaviour change. Regarding the suitable number of respondents in an NGT group, Delbecq and Van (1971) suggested that a total of 5 to 9 respondents is appropriate for producing good ideas³⁰. Campbell et al. (2018), on the other hand, pointed out that the recommended number of

respondents in an NGT group could be 9 to 12¹¹. In this regard, the researcher decided to choose respondents with related knowledge backgrounds. This includes those with backgrounds in design science, behavioural science, and public health. Usually, a complete NGT discussion entails around five to seven procedures. In the present study, five steps were carried out sequentially, as per Perumal's (2017) study. The steps are (1) introduction and explanation; (2) silent generation of ideas; (3) ideas sharing; (4) group discussion; and (5) prioritising plus ranking³¹.

Statistical analysis

The Microsoft Excel 2019 software was utilised for descriptive statistical analysis. The analysis mainly involves two facets of examination. First, the researcher represented the sociodemographic characteristics of informants in the user interview and NGT discussion using several statistical parameters such as mean, standard deviation (SD), frequency, and percentage. Second, the researcher described several items from the findings made during the observation, interview, and NGT discussion using similar statistical parameters.

RESULTS

The Findings of Observation

Surveillance and monitoring

Surveillance is a direct and vital intervention measure for behaviour change during a pandemic. There are currently various surveillance measures being implemented in public places in Hefei, China. For instance, smart doors equipped with thermal sensors were set at the entrance of two railway stations and a local hospital, which were used to filter individuals with abnormal body temperatures (see figure 1). These smart doors may prove to be effective for screening and monitoring during the current COVID-19 pandemic. Besides, public workers are often spotted standing at the main entrance of these public places. Their primary responsibility is to check and remind people to wear face coverings, keep their social distance, and display green health codes (which indicate a low-level risk of infection). As outlined in Table 1, 23 out of 32 situations (71.9%) observed in the current study comply with the observation criteria while 9 out of 32 situations (28.1%) do not.

Publicity and information dissemination

Authorities in China have launched various intervention measures to educate and disseminate information and knowledge to the public. These measures include publicity boards and posters, voice boxes, and smartphone applications. Figure 2 demonstrates a publicity poster used to promote hand hygiene behaviour change in public spaces. These marked posters integrate images with text to disseminate information and are often placed at the public spaces where people may easily spot them. These publicity measures can disseminate knowledge and remind citizens of performing pandemic-related behaviour. According to our survey, most sample sites have adopted publicity and information dissemination measures for behaviour change (29 out of 32 sites), accounting for 90.6% of the total observed sites.

Auxiliary facilities and tools design

Auxiliary facilities and tools have been designed to support people's behaviour change in public spaces during a pandemic. Figure 3 displays a health code sign and a thermal detector at the entrance of a hotel. Health codes are recently used to screen travellers from high-risk regions, thereby minimising the risk of cross-region transmission. Thermo-detectors - a type of handheld device that is used to measure body temperature - function as replacements for smart temperature measurement facilities. These tools and equipment play various roles in supporting and encouraging public behaviour change. From Table 1, it can be noticed that 78.1% of the observation sites have set auxiliary facilities and tools to promote pandemic-related behaviour change.

People's Real Behaviour Change Situations

Figure 4 displays an observation site (a local hospital) in Hefei, China. Evidently, many citizens do not properly follow the behaviour change rules. While everyone seems to be wearing face masks, most of them do not fully cover their noses and mouths. This incorrect way of wearing masks may hamper effective virus transmission prevention. Moreover, some signs that are used to remind citizens to keep their social distance in public places are often overlooked, especially when there is a massive crowd. Table 1 summarises the findings of people's actual behaviour performance in public areas. Of the 32 observation sites, only 10 of them exhibit ideal behaviour performance, accounting for 31.3% of total sites.

Table 1: The result of situations complying with observational criteria (N=32)

Oservational criteria	Yes Frequency (%)	No Frequency (%)
Surveillance and monitoring measures or facilities were observed in public spaces	23 (71.9%)	9 (28.1%)
Publicity and information dissemination measures or facilities were observed in public spaces	29 (90.6%)	3 (9.4%)
Auxiliary facilities and tools design were observed in public spaces	25 (78.1%)	7 (21.9%)
The situations that most people follow behaviour change rules were observed in public spaces	10 (31.3%)	22 (68.7 %)



Figure 1: Smart doors in railway stations and a hospital



Figure 2: Publicity poster in a governmental administration space



Figure 3: QR code signs and thermo-detectors



Figure 4: People's behaviour performance in a hospital

Demographic profile of informants

Table 2 summarises the demographic profile of 22 informants. Among them, 11 were male and 11 were female, with a mean age of 31.6 (SD=7.2). The informants' ages ranged from 22 to 53. The group of informants comprises five university lecturers in the design department, four designers, five health workers, six administrators

in public spaces, and two other occupations. Additionally, 81.8% of the informants (18) came from Hefei or the city near Hefei. The Mean (SD) of working experience is 6.7 (5.3). Overall, the sociodemographic characteristics of the respondents are suitable for data collection.

People's perceptions towards behaviour change during pandemics

Table 3 summarises people's responses to interview questions, reflecting individuals' perceptions of behaviour change situations during the current pandemic in Hefei, China. Firstly, it could be observed that most respondents (18 out of 22) argued that behaviour change was critical and necessary for pandemic prevention and control. Secondly, 16 out of 22 informants (72.7%) had the intention to adopt preventive behaviours

during the pandemic. Thirdly, 12 out of 22 informants (54.5%) believed that there was a gap between behaviour change intentions and behaviour performance. Fourthly, 17 out of 22 informants (77.3%) had experienced challenges when adopting pandemic-related behaviour. Lastly, most informants (19 out of 22) argued that various design interventions had been imposed on public spaces to prompt behaviour modifications. However, only 10 of them deemed that these interventions were effective.

Table 2: Demographic profile of informants in the interview (N=22)

Variable	Parameters	Frequency (%)	Mean (SD)
Age			31.6 (7.2)
Working experience (Year)			6.7 (5.3)
Gender	Male	11 (50%)	
	Female	11 (50%)	
Occupation	University lecturers in the design department	5 (22.7%)	
	Full-time designers	4 (18.2%)	
	Health workers	5 (22.7%)	
	Administrators in public spaces	6 (27.3%)	
	Others	2 (9.1%)	
City	In Hefei or the city near Hefei	18 (81.8%)	
	In the city far from Hefei	4 (18.2%)	

Table 3: The findings of the user interview (N=22)

Interview Questions	Yes	No/Not mention
	Frequency (%)	Frequency (%)
Whether the behaviour change is critical/necessary for pandemic prevention?	18 (81.8%)	4 (18.2%)
Are you willing to perform preventive behaviours during pandemics?	16 (72.7%)	6 (27.3%)
Is there a gap between behaviour change intentions and actual behaviour change?	12 (54.5%)	10 (45.5%)
Do you face any challenges when performing pandemic-related behaviours?	17 (77.3%)	5 (22.7%)
Are there any design interventions in public spaces for people's behaviour change during pandemics?	19 (86.4%)	3 (13.6%)
Whether the current design interventions in public spaces effective for people's behaviour change during pandemics?	10 (45.5%)	12 (54.5%)

The Findings of NGT Discussion

Demographic profile of respondents

Finally, three groups of respondents were recruited for the NGT discussion. The first group comprised nine postgraduate students majoring in design, the second group comprised six designers and two salesmen, and the third group comprised five health workers with adequate working experience. Table 4 displays the demographic profile of the 22 respondents. Six of them were male, while 16 were female, with a mean working experience of 3.73 years (SD=2.45). All respondents were from Hefei or the city near Hefei.

Perceived challenges and design limitations for behaviour change during pandemics

A series of themes emerged from NGT Question 1 (What are the key challenges and barriers for people's behaviour change during pandemic situations in public spaces in Hefei, China?) and Question 2 (What are the limitations of current designs for pandemic-related behaviour change in public spaces in Hefei, China?). From the results, the researcher summarised the key challenges and design limitations of behaviour change during a pandemic. Table 5 lists the main findings of key challenges for people's behaviour change, ranked from lowest to highest in mean as follows: Difficulty of habits and behaviour formation (Mean=2.1, SD=1.0); Lack of surveillance

(Mean=2.6, SD=1.2); Uncomfortableness and inconvenience (Mean=3.1, SD=1.5); Lack of guidance and support (Mean=3.6, SD=1.7); Limitations of environments (Mean=5.0, SD=1.4); Pandemic fatigue (Mean=5.9, SD=1.5); and Poor information access (Mean=6.1, SD=1.2). Table 6, on the other hand, outlines the six key limitations of current design interventions of behaviour change during a pandemic. They are sorted in

increasing mean values as follows: Functional imperfection (Mean=2.0, SD=0.9); Narrow coverage (Mean=2.4, SD=1.1); Poor user experience (Mean=2.8, SD=1.5); Lack of immediate feedback (Mean=3.6, SD=1.5); Human resources cost (Mean=4.9, SD=1.1); and No consideration of universal design (Mean=5.3, SD=0.9).

Table 4: Demographic profile of informants in the NGT discussion (N=22)

Variable	Parameters	Frequency (%)	Mean (SD)
Working experience (Year)			3.73(2.45)
Gender	Male	6 (27.3%)	
	Female	16 (72.7%)	
Occupation	Postgraduate students	9 (40.9%)	
	Full-time designers	6 (27.3%)	
	Health workers	5 (22.7%)	
	Salesmen	2(9.1%)	
City	In Hefei or the city near Hefei	22 (100%)	
	In the city far from Hefei	0(0%)	

Table 5: People's perceived challenges for behaviour change during pandemics

Themes	Description	Mean (SD) of voting results	Final rank
Difficulty of habits and behaviour formation	Indicates that individuals get used to the original habits and behaviour patterns. Hence, they often have difficulties in changing original habits and developing new ones. Furthermore, some pandemic-related behaviours go against human nature.	2.1 (1.0)	1
Lack of surveillance	Refers to the lack of external restrictions and constraints used to prevent individuals from breaking behaviour change rules during a pandemic. This usually includes two aspects: manual and automatic surveillance.	2.6 (1.2)	2
Uncomfortableness and inconvenience	Involves users' unpleasant feelings or experiences when performing the recommended behaviour change during a pandemic, which may make them reluctant to change their behaviour patterns.	3.1 (1.5)	3
Lack of guidance and support	People cannot acquire guidance and support that help them to perform pandemic-related behaviours more easily.	3.6 (1.7)	4
Limitations of environments	The densely populated public spaces and environments make it difficult to perform the recommended behaviour during pandemics.	5 (1.4)	5
Pandemic fatigue	Indicates that consistent and iterative pandemic situations can exhaust people's behaviour change willingness and intentions.	5.9 (1.5)	6
Poor information access	Reveals that individuals lack access to immediate first-hand information about the pandemic. Sometimes, they may be exposed to fake news or misinformation.	6.1 (1.2)	7

Table 6: Limitations of current design interventions for behaviour change during pandemics

Themes	Description	Mean (SD) of voting results	Ranks
Functional imperfection	Incomplete and isolated functions that cannot cater to people's diverse needs and fail to provide enough support for pandemic-related behaviour change.	2 (0.9)	1
Narrow coverage	Cannot play a role in guiding and supporting behaviour change over a large public space.	2.4 (1.1)	2
Poor user experience	Contribute very little to improving users' experience when adopting the recommended behaviour change during a pandemic.	2.8 (1.5)	3
Lack of immediate feedback	Cannot provide immediate user feedback when guiding or limiting pandemic-related behaviour change.	3.6 (1.5)	4
Human resources cost	Depend heavily on human resources and may cost too much human labour.	4.9 (1.1)	5
No consideration of universal design	Do not consider the characteristics and needs of diverse user groups, especially vulnerable groups in society (the elderly or children).	5.3 (0.9)	6

DISCUSSION

The research findings reveal the various facets of the behaviour change situation in Hefei during the COVID-19 pandemic. Currently, the Chinese authorities have launched various policies and intervention measures to promote people's behaviour change. Different types of public facilities and auxiliary tools have been designed to help individuals better adopt new pandemic-related behaviour. By imposing these interventions, many citizens have realised the significance and necessity of behaviour change during the pandemic. Some of them adopt positive attitudes to change their behaviour patterns and lifestyles for pandemic prevention and control.

Nevertheless, many still do not follow the appropriate behaviour change regulations in public spaces. Some of them are unwilling to follow behaviour change rules, while others do not perform preventive behaviours correctly. As Chan et al. (2021) stated, a large-scale and real behaviour change is difficult and challenging during the pandemic⁸. Furthermore, some respondents stated that they have experienced various challenges when trying to adopt behaviour changes. Moreover, the current design interventions may not be enough to promote the intended behaviour changes. The respondents also mentioned that the discrepancy between behaviour change intentions and actual behaviour performance should also be focused on. In many cases, people may not perform pandemic-related behaviour for various external reasons, despite having positive attitudes toward such changes. This finding echoes a previous behaviour study that stressed the importance of actual behaviour performance in relation to attitudes³².

Furthermore, this study identified and ranked several key challenges and design limitations for people's behaviour change during a pandemic. Firstly, based on the voting results, the biggest obstacle identified is new behaviour formation. Usually, individuals often get too used to their original behaviour patterns and lifestyles for a long period, so much so that it is difficult to disrupt their behaviour and force them to change. Hence, designers should consider how to guide behaviour change more naturally, instead of imposing rough and abrupt interventions. Behaviour change interventions should not severely hinder individuals' needs and wants. Humans are socially cooperative creatures. Social contact and communication are crucial requirements of life as per Maslow's needs theory³³. This finding is consistent with Van Bavel's (2020) research which revealed that some pandemic-related behaviour modifications may go against human's social nature⁶. In that regard, designers should consider how to reduce the adverse impact of interventions on individuals' various needs and wants.

Furthermore, lack of surveillance is the second most crucial challenge for behaviour change during a pandemic. Forcing individuals to adopt the recommended behaviour through surveillance is the only effective way to ensure that even those who are unwilling to do so voluntarily would comply. Unfortunately, although surveillance at the entrance to public places is usually strict, the same level of surveillance is usually not imposed on people who have already entered. As discussed above, surveillance relies heavily on human resources. Due to the limited number of workers, it is impossible to impose continuous surveillance over people in public areas. Moreover, as mentioned earlier, neither automatic nor manual surveillance can promote behaviour change inside

public spaces. This is where design interventions play the most essential role, through the incorporation of automatic surveillance.

Poor behaviour experience was also noted as among the main challenges and design limitations of pandemic-related behaviour change. Generally, most protective behaviours are inconvenient, uncomfortable, or time-consuming. These vexations make it challenging for individuals to adopt the necessary behaviour changes. In that regard, designers should attempt to reduce obstacles to behaviour change and improve behaviour experience through design interventions. For instance, a transparent face mask design would enable people to see others' expressions when having face-to-face communication. On that note, providing behaviour support is a good policy action. Besides that, immediate feedback and information should be prepared to remind individuals of behaviour modifications when needed. For instance, designers can use marks or signs to guide or steer individuals' social distancing behaviour.

Universal design principles should be valued by designers when developing new designs or improving current ones. According to our survey, current designs hardly consider the differentiation among distinct users and the needs of vulnerable groups such as the elderly, children, or the disabled. For example, when a mother carries her baby, she may not be willing to sit separately with the child. In this case, social distancing signs on seats may not be practical. Cases of these instances need to be considered when designing auxiliary tools to provide behavioural support in public spaces.

Strengths of research

This study is among the first to integrate the knowledge of design and behaviour science to be applied within a global pandemic context. In that regard, this study is a typical representation of interdisciplinary work for pandemic prevention and control. Furthermore, this study explores the potential of addressing pandemic-related challenges using design interventions. Thus, this research expands the knowledge of "designing for behaviour change" and "designing for pandemic prevention and control." Moreover, the integration of three qualitative research methods may prove to be more advantageous than the single method, concerning the quality of data collection and analysis. As a result, this study enables stakeholders to have an in-depth comprehension of behaviour change during a pandemic.

Limitations and recommendations

There are several limitations in the present study. Firstly, the research scope is relatively narrow. The sample sites are in Hefei, China and all informants are Chinese citizens. For these reasons, the research findings may not be

generalized to other regions. Generally, pandemic-related behaviour may be affected by various sociocultural factors, such as regions, cultural contexts, and living environments³⁴. Hence, future research is recommended to be conducted in diverse backgrounds, which may also involve cross-regional comparisons. Secondly, the data collection and analysis methods are relatively simple. The researcher only used qualitative methods to collect data and conducted a descriptive statistical analysis. To improve the subjectivity and applicability of the results, it is recommended for future studies to leverage quantitative methods during data collection and analysis. For instance, interested researchers may conduct an ANOVA test to explore the association between demographic characteristics and individuals' behaviour performance. Thirdly, the present study is among the earliest initial investigation of the behaviour change situation during pandemics. Therefore, the theoretical findings at this stage may not be sufficient to provide valuable insights for policymaking and design practices. Hence, the researcher recommends further examination of individuals' behaviour change mechanisms and the construction of a more mature theoretical framework in the future.

CONCLUSION

In the context of the modern society we live in, the spread of viruses may trigger a global pandemic and undermine public security and social order. Therefore, the topic of designing for pandemic prevention is becoming increasingly prevalent. This study explores the existing situation of behaviour change during the current COVID-19 pandemic in public spaces in China. The existing situation could be categorized into five aspects: surveillance and monitoring; publicity and information dissemination; public facilities and auxiliary tools design; people's behavioural intentions and attitudes; and behaviour performance. Additionally, seven key challenges and six design limitations were identified and ranked according to their importance. Based on the above, the researcher discussed the question of "how to develop practical designs and enact policies to help individuals perform preventive behaviours during pandemics?". In this regard, designers can find the limitations of current designs during pandemic situations and explore ways to improve them. For instance, to address the issue of inadequate surveillance on behaviour change in public spaces, designers can consider constructing smart surveillance systems through public facilities and user interface designs. Therefore, this study may provide valuable references for design researchers when producing design schemes or proposing design strategies for pandemic prevention and control. In addition, theoretical findings in this study can also be

utilised to guide related policymaking and social control measures during a pandemic.

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Conflict of interest

The authors declare no potential conflict of interest.

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REFERENCES

1. Emanuel EJ, Persad G, Upshur R, Thome B, Parker M, Glickman A, Zhang C, Boyle C, Smith M, Phillips JP. Fair allocation of scarce medical resources in the time of Covid-19. *New England Journal of Medicine*. 2020 May 21;382(21):2049-55.
2. Summers C, Wu P, Taylor AJG. Supporting Mental Health During the COVID-19 Pandemic Using a Digital Behaviour Change Intervention: An Open-Label, Single-Arm, Pre-Post Intervention Study. *JMIR Form Res [Internet]*. 2021;5(10):e31273. Available from: <https://formative.jmir.org/2021/10/e31273>
3. Betsch C. How behavioural science data helps mitigate the COVID-19 crisis. *Nat Hum Behav*. 2020;4(5):438.
4. Wu Y, Shen F. Exploring the impacts of media use and media trust on health behaviours during the COVID-19 pandemic in China. *J Health Psychol*. 2021;1359105321995964.
5. Perra N. Non-pharmaceutical interventions during the COVID-19 pandemic: A review. *Phys Rep*. 2021;913:1-52.
6. Bavel JJ Van, Baicker K, Boggio PS, Capraro V, Cichocka A, Cikara M, et al. Using social and behavioural science to support COVID-19 pandemic response. *Nat Hum Behav*. 2020;4(5):460-71.
7. Ning L, Niu J, Bi X, Yang C, Liu Z, Wu Q, Ning N, Liang L, Liu A, Hao Y, Gao L. The impacts of knowledge, risk perception, emotion and information on citizens' protective behaviours during the outbreak of COVID-19: a cross-sectional study in China. *BMC public health*. 2020 Dec;20(1):1-2.
8. Chan DKC, Zhang C-Q, Weman-Josefsson K. Why people failed to adhere to COVID-19 preventive behaviours? Perspectives from an integrated behaviour change model. *Infect Control Hosp Epidemiol*. 2021;42(3):375-6.
9. Wang S, Wang J, Yang S, Li J, Zhou K. From intention to behaviour: Comprehending residents' waste sorting intention and behaviour formation process. *Waste Manag*. 2020;113:41-50.
10. Siu KWM, Xiao JX. Public facility design for sustainability: Participatory action research on household recycling in Hong Kong. *Action Res*. 2020;18(4):448-68.
11. Campbell KA, Fergie L, Coleman-Haynes T, Cooper S, Lorencatto F, Ussher M, et al. Improving behavioural support for smoking cessation in pregnancy: What are the barriers to stopping and which behaviour change techniques can influence them? Application of theoretical domains framework. *Int J Environ Res Public Health*. 2018;15(2):359.
12. Mangurian C, Niu GC, Schillinger D, Newcomer JW, Dilley J, Handley MA. Utilisation of the Behaviour Change Wheel framework to develop a model to improve cardiometabolic screening for people with severe mental illness. *Implement Sci*. 2017;12(1):1-16.
13. Reich Y. The coronavirus pandemic: How can design help? *Res Eng Design*. 2020; 31: 141-142.
14. Liu J, Kamarudin KM, Liu Y, Zou J. Developing Pandemic Prevention and Control by ANP-QFD Approach: A Case Study on Urban Furniture Design in China Communities. *Int J Environ Res Public Health*. 2021;18(5):2653.
15. Thomas MJ, Lal V, Baby AK, James A, Raj AK. Can technological advancements help to alleviate COVID-19 pandemic? a review. *J Biomed Inform*. 2021;117:103787.

16. Cash PJ, Hartlev CG, Durazo CB. Behavioural design: A process for integrating behaviour change and design. *Des Stud.* 2017;48:96-128.
17. Tromp N, Hekkert P, Verbeek P-P. Design for socially responsible behaviour: a classification of influence based on intended user experience. *Des issues.* 2011;27(3):3-19.
18. Wendel S. *Designing for behaviour change: Applying psychology and behavioural economics.* Sebastopol: O'Reilly Media; 2020.
19. Lilley D. Design for sustainable behaviour: strategies and perceptions. *Des Stud.* 2009;30(6):704-20.
20. Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011;6(1):1-12.
21. Mummah SA, Robinson TN, King AC, Gardner CD, Sutton S. IDEAS (Integrate, Design, Assess, and Share): a framework and toolkit of strategies for the development of more effective digital interventions to change health behaviour. *J Med Internet Res.* 2016;18(12):e5927.
22. Manuele FA. Prevention through design (PtD): history and future. *J Safety Res.* 2008;39(2):127-30.
23. Maurya S, Shin T, Watanabe K, Nakagoe H. Service creation for re-normalising essential business environment: a prevention based digital tech approach. *Proc Des Soc.* 2021;1:2631-40.
24. Gibbs SG, Herstein JJ, Le AB, Beam EL, Cieslak TJ, Lawler J V, et al. Review of literature for air medical evacuation high-level containment transport. *Air Med J.* 2019;38(5):359-65.
25. Wang CJ, Ng CY, Brook RH. Response to COVID-19 in Taiwan: big data analytics, new technology, and proactive testing. *Jama.* 2020;323(14):1341-2.
26. Gaspar JDS, Lage EM, Da Silva FJ, Mineiro É, De Oliveira IJR, Oliveira I, et al. A mobile serious game about the pandemic (COVID-19-Did You Know?): Design and evaluation study. *JMIR serious games.* 2020;8(4):e25226.
27. Borzenkova G, Golovátina-Mora P, Ramirez PAZ, Sarmiento JMH. Gamification Design for Behaviour Change of Indigenous Communities in Choco, Colombia, During COVID-19 Pandemic. In: *Transforming Society and Organisations through Gamification.* Springer; 2021. p. 309-34.
28. Croker RA. An introduction to qualitative research. In: *Qualitative research in applied linguistics.* London: Palgrave Macmillan; 2009. p. 3-24.
29. Biernacki P, Waldorf D. Snowball sampling: Problems and techniques of chain referral sampling. *Sociological methods & research.* 1981 Nov;10(2):141-63.
30. Delbecq AL, Van de Ven AH. A group process model for problem identification and program planning. *J Appl Behav Sci.* 1971;7(4):466-92.
31. Perumal VE. *Common Cultural Design Framework from Cultural Artefacts of Multi-Ethnic Society in Malaysia* (Doctoral dissertation, PhD Thesis, Universiti Putra Malaysia, Department of Industrial Design. Serdang: UPM).
32. Ang T, Wei S, Arli D. Social distancing behaviour during COVID-19: a TPB perspective. *Mark. Intell. Plan.* 2021 Jun 1;39(6):809-24.
33. Hopper E. Maslow's hierarchy of needs explained. *ThoughtCo, ThoughtCo.* 2020;24.
34. Liu J, Kamarudin KM, Liu Y, Zou J, Zhang J. Developing a Behavior Change Framework for Pandemic Prevention and Control in Public Spaces in China. *Sustainability.* 2022 Feb 21;14(4):2452.