Travel Medicine and Infectious Disease 60 (2024) 102729

Contents lists available at ScienceDirect

Travel Medicine and Infectious Disease

journal homepage: www.elsevier.com/locate/tmaid

Screening and early detection of communicable diseases on board cruise ships: An assessment of passengers' preferences on technical solutions

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A R T I C L E I N F O

Keywords:
Public health
Cruise-ships
Early detection
Communicable diseases
Technological solutions
Passengers' willingness

A B S T R A C T

Background: Implementing technological solutions to screen for and detect early the most prevalent communicable diseases on cruise ships is contingent on, among others, willingness of passengers to accept use of such solutions.
Method: We surveyed passenger preferences to record their willingness to accept technological solutions for screening and early detection of communicable diseases on cruise ships. Self-reported sociodemographic characteristics, use of technology and acceptance of solutions were recorded anonymously in paper format. Multiple logistic regression analyses investigated the association of demographic and other characteristics with willingness and barriers/concerns of passengers to endorse proposed solutions.
Results: Of a total of 1344 passengers on two successive cruises on board CELESTYAL OLYMPIA, 336 (1 every 4) participated in the survey. The vast majority of passengers (92.3 %, n = 310) agreed with at least one solution. Passengers showed lower levels of acceptance for more personalized solutions, such as use of wearable devices (45.5 %) and monitoring with cameras (64.0 %), whereas they were more receptive to less personally invasive solutions, such as integration of cabins with air purifiers (89.6 %) and air quality sensors (80.4 %). Age, self-employment status, educational level, and fear of contacting a communicable disease were significantly correlated with passengers' willingness to adopt proposed solutions.
Conclusions: To successfully integrate screening and early detection technological solutions in cruise ships, it is imperative that targeted awareness and education interventions are implemented on passengers to strengthen understanding and acceptance of such solutions and assuage concerns around monitoring and handling of personal health data.

1. Introduction

In principle, international travel can rapidly and extensively affect global health [1]. An array of epidemic prone diseases such as the pandemic (H1N1) in 2009 which originated in Mexico [2], the Middle East Respiratory Syndrome Corona Virus, which was isolated in 2012 in Saudi Arabia [3], the Chikungunya virus which emerged in the Americas in Saint Maarten in December 2013 [4,5] and the Ebola Virus in West Africa in March 2014 [6], were introduced into non-endemic areas through travel. Most of these communicable diseases occurring during international travelling by ship can be acquired through contaminated food and water, infected individuals embarking on the ship, as well as the environment [7–9]. Other challenges, such as development of a virus due to poor cleaning and safety measures, seasonal infections, and others, are introduced while cruising, often leading to transmission of health hazards that are seen on ships or also on land [8,10].

All the above challenges are further exacerbated on board cruise ships. These vessels transport thousands of passengers and crew on a single trip, with a typical cruise ship carrying 2000 passengers and 800 crew, and larger ships having a capacity of more than 5000 passengers and 2000 crew [2]. Outbreaks of infectious diseases on board cruise ships are natural consequences of travelling in such crowded and closed or semi-closed settings. The impact is further compounded by the fact that the average cruise lasts longer than 6 days, there are frequent group activities that increase passenger and crew contact and facilitate the spread of infection, and frequent stops are made, when passengers can

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https://doi.org/10.1016/j.tmaid.2024.102729
Received 6 October 2023; Received in revised form 24 April 2024; Accepted 28 May 2024
Available online 29 May 2024

leave the ship and new passengers and crew can board, providing new reservoirs for infection [11].

The continuing high impact of infectious diseases on board cruise ships, highlighted during the COVID-19 pandemic, has demonstrated the urgency to re-assess existing regulations and protocols [12,13] on maritime health and safety branches as well as optimize the current naval architectural and marine engineering systems to prevent, mitigate and manage such health emergencies. Yet, current guidelines do not make any reference to the introduction of e.g., wearables for monitoring health vitals amongst passengers and crew or sensors for early identification of changes in those vitals that could indicate the onset of a communicable disease. Regarding the latter, biosensors are described as compact analytical devices, incorporating biological or biomimetic sensing elements that are applied for the detection and monitoring of various analytes or pathogens important for the environment, health, and food industries [14]. For example, very recent literature [15] discusses the development of a framework integrating wearable sensors and an advanced machine learning (ML) model to assist with timely decisions on COVID-19 detection. Further, piezoelectric, and magneto-strictive biosensor materials have been shown to have a great potential for application in the detection of various viruses, yet none of the commercially available options could be used for pandemic diseases [14]. Further, extensive sanitation has become the primary approach in prevention and disruption of disease outbreaks. The search for new effective and sustainable approaches for infection control has recently led researchers to explore and reevaluate the innovative idea of using probiotics to “attack” surface pathogens [16].

Any such biosensing devices would need to be effectively and efficiently incorporated into the ship’s architecture. Design and construction of cruise ships is of major importance in terms of preventing an outbreak or mitigating the spread of the disease. The HS4U project (Healthy Ship 4 You – EU’s Horizon Europe Research and Innovation Actions) aims to put forward a basket of technological state-of-the-art solutions to strengthen and integrate screening and early detection of the most prevalent communicable diseases on board cruise ships, namely COVID-19 and norovirus. These solutions could become part of the pilot robot cabin that the project aims to deliver. In such a case, they would need to be endorsed and followed by passengers on board cruise ships and enforced or implemented by crew. To probe into the latter’s willingness to endorse or follow these solutions as well as record any drivers and barriers for their preferences, we conducted a stated preference survey in two audience groups on board cruise ships, passengers, and crew. This manuscript presents and discusses results from the passengers’ survey.

2. Methods

2.1. Study design

This was a non-interventional, cross-sectional study with a random sample to assess passenger preference for and willingness to accept use of state-of-the-art technological solutions to screen for communicable diseases on board cruise ships. Data was collected between April and May 2023 through paper questionnaires, on two successive cruises, on board the cruise ship CELESTYAL OLYMPIA. Passengers provided their written consent to participate in the survey. To ensure a representative sample, a paper questionnaire was handed for completion to every 4th passenger boarding the cruise. All answers were fully anonymized.

2.2. Study tool

A questionnaire was developed de novo in three languages, English, Greek and French to minimize sample exclusion criteria. The structure and content of the questionnaire was validated in a workshop within the HS4U project. The questionnaire included a section on sociodemographic characteristics, a section on passengers’ profile and a section on their willingness to accept technical solutions proposed to screen for and diagnose early communicable diseases’ outbreaks (the English version is presented in the Annex). The following solutions were surveyed: use of imaging devices, biosensors in sinks and toilets, biosensors installed in the HVAC system for air quality monitoring, antibacterial materials on cabin’s surfaces, large monitors in public spaces and/or cabins with real-time guidance in case of a disease outbreak. Barriers/concerns surveyed were health data security, social stigma in case of illness, effect of technical solutions on subject’s health, lack of comfort during the cruise and unwillingness to be monitored. The preliminary version of the questionnaire was circulated to an internal advisory committee for feedback and content validity evaluation and sent for approval to the project’s Ethics Committee Board. CVI was computed as the number of experts giving a rating of “very relevant” for each question divided by the total number of experts. All questions were considered very relevant and included in the final version of the questionnaire. A test-retest reliability study [17] included circulating questionnaires twice (one week apart) to the same 25 passengers/crew. Reliability coefficients from the test-retest analysis were all greater than 0.78 ($p < 0.001$) indicating significant agreement and acceptable reliability.

2.3. Eligibility to participate

A passenger was considered eligible to participate in this study, if he/she met all the following criteria: a) adult aged ≥18 years old, b) able and willing to sign the informed consent form, and c) able to read and write either in English or in Greek or in French.

2.4. Sample size

Power analysis was conducted to calculate the sample size required [18]. For the proposed study, the experimental unit was the passengers, so sample size referred to the total number of individual passengers. The a-priori power analysis was based on the primary outcome of the study, represented as percentages of the endpoint. To increase study impact, the secondary endpoint (to explore if willingness of passengers and crew to endorse/follow proposed state-of-the-art solutions differs according to demographic characteristics) was also included in the calculation with equal significance. Power analysis was performed using the G*Power software, version 3.1.9.6. Assuming 50 % of the subjects in the population or more would have the factor of interest (willing to endorse/follow proposed state-of-the-art solutions), and a population size of up to 3000 (passengers of two cruises), the study would require a sample size of approximately 350 for estimating the expected proportion with 5 % absolute precision and 95 % confidence. Concerning the secondary endpoint, it was calculated that with the proposed sample size of passengers the study would have 95 % power to perform a logistic regression analysis with dependent variables the study outcome (i.e willingness), at a significance level of 0.05 and for identifying an estimated odds ratio of 1.7 or more [19].

2.5. Data analysis

Continuous variables are presented with mean and standard deviation (SD) and/or with median and interquartile range (IQR). Quantitative variables are presented with absolute and relative frequencies. One proportion agreement method, the Content Validity Index (CVI) [17] was used to estimate quantitatively the content validity before the administration of the questionnaire. Intra-class coefficients (ICC) along with kappa coefficients were computed to measure the test-retest agreement.

Multiple logistic regression models were performed to investigate the association of demographic and other characteristics with willingness and barriers/concerns of passengers to endorse proposed state-of-the-art solutions. Odds Ratios along with 95 % Confidence Intervals were computed from the results of logistic regression analysis. Model diagnostics were evaluated using the Hosmer and Lemeshow statistic [20]. All reported p values were two-tailed. Statistical significance was set at $p < 0.05$ and analyses were conducted using SPSS statistical software (version 27.0).

3. Results

Three hundred thirty six (336) passengers out of a total of one thousand three hundred and fourty four (1344) completed the questionnaires. Passengers' demographic characteristics are presented in Table 1. All passengers reported engaging daily with technology for a median of 7–8 hours for either work or personal communication and entertainment purposes.

Passenger experience with cruises, health status and awareness of/attitude towards communicable diseases on board cruise ships is presented in Table 2. Most of the passengers (63.4 %) had been on a cruise before, the majority for more than 3 times. Almost three quarters of the sample (74.1 %) had noticed any health or sanitation safety measures in place on board the ship, particularly for communicable diseases. Of them, 61.8 % found those measures adequate and sufficient. Most were familiar with the most prevalent communicable diseases on board cruise ships and 54.5 % had been affected by one of them in the past. Seventeen per cent (17 %) of those had also been hospitalized for that condition. Nonetheless, half the passengers (50.3 %) reported not being afraid or probably not being afraid of contacting an infection during the cruise.

An overwhelming majority of passengers (92.3 %, n = 310) agreed with at least one technological solution. Nonetheless, when asked after specific solutions, passengers showed lower levels of acceptance for the more invasive solutions such as use of wearable devices (45.5 %) and monitoring of their health with cameras (64.0 %), whereas they were more receptive to solutions which improved the air quality of the cabin, including the integration of the cabin with air purifiers (89.6 %) and air quality sensors (80.4 %). The ranking of passenger acceptance for proposed solutions is presented in Table 3.

The main reason for agreeing with one solution was being in favor of any new technology (77.4 %), followed by assurance that the solution would safeguard/remove any health-related concerns during the cruise (76.5 %). On the other hand, the main reasons for disagreeing were not wanting to be monitored (80.4 %) and worrying about their health data security (72.0 %) (Table 4).

Multiple logistic regression analyses were conducted in a stepwise method (Table 5) in order to identify factors associated with passengers' willingness to adopt the proposed solutions. Greater age was significantly associated with lower probability of agreeing with cameras detecting passengers with fever and with wearable devices (e.g., smartwatch) for health monitoring. Passengers who were afraid of contacting a communicable disease or infection on board had significantly greater odds of agreeing with cameras detecting fever, wearable devices (e.g., smartwatch), outfitting cabin's sink and toilet with virus sensors, outfitting cabin with air quality sensors, outfitting air purifier in the cabin and the air conditioning system, coating cabin's and/or public spaces surfaces with antibacterial/antiviral materials, and using cabin's and/or public spaces TVs for real-time guidance and advice in cases of

Table 1
Passengers' demographic characteristics (N = 336).

	N	%
Gender		
Male	131	39.0
Female	205	61.0
Age (years)-mean (SD)	59.1 (14.2)	
Highest degree of education		
Less than high school degree	18	5.4
High school degree or equivalent	44	13.1
College degree	66	19.6
Bachelor's degree	118	35.1
Master's or PhD degree	89	26.5
Employment status		
Employed/Self-employed	176	52.4
Unemployed	18	5.4
Retired	139	41.4
Disabled, not able to work	1	0.3
Other	2	0.6
Marital status		
Not married or not living with a partner, no children	47	14.0
Not married or not living with a partner, with children	9	2.7
Married or living with a partner, no children	98	29.2
Married or living with a partner, with children	120	35.7
Divorced or separated, no children	8	2.4
Divorced or separated, with children	22	6.5
Widowed, no children	4	1.2
Widowed, with children	27	8.0
Other	1	0.3

Table 2
Passengers' profile.

	N	%
Is this your first time on a cruise?		
No	213	63.4
Yes	123	36.6
If no, how many times have you been on a cruise to-date?		
1	24	11.4
2–3	79	37.4
More than 3	108	51.2
Have you noticed any health or sanitation safety measures in place on board the ship, particularly for communicable diseases?		
No	87	25.9
Yes	249	74.1
If yes, do you find them adequate & sufficient?		
Yes	154	61.8
Probably Yes	71	28.5
I am not sure	15	6.0
Probably No	7	2.8
No	2	0.8
Are you familiar with the following communicable diseases?		
COVID-19	325	96.7
Influenza	320	95.2
Gastrointestinal diseases	302	89.9
Legionella	225	67.0
Are you afraid of contacting a communicable disease/infection on board the ship?		
Yes	55	16.4
Probably Yes	82	24.4
I am not sure	30	8.9
Probably No	66	19.6
No	103	30.7
Have you ever been diagnosed with a chronic condition?		
No	275	81.8
Yes	61	18.2
If yes, were you hospitalized?		
No	157	46.7
Yes	179	53.3
Have you ever been affected by one of the four communicable diseases?		
No	153	45.5
Yes	183	54.5
If yes, were you hospitalized?		
No	279	83.0
Yes	57	17.0

Table 3
Ranking of acceptance for the proposed technological solutions.

List of technological solutions	N	%
Air purifier in the cabin and the air conditioning system	301	89.6
Outfitting the cabin with air quality sensors	270	80.4
Cabin's and/or public spaces' surfaces coated with antibacterial/antiviral materials	263	78.3
Cabin's and/or public spaces' TVs used for real-time guidance and advice in cases of disease outbreaks	252	75.0
Cameras detecting passengers with fever	215	64.0
Outfitting cabin's sink and toilet with virus sensors	206	61.3
Wearable devices (e.g., smartwatch) for health monitoring	153	45.5

Table 4
Reasons for agreeing or disagreeing with technological solutions.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Agree/Strongly Agree
	N (%)	N (%)	N (%)	N (%)	N (%)	%
If you "agree" or "strongly agree" with any of the solutions, why?						
I am in favor of use of any new technology	9 (2.9)	21 (6.8)	40 (12.9)	138 (44.5)	102 (32.9)	77.4
It would safeguard/remove any health-related concerns during the cruise	8 (2.6)	15 (4.8)	50 (16.1)	150 (48.4)	87 (28.1)	76.5
If you "disagree" or "strongly disagree" with any of the solutions, why?						
I am worried about my health data security	3 (2.8)	12 (11.2)	15 (14)	48 (44.9)	29 (27.1)	72.0
I am worried of being socially stigmatized in case of illness	2 (1.9)	27 (25.2)	22 (20.6)	41 (38.3)	15 (14)	52.3
I am worried about the effect it might have on my health	8 (7.5)	21 (19.6)	41 (38.3)	27 (25.2)	10 (9.3)	34.6
I am worried about feeling uncomfortable during (my work) on the cruise	7 (6.5)	24 (22.4)	34 (31.8)	24 (22.4)	18 (16.8)	39.3
I don't want to be monitored	3 (2.8)	4 (3.7)	14 (13.1)	47 (43.9)	39 (36.4)	80.4

disease outbreaks. Women had a 38 % lower probability of agreeing with wearable devices (e.g., smartwatch) compared to men. Furthermore, participants with higher levels of education were less likely to agree with outfitting cabin's sink and toilet with virus sensors, coating cabin's and/or public spaces surfaces with antibacterial/antiviral materials and using cabin's and/or public spaces TVs for real-time guidance and advice in cases of disease outbreaks. Passengers who were on their 1st cruise were less likely to agree with coating cabin's and/or public spaces surfaces with antibacterial/antiviral materials compared to passengers who had been on a cruise in the past. Employed/self-employed passengers were more likely to agree with outfitting cabin's sink and toilet with virus sensors, adding air purifier in the cabin and the air conditioning system and coating cabin's and/or public spaces surfaces with antibacterial/antiviral material, while passengers who had been diagnosed with a chronic disease had 5.46 times greater probability of agreeing with air purifiers in the cabin and the air conditioning system. The likelihood of agreeing with using cabin's and/or public spaces TVs for real-time guidance and advice in cases of disease outbreaks was greater in those that had been affected by a communicable disease in the past.

4. Discussion

This is the first study in the literature to record and present willingness of passengers of a large cruise ship to endorse or allow use of state-of-the-art technological solutions to screen for and detect early communicable diseases on board cruise ships. Our study confirms that introducing technological solutions to aid with the early detection of communicable diseases such as COVID-19 and norovirus on board cruise ships may be challenging, particularly as regards the actual endorsement and adoption of such tools by passengers. The great majority of passengers identify this gap and agree with at least one proposed technological solution, however there are passengers who may be hesitant to sign up for such solutions, because of monitoring and/or data handling and security concerns. Self-employment, and fear of contacting communicable diseases on board the ship appear to positively impact on acceptance levels for such solutions, whereas greater age and higher levels of education are related to lower acceptance and willingness to adopt levels.

Our survey confirms that, amongst passengers, there persist contradictory priorities that may impact on future surveillance policies on board cruise ships: on the one hand, passengers are looking to optimize their time both on and off board and maximize the return on their investment, and for this, they need to be healthy; on the other hand, and for the same reasons, they are unwilling to accept -earlier than necessary- the limitations of mitigation policies for a communicable disease, such as frequent monitoring and/or in-cabin quarantine. This is part of the reason respondents downplay the importance of contacting a communicable disease, despite the majority having already experienced one on board a cruise. This finding is different from a recent study by Park et al. [21], not conducted on cruise ships, in which significant changes in users' privacy attitudes toward symptom tracking apps are reported as compared to the pre-COVID 19 era, primarily due to disease uncertainty.

Further, there is an evident hesitance towards wearable solutions and those that monitor vitals during the cruise. This is primarily attributed to concerns about the (mis)use of sensitive personal data, which may be also related to the more immediate impact of having to quarantine or be forced off the ship. Our results confirm previous literature on the impact of privacy concerns on low or no acceptance of use of tracing solutions [22]. In several instances [23,24], passengers were reluctant to share sensitive health data and had concerns about how their personal information would be handled and stored. However, the majority agreed to have the most important vital signs such as heart rate, blood pressure, body temperature, and oxygen saturation measured. Especially with regards to pandemic tracking apps, surveys [25,26] indicated that people tend to rationalize the trade-off between public health and personal privacy by invoking the concept of "the greater good." Three different studies in Germany [27], the UK [28] and Belgium [29] showcased varying levels of acceptance of tracing apps, with trust, understanding, perceived benefits, self-efficacy, and perceived barriers identified as predictors of intention to endorse such apps.

Therefore, concerns about privacy violations and overly broad surveillance cannot be addressed without an upfront and thoroughly explained data monitoring process, that ensures health related data are used only for specific stated purposes, stored only for the time necessary, e.g., the duration of the cruise, and then, effectively destroyed, and managed by a person qualified to read and maintain such sensitive data, such as the physician on board a cruise. Literature has already showcased that, for contact tracing to work effectively, solutions should be implemented systematically, and this requires the secure collection, processing, storage, and discarding of contact tracing information of people in real time, without impinging on their privacy and rights [30].

Particularly amongst those with chronic health conditions, who have been disproportionately burdened by COVID-19 morbidity and mortality, COVID-19 contact tracing may be of extreme importance, in terms of public health, yet its acceptability is still relatively low [31], even outside cruise ships. These more "vulnerable" populations should be the first target of any outreach effort to inform use of monitoring technological solutions on board cruise ships.

Age is also a major factor that may impact on willingness to adopt health monitoring technologies, including wearables. In our study, younger passengers showed greater willingness to accept more technological interventions. This finding is in line with results from a national survey in the US with 1481 older adults [32], which examined use of wearable devices and its key predictors versus sociodemographic factors, health conditions, and technology self-efficacy. The survey revealed low levels of wearable use (17.5 %) and significant positive associations between technology self-efficacy, health conditions, and demographic factors (gender, race, education, and annual household income) and use of wearable devices.

Table 5
Multiple logistic regression analysis results.

Dependent variables (*in bold*)	OR (95 % CI)$^{+}$	P
Cameras detecting passengers with fever		
Age (one year increase)	0.98 (0.96 — 0.99)	0.006
Are you afraid of contacting a communicable disease or infection on board the ship? (yes vs no)	2.12 (1.34 — 3.36)	0.001
Wearable devices (e.g., smartwatch) for health monitoring		
Age (one year increase)	0.98 (0.97 — 0.99)	0.017
Are you afraid of contacting a communicable disease or infection on board the ship? (yes vs no)	1.68 (1.08 — 2.61)	0.022
Gender (females vs males)	0.62 (0.39 — 0.97)	0.035
Outfitting cabin's sink and toilet with virus sensors		
Are you afraid of contacting a communicable disease or infection on board the ship? (yes vs no)	3.42 (2.10 — 5.56)	<0.001
Employed/self-employed (yes vs no)	2.13 (1.31 — 3.45)	0.002
Highest degree of education		
College degree vs lower than high school degree/High school degree or equivalent	0.27 (0.11 — 0.64)	0.003
Bachelor's degree vs lower than high school degree/ High school degree or equivalent	0.25 (0.11 — 0.57)	0.001
Master's or PhD degree vs lower than high school degree/High school degree or equivalent	0.19 (0.08 — 0.43)	<0.001
Outfitting the cabin with air quality sensors		
Are you afraid of contacting a communicable disease or infection on board the ship? (yes vs no)	2.52 (1.43 — 4.46)	0.001
Air purifier in the cabin and the air conditioning system		
Are you afraid of contacting a communicable disease or infection on board the ship? (yes vs no)	3.03 (1.38 — 6.63)	0.006
Employed/self-employed (yes vs no)	2.78 (1.30 — 5.91)	0.008
Have you ever been diagnosed with a chronic condition? (yes vs no)	5.46 (1.24 — 23.99)	0.025
Cabin's and/or public spaces surfaces coated with antibacterial/antiviral materials		
Are you afraid of contacting a communicable disease or infection on board the ship? (yes vs no)	3.28 (1.84 — 5.88)	<0.001
Employed/self-employed (yes vs no)	2.09 (1.18 — 3.69)	0.011
Is this your first time (been or have worked) on a cruise? (yes vs no)	0.53 (0.30 — 0.94)	0.029
Highest degree of education		
College degree vs lower than high school degree/High school degree or equivalent	0.36 (0.12 — 1.11)	0.076
Bachelor's degree vs lower than high school degree/ High school degree or equivalent	0.25 (0.09 — 0.70)	0.008
Master's or PhD degree vs lower than high school degree/High school degree or equivalent	0.31 (0.11 — 0.91)	0.032
Cabin's and/or public spaces TVs used for real-time guidance and advice in cases of disease outbreaks		
Are you afraid of contacting a communicable disease or infection on board the ship? (yes vs no)	2.23 (1.32 — 3.78)	0.003
Have you ever been affected by one of these diseases? (yes vs no)	1.85 (1.10 — 3.11)	0.021
Highest degree of education		
College degree vs lower than high school degree/High school degree or equivalent	0.30 (0.11 — 0.84)	0.022
Bachelor's degree vs lower than high school degree/ High school degree or equivalent	0.29 (0.11 — 0.74)	0.010
Master's or PhD degree vs lower than high school degree/High school degree or equivalent	0.20 (0.07 — 0.52)	0.001

$^{+}$Odds Ratio (95 % Confidence Interval).

Our survey adds to the emerging literature on the need to monitor health vitals, particularly in closed spaces, to help detect earlier and manage more effectively communicable disease outbreaks, such as COVID-19. On board cruise ships, COVID-19 contact tracing has been evolving since the re-opening of cruises post pandemic. Royal Caribbean International have invested in security camera enhancements that allow existing surveillance infrastructure to detect the places passengers have been -and who they've been in proximity with- using facial recognition [33]. In addition to video surveillance and facial recognition, cruise lines are turning to other tracking methods for contact tracing, many of which are wearables [34], and may include screening before the voyage begins to record heart rate, breathing rate, body temperature, blood oxygen, complete a chat questionnaire and provide a photo ID. Nonetheless, the success of contact tracing apps greatly depends on their large uptake within a population. Literature, to date, confirms a gap on availability and assessment of acceptance of use of tracking devices or sensors within cruise ship cabins. Given the high sensitivity of health monitoring within cabins, interventions to assess and report on willingness to monitor health vitals using sensors appears to be underdeveloped. This is an area, where HS4U with its robot cabin, may substantially add to both current understanding and state-of-the-art and the relevant literature.

4.1. Limitations

Our findings are based on a quantitative analysis to identify levels of willingness to accept specific technological solutions as well as any barriers to this acceptance and assess extent of impact of various profile factors on both. This study would be well complemented with a qualitative survey (focus group) which would probe into details of proposed technological solutions relative to the process that will be applied for data management to assess whether acceptance levels can be enhanced as well as identify the most appropriate and effective way to organize and implement an awareness and education campaign amongst cruise passengers.

5. Conclusions

Our study confirms that passengers may be reluctant to adopt extensive technological solutions that may aid screening for and early detection of communicable diseases on board cruise ships. Such passenger acceptance may have to be cultivated through targeted awareness and education interventions that have the potential to assuage concerns around use of technologies and monitoring of personal health data. To this end, it is imperative that -very early on in the HS4U project-processes are developed that concretely describe how health monitoring data would be reviewed and stored for early detection of communicable diseases purposes and how, ultimately, privacy and data safety would be safeguarded once the project is fully developed. It is, then, necessary to work with our cruise partners to customize this information into awareness and education materials that target cruise passengers and help explain the process, its expected outcomes, and its importance in safeguarding public health, and, thus, create an environment of trust during the cruise.

Data sharing

The authors are committed to sharing full survey datasets with qualified external researchers. The requests are to be made to the corresponding author and will be appraised based on scientific merit.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the HS4U project and was conducted in line with the ethical standards set by the Declaration of Helsinki. Participation was voluntary, anonymized, and informed consent was requested and obtained from all participants.

Funding

This paper is supported by the European Union's Horizon Europe Research and Innovation Actions programme under grant agreement No 101069937, project name: HS4U (HEALTHY SHIP 4U). Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure, and Environment Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

CRediT authorship contribution statement

Christina Golna: Conceptualization, Investigation, Project administration, Writing – original draft, Writing – review & editing. **Ioannis Anestis Markakis:** Formal analysis, Project administration, Writing – original draft, Writing – review & editing. **Chara Tzavara:** Data curation, Formal analysis. **Pavlos Golnas:** Conceptualization, Investigation, Writing – review & editing. **Aikaterini Ntokou:** Investigation, Writing – review & editing. **Kyriakos Souliotis:** Conceptualization, Methodology, Supervision, Writing – original draft, 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.

Acknowledgements

The authors would like to acknowledge Mr Pambos Skapoulis, Ms. Afroditi Stratakou and Mr. Panagiotis Megalooikonomou from Celestyal Cruises for their invaluable help with organizing and implementing data collection on board CELESTYAL OLYMPIA.

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