First Choirs Standing? What risks were taken by choirs returning early to singing during the 2020 Covid pandemic, how were the risks managed and what were the outcomes?

Martin Ashley PhD
Editor-in-chief, ABCD Choral Directions Research

Status of this paper

This paper is a work-in-progress preprint. It has not yet been peer reviewed and an updated version of it is now being prepared. It has been made available because of the urgency of the topic and the rapidity with which the field is changing.

Abstract

The 2020 pandemic caused by the SARS-CoV-2 virus ("Covid-19") resulted in a world-wide cessation of choral singing. Resumption of choral singing took place at varying times and to different degrees according to conditions pertaining locally around the world. In all cases it was recognized that the activity must be risk-assessed and that until the SARS-CoV-2 virus has been eliminated by means such as vaccination, the precautionary principle must apply to any future choral rehearsal or performance. Risk is often expressed in general terms such as "high", "low" or "acceptable". In the absence of a more specific or quantifiable assessment, it is difficult to determine whether a rehearsal or performance should go ahead. However, there are also drawbacks to quantification as probability. Low probabilities do not eliminate risk and may even generate secondary uncertainty. Choirs that resumed rehearsal early in the pandemic devised control measures that, in the judgement of their managers, would result in an acceptably "low" risk. Given the level of scientific uncertainty prevailing at the time, a high level of precaution was applied to the interpretation of "low" or "acceptable" risk. The judgements of the "first choirs to stand" appear to have been vindicated in that no infections associated with their performances were reported. Subsequent scientific research has also vindicated the judgement of the first choirs to stand that airborne infection was a significant risk that should be controlled for. At the time these choirs planned their performances, the World Health Organisation was advising that "no airborne transmission had been reported".

Introduction

Last Choir Standing was a formulaic TV talent show broadcast by the BBC during 2008. First Choir Standing has a rather different and altogether much weightier meaning. It refers to the first choirs to bring singers together to perform in an enclosed space after the global cessation of such activity resulting from the SAR-CoV-2 pandemic. Though popularly attributed to a wet market in Wuhan, China, phylogenic analysis has shown ancestry for the SARS-CoV-2 virus throughout 2019, with evolution culminating in November (Li et al 2020; Andersen et al, 2020). The world did not take the problem seriously, however, until it became clear that the outbreak in China was spreading globally during February 2020. In Europe, Italy was the first country to be stricken seriously and went into lockdown on 3rd March. The now infamous outbreak during a choral performance in Amsterdam occurred a week later, on the 8th March, with the similarly devastating Skagit Valley rehearsal in

Washington state on 10th March. Many countries imposed national lockdowns soon after these events, both Germany and the United Kingdom doing so on the 23rd March. From March onwards, choral singing was largely off the global agenda.

The justification for such severe measures is that the SARS-CoV-2 is a novel coronavirus for which there is no evolved immunity, and no drug treatment or vaccination programme presently available. Moreover, the SARS-CoV-2 virus appears to result in an unusual degree of variance in potency and effect, being apparently unpredictable in how it affects individuals. Effects range between asymptomatic infection through mild flu-like symptoms to respiratory or multi-organ failure and death. Longer-term effects specific to singing, including debilitating post-viral fatigue (Williams, 2020; Moldofsky, and Patcai, 2011) or lasting damage to vocal apparatus, have been identified as requiring further investigation (Helding et al, 2020). The known risk from asymptomatic carriers or those with mild symptoms also appears to be higher than first assessed (Havers et al, 2020) and likely to increase as schools return (Stein-Zamir et al, 2020), though this must be balanced against an even greater risk of keeping schools closed (DELVE, 2020). The overall level of scientific uncertainty and hence perceived risk is unusually high (King et al, 2020).

Governments have had little option under such circumstances to exercise the precautionary principle with significant rigour. Inevitably, interpretations and practices relating to precaution have varied around the world with the result that, whilst choral singing was prohibited in the UK for four months, earlier resumption was allowed in other countries. However, until the virus is eliminated, which may be possible only if an effective vaccine can be found, choirs around the world are going to have to adapt to a risk-assessment driven process. There is no consensus yet as to how the risk-assessment process should best be informed and managed. Should there be quantification of probability, or merely a broad qualitative expression? Should governments or health authorities be the main assessors, or should there be a degree of devolution to choirs allowed to make their own autonomous judgements? If so, what knowledge bases should be accessed by choir managers attempting to devise control measure that demonstrate risk mitigation? This paper takes an empirical approach to the issue, observing how choirs that have resumed singing have done so and looking for evidence of the consequences. There is no guarantee that the first choirs to have stood will not face retrenchment if conditions initially favourable deteriorate. The intended approach is iterative. The first choirs to have stood will be, as much as is possible, revisited at periodic intervals to document consequences and changes. It is argued that there is a need for such empirical work as well as the experimental and randomised control trial approaches that have dominated the science.

National approaches to managing pandemics

Until the situation described above changes, only non-pharmaceutical interventions (NPIs) can be deployed. The UK government was significantly influenced in the early stages by Ferguson et al (2020) whose epidemiological modelling suggested two possible approaches, *mitigation* or *suppression*. Mitigation aims to slow but not stop epidemic spread, thereby managing peak healthcare demand and protecting the most vulnerable. Suppression attempts to maintain a low level of case numbers indefinitely. Not considered by Ferguson et al is a third strategy, that of *elimination*. Elimination attempts to achieve total eradication of the virus, a successful strategy in the case of Smallpox but not yet in the long running case of measles/rubella (Public Health England, 2019). The suppression strategy has been followed in the UK on the advice of the government's SAGE group and is the familiar one based upon an initial lockdown followed by easing of restrictions. It has been the pragmatic choice of

the majority of advanced democratic economies that on the one hand recognise that mitigation would overwhelm their health care systems whilst on the other, elimination is impossible by NPI alone.

In the present paper, Norway, Germany and Australia have followed different versions of the suppression strategy. They do so, however, at a cost. Ferguson et al are quite clear that until an efficacious vaccine has been proved to work and administered to most of the population, suppression will have to be maintained indefinitely. Their modelling showed that in order to keep R below 1, a combination of case isolation, social distancing of the entire population and either household quarantine or school and university closure are required in perpetuity. Such measures must also be supported be a reliable "track and trace" system which the UK has been slow to develop. Although only a stochastic model, this work seems to be proving chillingly prophetic at the present time of writing when the possibility of closing UK pubs, restaurants and other businesses as a consequence of schools and universities reopening is being considered.

Stage et al (2020) in a comparative study of schools re-opening across Europe make a similar point to the one made by the present author about choirs. Where the national R number is low, schools might reopen, as might choirs. Where it is higher, both schools and choirs create a risk of further outbreaks. Norway locked down relatively early and completely on the 12th March, closing schools from that date. A low "R" was attained earlier than many countries, but the Norwegian Institute of Public Health published the following warning on the 5th May:

> The epidemic has so far resulted in a low burden of disease in Norway, but the burden of action is significant, including both well-documented socio-economic consequences and probable public health consequences. . . . The overall goal should be that the burden of the disease of the epidemic should remain low, the health service should not be overloaded, and adverse ripple effects and costs of infection control measures should be low. To achieve this, the strategy must be dynamic. . . .adjusted according to the development of the epidemic and knowledge. The core is still hygiene measures, early detection and isolation of infected and tracking follow-up (and quarantine) of close contacts to the infected. (Folkehelseinstituttet, 5. mai 2020)

The impact of the Norwegian strategy will shortly be considered through a case study of the Nidaros (Trondheim) Cathedral boys' choir.

Some countries did not introduce widespread suppression lockdowns. Some were unable to do so on account of large, dispersed populations and poor levels of education and communication. This obvious difficulty may have discouraged the World Health Organisation from advocating measures that would be unaffordable for poor countries (Tang, 2020). In others, erratic leadership from mostly right-wing populist regimes seems to have been a common factor. However, Sweden followed a deliberate calculated policy that perhaps owes more to mitigation than suppression. Considerable trust was placed in the country's national epidemiologist, Anders Tegnell.

Tegnell's more liberal policies were widely misrepresented in foreign newspapers. It was not true, as some claimed, that there were no lockdown measures. Universities and high schools were ordered to close on 17th March, whilst cafes, restaurants and bars were confined to table service only from 24th March. Large outdoor gatherings (50+) were also banned and exhortations to wash hands regularly, maintain social distance and work from home were issued much as in other countries. Nevertheless, primary schools did not close and Tegnell was of the view that Sweden's traditional stress upon free will and individual responsibility should be respected. He specifically denied that so-called "herd immunity" was being attempted, citing the need to balance health measures against measures of economy and mental well-being. The results have made for interesting reading. Compared with its close neighbour, Norway, Sweden appears to have fared badly. By 6th June, Sweden had recorded

4468 deaths out of a population of 10.18m against Norway's 237 deaths out of 5.31m. The deaths per 100 000 were respectively 43.2 (Sweden) and 4.4 Norway.

However, by the same measure, the UK had fared worse than Sweden with 58.5 deaths per 100 000 by 6th June. By the 28th July, Sweden was able to report a rapidly falling infection rate with 398 new cases by the beginning of August as against 767 the previous week and 2530 at the beginning of July. Reasons for this apparent success will doubtless be put forwards, but as Tegnell reports, the predictions of the Ferguson et al model for Sweden were not realised. What is of immediate significance is the "Achille's heel" of Tegnell's strategy. As an analysis by Kamerlin and Kasson (2020) shows, there was a higher proportion of deaths amongst the older section of the population than in countries with more stringent lockdown, a fact not denied by Tegnell. As will be seen later, this is of some significance for the choir studied – the Stockholm Boys' Choir.

Finally, the perhaps improbable elimination strategy has been rigorously pursued by New Zealand. Importantly, the New Zealand Ministry of Health clarify that they are not attempting total eradication, as in the case of smallpox.

> Elimination of COVID-19 (or any disease) means reducing new cases in a defined geographical area, in this case Aotearoa/New Zealand, to zero (or a very low defined target rate). Elimination is distinct from eradication. Eradication refers to the complete and permanent worldwide reduction to zero new cases of the disease through deliberate efforts (eg, smallpox). Eradication of COVID-19 is not possible at this stage (and may not ever be possible) (Ministry of Health, Government of New Zealand, 2020)

In order to achieve this, the NZ government published early on a four-level alert system:

- Level 4: Lockdown, likely the diseases is not contained. Introduced 25th March
- Level 3: Restrict, high risk the disease is not contained. Introduced 27th April
- Level 2: Reduce, the disease is contained but the risk of community transmission remains. Introduced 13th May.
- Level 1: Prepare, the disease is contained in New Zealand. Introduced 8th June

The strategy appears to have been successful in that by the 8th of June, Covid had indeed been eliminated, if not eradicated from New Zealand. The country is on standby to revert to higher levels should the situation deteriorate.[1] Such has been New Zealand's success that the UK's Independent Sage group has deviated from the official Sage group to advocate an elimination strategy (King et al, 2020). A key argument is that the UK, like New Zealand, is an island and could therefore exclude cross-border contamination. This seems an unrealistic proposition given Britain's position as a major European air hub and is regarded by Tegnell as unattainable. Nevertheless, the Scottish government has deviated from Westminster by pursuing an elimination strategy, and at the time of writing, Scotland does indeed appear to be faring rather better than England (566 deaths out of 5.5m population in Scotland, 46 566 deaths out of 59m, England). The case of the New Zealand elimination strategy is illustrated shortly by Auckland Cathedral's music department.

Approaches to risk management

Three fundamental approaches to risk management have been identified as being in use.

- Control measures only
- Ordinal scales

[1] Since this was written, an outbreak occurred in Auckland that is currently being investigated. It is possible it entered the country through contaminated freight.

- Probability

In this section, each is described briefly and assessed for suitability in the practical situation of choir management by lay people. As will be seen later, the risk management strategies used by the first choirs standing were largely of the control measures only variety. The discussion will tackle the question of whether either of the other two strategies would have been preferable as well as attempting an evaluation of how effective the control measures were.

Control measures only

An example of this approach has been produced by the Church of England and is illustrated in Fig I. The assumption is that if the controls are all carried out and shown to have been done so in documentation, then the risk will have been reduced to the lowest practicable level and the person responsible will have acted reasonably and in good faith.

Figure I
Control measures recommended for church cleaning

THE CHURCH OF ENGLAND

Area of Focus	Controls required	Additional information	Action by whom?	Completed – date and name
	Ensure all waste receptacles have disposable liners (e.g. polythene bin bags) to reduce the risk to those responsible for removing them.			
	If possible, provide safe means for worshippers and visitors to record their name and contact details; retain each day's record for 21 days			
	Give due notice of the resumption of use of the building to neighbours, congregation and wider community, ensuring that visitors and worshippers will know what to expect when they come.			
Cleaning the church before and after general use (no known exposure to anyone with Coronavirus symptoms) Advice on **cleaning church buildings can be found here.**	If the church building has been closed for 72 hours between periods of being open then there is no need for extra cleaning to remove the virus from surfaces.			
	If 72-hour closure is not possible then check all cleaners are not in a vulnerable group or self-isolating.			
	Set up a cleaning rota to cover your opening arrangements.			
	All cleaners provided with gloves (ideally disposable).	Register with Parish Buying for procurement options.		
	Suitable cleaning materials provided, depending on materials and if historic surfaces are to be cleaned.	Register with Parish Buying for procurement options.		
	Confirm person responsible for removing potentially contaminated waste (e.g. hand towels) from the site.			

A wide range of scenarios is covered, and the controls seem comprehensive. No scientific references are given though it can be presumed that the House of Bishops has been careful to take appropriate advice. For example, the advice that there is no need for extra cleaning if the church has been closed for 72 hours or more is presumably derived from work on surface stability (van Doremalen et al, 2020) though there is no means of knowing the extent to which work on complicating or confounding factors such as stability in different conditions (Chin et al 2020) or variations in the viral load of individuals (Heneghan et al, 2020) has been considered.

Ordinal scales

The person(s) responsible for implementing given control measures does not actually carry out a risk assessment, they merely carry out a set of instructions and must take it on trust that they will have

reduced the risk acceptably by following the control measures they have been given. When ordinal scales are used, the risk assessor is involved in making a judgement about how effective the control measures might be and has the option of demonstrating increased risk mitigation through the introduction of further control measures. A scale of 1 – 5 is used to determine the likelihood of a hazard occurring and the severity of the consequences. The method is a well-established one that has been in use for some time in the heritage railway industry where safety-critical risk assessments are required by the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS). The present author has long-standing experience of this system in his capacity as safety manager for one such enterprise. It has also been used in the UK by *Music Mark*, a corporate member association for the music education sector.

In this approach a hazard is defined as "anything that has the potential to cause actual harm" whilst risk is given by a simple computation of the product of how likely the hazard is to occur (L) and the seriousness of the consequences of its occurring (C). R=LxC. The critical difference between this system and following given controls is that the computation must be done twice, once before the identification of control measures (R^1) and again after the implementation of those measures (R^2). If there is a clear difference between R^1 and R^2, the control measures can be deemed effective. The values of R are also read off against a table of risk acceptability with actions to be taken which range from 'no action required but continue to review' (1-2) to 'cease the activity immediately' (20-25). This type of approach was advocated for choral singing by Spahn and Richter (2020) who stated that "effective risk management usually requires a precise risk analysis with an associated likelihood of occurrence and knowledge of the effectiveness of certain risk-reducing measures."

Spahn and Richter give little practical guidance as to how this is to be done. Figure II below is an adaptation for choirs by the present author of a system in use on several large heritage railways.

Figure II
Categoric Risk Mitigation adapted from ROGS for Choirs

L Value	Likelihood	C Value	Consequence
1	Very unlikely	1	Inconvenience – absent child
2	Unlikely	2	Pattern of significant absence
3	Fairly likely	3	All families have to quarantine 14 days
4	Likely	4	Several hospitalisations requiring oxygen
5	Very likely	5	Catastrophic – ventilators, death(s)

R Value	ACTION TO BE TAKEN
20–25	Stop – stop activity and take immediate action
15–16	Urgent action – take immediate action and stop activity if necessary, maintain existing controls rigorously
8–12	Action – improve within specified timescale
3–6	Monitor – look to improve at next review or if there is a significant change
1–2	No action – no further action but ensure controls are maintained and reviewed

Figures IIIa and b give examples of the system in use. In Figure IIIa, the assumption is made that the choir has a mixed age demographic that includes members over 70. It is well established and little

disputed in the literature that there is a strong relationship between age and susceptibility. Ferguson et al (2020) give an infection fatality ratio of 0.006% for the 10 – 19 age group. This rises alarmingly to 5.1% for over 70s and 9.3% for over 80s. Only 0.3% of infected 10 – 19-year-olds require hospitalisation as opposed to 24.3% for over 70s and 27.3% for over 80s. Of the 24.3% admitted to hospital 43% of over 70s and 71% of over 80s require critical care, i.e. ventilator treatment (Ferguson et al, 2020: 5). There can be very little doubt than that if such persons are in a choir, a high number for the likelihood of infections must be selected. Similarly, a high number for the consequences. In the example below, 4 is selected for likelihood (meaning "likely") and 4 for consequence (meaning "several hospitalisations requiring oxygen"). 4 x 4 = 16 which reads as "take urgent action and stop activity if necessary". The risk is clearly unacceptable. However, a control measure of "over 70s and persons with underlying health issues asked not to attend" can be devised and implemented. When this is done, the likelihood decreases to 2 ("unlikely") and the consequence to 3 ("all families have to quarantine for 14 days"). 2 x 3 = 6. The risk is just acceptable, but the situation requires constant and regular monitoring with periodic reassessment.

The choir could, in theory, then go ahead and rehearse together. As will be seen later, this happened fairly quickly in the countries where the "first choirs stood", but the UK government, acing on the advice of Public Health England, took a more risk averse approach, prohibiting all choral singing for much of the summer.

Figure IIIa
Part of a categoric mitigation risk assessment for hypothetical mixed-age choir

		L	C	R	Action
Hazard	Members of vulnerable groups in the choir	4	4	16	Immediate measures required. Stop activity if necessary
Control	Over 70s and persons with underlying health issues asked not to attend	2	3	6	Monitor. Look to improve at next review or if there is a significant change

Figure IIIb illustrates another well-known hazard where the evidence suggests that the L number should be higher than 2. It is almost certain that respiratory mucus particles will fall onto music copies where they will evaporate leading to some build-up of viral concentration. This method of fomite transmission has been assumed to be significant, though some authors point out that it is close person to person contact that is the more likely means of transmission (Goldman, 2020; Somsen et al, 2020). Should music copies become contaminated, the virus remains viable on a printed paper surface for up to three hours (Chin et al, 2020). Fomite transmission through a singer handling a copy used by another singer less than three hours previously might merit a 2 or 3. The method does not eliminate subjective judgement, but an L number of 5 might well be justified for two singers sharing one copy because this would bring them into close proximity.

A control of 'issue personal copies in plastic folders which are kept for duration and must not be shared or left lying about' would address both issues and in the example below brings the L number down to 1, meaning that where there is no government prohibition, this consideration alone need not stop the choir singing.

Figure IIIb
Categoric mitigation for paper music copies

		L	C	R	
Hazard	Contaminated music copies	4	3	12	Improve within a specified timescale
Control	Performers issued personal copies in plastic folders which are kept for duration and must not be shared or left lying about.	1	3	3	Monitor. Look to improve at next review or if there is a significant change

It is important to stress that the numbers 1 - 5 are of limited statistical power because the are ordinal and not suitable for parametric treatment. Neither are they measures of probability. Whilst it is true, valid and useful to state that a 2 is quite a lot better than a 4, it would not be true to state that a death is five times as bad as a singer absent for a couple of rehearsals. There is a tension here with the requirement set out by Spahn and Richter for a "precise measurement". They state:

> Effective risk management usually requires a precise risk analysis with an associated likelihood of occurrence and knowledge of the effectiveness of certain risk-reducing measures. At the moment, however, we do not yet know much about the transmission of SARS-CoV-2, so that risk management currently means an equation with many unknowns. (Span and Richter, 2020: 32).

An "equation with many unknowns" may be a risk in itself. Ordinal risk assessment scales work on the principle that the assessors make an "educated decision". This is unproblematic when the risk is a well-known one such as falling off a ladder, and the assessor is knowledgeable and experienced in the industrial use of ladders. The SARS-CoV-2 virus, however, is a novel one and the number of people who can truly make "educated decisions" embracing all the associated hazards must be very small. Other objections, such as a failure to allow for frequency of exposure (a choir meeting daily should not score the same as a choir meeting only once a month) can be overcome by a more sophisticated calculus but the "educated decision" difficulty remains – hence the case for the epidemiological laity taking control measures on trust as in the Church of England template.

Calculating probability

Risk as a probability can be computed empirically if sufficient statistical data are available. Obvious examples would include calculating relative risks in transport which can be on a basis such as miles travelled per casualty. Ample data over many years are available. No such data are available for SARS-CoV-2. The nearest approximation might be for a previous novel coronavirus, though how useful this might be is open to question. Equations from which probability might be derived exist or are being developed for many discreet events and circumstances relevant to different types of hazard associated with the transmission of the SARS-CoV-2 virus. One such is the Wells-Riley which is well established in the field of airborne infection.

The Wells-Riley equation is based upon the concept of a quantum of infection, first proposed by Wells in 1955. Wells' work was seminal in persuading a sceptical world that viral infections were transmitted by airborne routes. The "quantum" he proposed is the minimum dose necessary to cause infection in a host. The task is to model the accumulation, transmission and distribution of quanta in confined spaces. In 1955, the focus of interest was pulmonary tuberculosis, and this has not gone away since that disease has not been eradicated (Nardell, 2016). The Wells–Riley equation was itself developed by Riley et al in the context of a measles epidemic (Riley et al., 1978). Measles is known to be highly contagious through the airborne route. Noakes and Sleigh (2008) pointed out that lessons about

airborne infection appeared not to have been learned by the time of the 2003 SARS outbreak when this route was at first underestimated. Detailed studies developing the Wells-Riley concept were lacking at that time and it is somewhat extraordinary that history appears to have repeated itself yet again with the failure of the WHO to recognise airborne transmission at the outbreak of SARS-CoV-2 (Morawska and Milton, 2020).

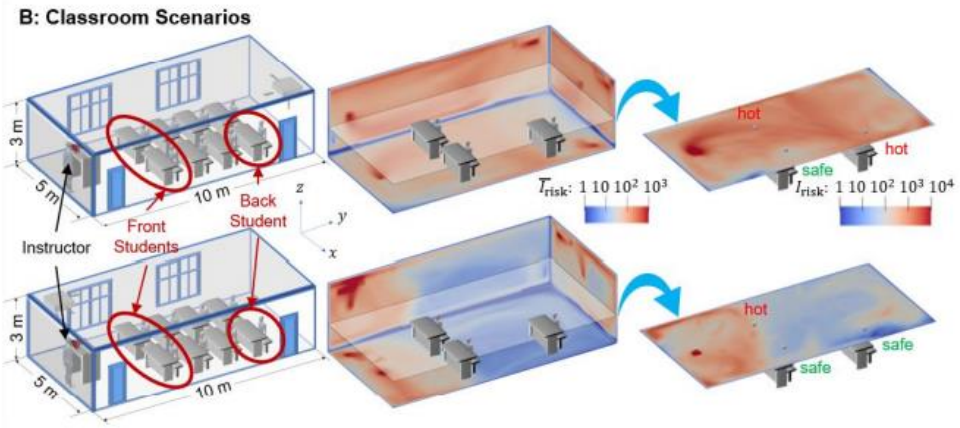
Jiminez (2020) has been developing an Excel based model that can be used by anybody who is prepared to work at understanding it and inputting the data. Herein lies perhaps the first problem with this approach. The study by Caplin and Flick (2020) reveals difficulties in promoting the engagement of choir directors with quantitative data. Data gathered from 23 of the "first choirs to have stood" included location, age range, rehearsal space including floor area, distance between singers and placing of singers and rehearsal pattern including breaks. Qualitative responses such as "2 hrs with 15 min break, Window and doors 2 metres in front, back and on the sides, in two rows" were unproblematic, as were simple measures such as floor area of rehearsal space in most cases, but the request for "assessment of ventilation possibilities – on a scale of 1 – 10" produced only seven responses, not all of which gave a number between 1 and 10. The problem may have been the formulation of the question. Data that would drive anything in the nature of a Wells-Riley based spreadsheet need to be unproblematic for choir directors to obtain.

Assuming such difficulties can be overcome, there are then shortcomings with the Wells-Riley model itself. Noakes and Sleigh caution that it assumes complete, homogenous air mixing. Recent studies such as Shao et al (2020) have shown that this is a matter of no little significance. Jiminez is careful to point out that his model is for aerosol transmission only and makes assumptions such as strict 2m distancing. This difficulty might be overcome by the use of a dose-response model (Sze-To and Chao, 2009) but to the present author's knowledge, no attempts to do this have yet been made. Jiminez recognises many other shortcomings. The presence of just one adult with an underlying health condition might confound the results which would surely need to be different for a youth choir as opposed to a choral society. The model does not include such fundamental variables. It might need to be run twice, once with an assumption of mask wearing and once without. The efficiency of different kinds of mask and the ways in which they are worn has been shown by the parallel studies of Miller (2020) and Srebric (2020) to be important variables.

Jiminez states that the model is deliberately kept simple so that it can be understood and changed easily. This raises the difficulty that an impression of greater power will be attributed to the results than might be justified, always an issue to be considered when parametric approaches are compared with ordinal approaches. The actual power of the numbers is addressed by Jiminez who states that a 1% chance of infection obtained by the model in reality could be 0.2% or 5%. "It just won't be .001% or 100%" (Jiminez, 2020). Missing from this is any attempt to make a link between a probability of between 0.2% and 5% and an L number. Does this level of probability count as "very unlikely" (1), "unlikely" (2) or perhaps "likely" (4)?

A similar question arises in the case of the study by Shao et al which illustrates both the complexity and power of computed risk approaches. Figure III below shows the modelling by these authors of a classroom scenario in which design of ventilation is critical for reducing the risk of particle encounters.

Figure III
Classroom ventilation scenario in risk assessment through particle count



In this model, the students are largely passive whilst the teacher speaks for fifty minutes. In accordance with work such as Asadi et al (2019), the projecting voice of the teacher emits significantly more particles than does the passive breathing of the students. A badly placed ventilator at the rear of the room results in a dangerous concentration of aerosols enveloping the student at the back of the room. The risk for the students near the teacher at the front is less. This demonstrates amongst other things that models of choir rehearsals in which a 6m spacing between conductor and front row of singers are probably too simplistic. At the very least, a 6m spacing might give a false impression of security.

Shao et al make no attempt to create an interface between their model and the kind of data that a lay person might be able to input. They evaluated risk as the total particle number passing through a specified location during a period of simulation. This can be interpreted as the number of particles a person could inhale during their time in a given location (Irisk). "Hot" and "safe" zones were then identified through five graduations of particle count from 1 - 10^4. From this, a control measure that could be implemented by a lay person could be derived, though there is clearly much work to do in providing information on the efficiencies and deficiencies of ventilation systems (the authors' stated intentions).

There is still no solution to the problem of whether an (Irisk) of 10^3 or 10^4 counts as a category 4 ("likely"), a 5 ("very likely") or perhaps only a category 3 "fairly likely". It is clearly not possible is for a lay person to make the (Irisk) calculation themselves, and similar calculations need to be made for many necessary mitigations. This serves to illustrate just how complex the entire process is, and it may be that the least unsatisfactory solution is simply to take prescribed control measures on trust. As will be seen shortly, this is largely what the persons making decisions on behalf of the first choirs standing did. By their own explicit admission, they could not be called "educated decision makers". Their decisions were made in all cases sincerely and carefully, but with the understanding of a scientific lay person and in most cases without even the benefit of a simple control template such as that provided by the Church of England. One possibility to be considered in this paper is that the lay risk assessors in countries such as Norway, Germany or Australia were in fact *over-cautious* as a result. The first choirs standing certainly exercised a high degree of precaution – commensurate with judgements of risk in situations of high uncertainty.

Method of the present empirical study

Given that there is known variability in infection rates across national boundaries, the first task in an empirical study is to compile reference data on transmission, infection and death rates in different nations. It was these data that largely informed the policies of national governments concerning whether choirs could rehearse in their respective countries. Variables such as population density, climate and median population age need to be considered also in making international comparisons. Some order must also be brought to bear on timing. The data are therefore organised in reporting periods as befits a method that is planned to be iterative. Two have initially been identified:

- Period 1: A census day during the 2020 summer term
- Period 2: A census day in September when most choirs return after a summer break

It is anticipated that cases may be subject to seasonal variation which may result in localised curbs on choir activity. This is an unknown at the time of writing but will be considered in subsequent iterations of the study. Initial data at national level will also need to be refined to bring out similarities and differences at regional or even local levels across national boundaries.

Choir directors were invited first to submit a written account of how things appeared from their viewpoint and what they were doing in practice. These accounts were then coded thematically and analysed through the MAXQDA discourse analysis software. Through this process it was possible to identify what the choir directors understood the risks to be and the control measures that they had identified to manage them. Two surveys were then constructed in order to assess the relative attention of each choir to the identified risks and measures. Table 1 shows the risks identified by the choirs and the control measures they devised to mitigate them. Ranking is in order of the frequency of mention, not the level of risk as quantified in the scientific literature. The table therefore reflects perceptions that were held during the early stages of the pandemic. Greater detail is provided later when case studies of each choir are presented.

Table 1
Perceived Risks and Controls Devised

Perceived Risk	Controls Devised
Contaminated surfaces	Enhanced cleaning Removal of furniture/music stands
Close proximity of singers	Reduction of singer numbers Spacing/distancing (various) Floor markers One-way systems Sectional rehearsals
Infected singers attending	Voluntary quarantine
Poor ventilation	Air conditioning Open doors and windows Breaks to allow air to clear
Small rehearsal spaces	Larger rooms Outdoor rehearsals
Older singers	Not members of the choir Restricted attendance
Personal hygiene	Provision of sanitiser Supervision of children
Long rehearsals	Shorter rehearsals
Travel	Cancellation of engagements

The need for enhanced cleaning to mitigate the risk of contaminated surfaces appears to have influenced the choirs the most, which may reflect the stress upon fomite transmission that occurred early in the pandemic. Next most frequently mentioned were a variety of measures clearly influenced by the messaging about social distancing that has been constant throughout the pandemic and remains a key measure at the time of writing. The directors/managers were equally well-aware of the dangers of airborne transmission, however. Given that the surveys took place before the WHO changed its position on the issue of airborne transmission, the extent to which choirs perceived this risk is notable. There was a strong recognition of the need to exclude singers with symptoms, but the approach was almost invariably through voluntary, self-declaration measures. The risk from older singers was recognised more by implication in that there is a sampling bias to choirs with younger singers. Personal hygiene received fewer mentions that might have been expected, given the stress at the time upon hand washing which continues at the time of writing. Possibly the choirs saw this as the responsibility of individuals and assumed compliance. Only two choirs mentioned shortening rehearsals, which is perhaps surprising given the likelihood that long rehearsals in enclosed spaces will increase the airborne transmission risk. Finally, only one choir mentioned anything to do with travel, and this was the cancellation of a tour programme. The risk of contracting and introducing infection through car sharing or public transport on the way to rehearsal did not seem to be perceived or may not have been relevant to the way particular choirs functioned.

Table 2 is derived from review of the scientific literature and identifies other risks that were *not* mentioned by the choir directors.

Table 2
Risks for which choirs cannot devise control measures

Identified risk	Why a risk?
A high level of community infection rate (R number above 1)	Increased risk of infected individuals attending, including asymptomatic carriers
Transmission in the home	Close contact in the home reported as one of the most potent means of transmission
Climate and weather	Viral potency and contagion likely to rise in colder, wetter months
Cross-contamination from other activity	Risk proportionate to the diversity of activity, perhaps more an issue for amateur than professional singers
Ethnicity	Higher transmission and infection reported amongst ethnic minority communities and individuals

The principal significance of Table 2 is that it is difficult or impossible for the choirs to devise control measures to mitigate such risks. Unless the choir can move to another region or country, it has no control over the risks arising from a high R number in the general population. There can be no control over the climate and weather, other than perhaps planning concerts for the warmer summer months when less contagion might be expected. With the possible exception of high-level professional groups, choir directors are hardly in a position to demand changes to the domestic arrangements of their singers or dictate arrangements for “social bubbles”. Similarly, if singers are involved in a number of other activities, including going to work, playing sport, visiting family or eating in restaurants, the choir conductor is hardly in a position to stop them. Ethnicity is a particularly difficult issue. Few conductors

would want to risk or even consider a control measure such as barring certain ethnic groups, even if it were done with the best of intentions on scientific evidence.

It is perhaps because the conductors were aware that they had little or no control over these risks that they did not mention them. Nevertheless, they are significant risks. A choir might exercise the utmost diligence regarding the matters over which it does have control, yet if the R number is high, the chances of infected individuals attending rehearsals are proportionately high. If there are, for example, unidentified weaknesses in the ventilation arrangements as suggested by Shao et al (op. cit.), one individual could still infect many in the choir. For reasons such as this, choirs should perhaps expect and accept that national governments and regional health authorities may impose lock-down restrictions in response to trends in the populations for which they are responsible.

Case studies

Norway. Norway as a country is in a comparatively low risk category with a small, dispersed population and reported death rate of only 4.4 persons per 100 000 (cumulative additional deaths by 6th June: 237). The resumption of choral singing was permitted from 22nd April onwards, with a guide issued by the Norwegian Music Council and authorized by the Norwegian Health Council. A small, qualitative study of choirs responding was undertaken at an early stage by Caplin and Flick (2020). This identified twenty-three choirs that had recommenced singing from Norwegian choir week 19 onwards. Full details of the permitted conditions were given in Ashley (2020). The choirs ranged in type from mixed youth choirs to female choirs and an adult male choir with age range 23 – 82 years. The criterion for assessing the efficacy of the control measures was a request for a weekly update on "proven infections". Answers given were almost invariably "none" with just three instances of "unknown".

Nidaros Cathedral, Trondheim

To be the first choir to stand is not to claim a prize or accolade but to bear the burden of risk on behalf of the wider choral community. If any credit is due, it must go in this study the Nidaros Cathedral Boys Choir in Trondheim. This may not have been the very first choir to stand, but it was the first to come to the attention of the present author and participate in this study.

The conductor reported on the new rehearsal arrangements thus:

Week A: rehearsals within individual voice groups, which all are under 20 participants strong.

Week B: we split up the full choir into four sub-choirs of 20-22 participants, all SSAATTBB setup with each of the SSAA voices consisting of at least one well experienced, one less experienced and one new chorister. Those sub-choirs are giving us something we never have experienced before: new groupings, more space between singers, new setups where choristers are unable to rely on "that one sturdy soprano, who always sings correctly".

Control measures implemented by Nidaros Cathedral Boys Choir

Time of year	April-May. Sunday Eucharist (broadcast) 10th May Staged Performance for Norway Constitutional Day, 17th May
Location	Approx 250 miles north of Oslo on south shore of Trondheim Fjord. 63°N 10°E. Fourth largest city in Norway. Population density 539 /km^2
Cross-contamination[2]	Male cathedral choir in university city (portfolio-professional/education).
Airborne transmission	Large cathedral with natural ventilation. Doors kept open. 2.5 hour rehearsals reduced to 90 minutes
Age and ethnicity	Normal complement. Approx. 60 boys aged 9-15 and 30 adult men Reduced to 8 boys and 7 men for 10th May Eucharist Maximum of 20 in any rehearsal. Increased use of sectional rehearsals with reconfiguration to four equal sub-choirs. In each sub-choir, an experienced and younger boy paired.
Proximity to others	Normal rehearsal room not used. 300m^2 space for exclusive use of choir in adjacent building. Performers widely spaced in main area of cathedral (see illustration below).
Contaminated surfaces	Antibacterial spaces at entries to room. Boys constantly supervised. All music stands removed.
Quarantine	All travel and external engagements cancelled. None reported
Outcome	No reported infections.

Sweden

Gosskor, Stockholm

The events leading up to the summer concert of the Stockholm Boys' Choir show strong congruence with the conditions reported in Sweden earlier, particularly voluntary restraint, schools remaining open and a high death rate amongst the oldest members of the population. Many choirs in Stockholm did voluntarily close down, but the boys choir continued to meet, preparing for its end of summer term concert. This was streamed via a ticketing pay wall, and no live audience was present. The choir director reported that "… Primary and secondary schools have been going on as usual here … Our biggest problem here has been the elderly and demented people (sic), so children´s activities are not the biggest concerns for the authorities." Notable in the table below is the degree of voluntary restraint exercised by individual families, the director reporting that "the groups have naturally been smaller because anyone with slightest symptoms have stayed at home." On 6th June the reported

[2] It has been difficult to assess cross-contamination (i.e. singers infecting their choirs as through contracting the virus through another activity outside choir.) The assumption has been built in, therefore, that if the choir is a professional one, or involves children under the control of their schools, the potential for cross-contamination might be lower than in the case of amateur choirs where the membership is much more diverse.

death rate was 43.2 persons per 100 000 (against 4.4 in Norway) with 4468 additional deaths having accumulated by 6th June (Norway: 237).

Control measures implemented by the Stockholm Gosschor

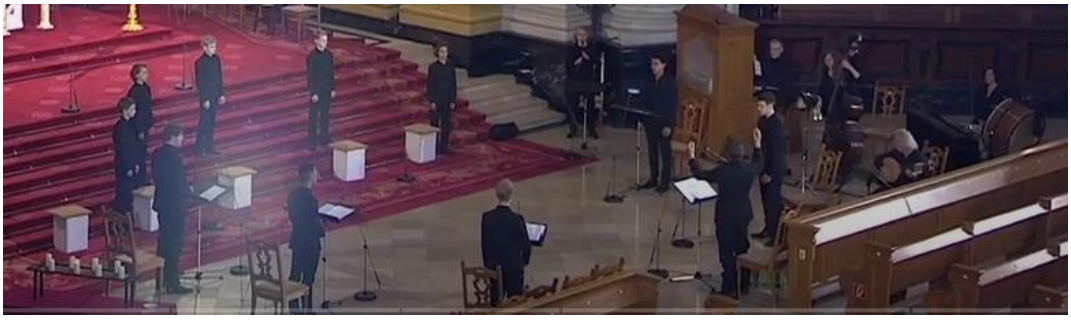
Time of year	
Location	Baltic Sea coast opposite Gulf of Finland. 59° N, 18° E. Capital city. Population density 4800/km^2
Cross-contamination	Secular Boys choir in in capital city (education/youth)
Airborne transmission	Floor to ceiling air conditioning system installed. Rehearsal times shortened.
Age and ethnicity	90 boys, 30 teenagers, 10 young adults, 10 mature adults. 50% absence in March, reducing to 25% absence in May
Proximity to others	Normal rehearsal venue used (relatively small room of normal height) Boys stand further apart, making use of absences. Some use of stickers and markers.
Contaminated surfaces	Hand alcohol supplied. Room cleaning frequency increased.
Quarantine	Instructed not to attend if any symptoms. Self-quarantine by parents reported as above.
Outcome	No reported infections.

Germany

Of all the countries from which reports have been received, Germany is perhaps the least homogenous. The 16 states have adopted their own approaches, often reacting to relatively localised events. Federal directives have played less of a role although a national lock-down and curfew was finally announced on March 22nd. Analysis of events before and after this date suggests that Germany's widely reported relative success in controlling the pandemic was achieved only through much state-wide controversy and internal criticism. Differences in state approaches were notable in data received from Berlin and Bavaria.

Staats und Domchor, Berlin.

The Staats und Domchoir of Berlin (state and cathedral choir) is part of the Universität der Künste Berlin (arts university). Over 250 boys receive a musical education in groups ranging from *Dominis* kindergarten to the *Voces in Spe* changing voice choir. The main concert choir consists of about 60 boys and 30 men. From this large complement a small ensemble of 5 boys and 5 men was selected to prepare for a VE day memorial service on 8th May, with rehearsals resuming from 1st April. This is the "first standing" performance considered here.



Control measures implemented by the Staats und Domchor, Berlin

Time of year	April-May 8th
Location	Berlin 121 miles inland from coastal town or Rostock. 53°N 13°E Population density: 4000/km^2
Cross-contamination	Large male choir associated with arts university, cathedral and federal state. 60 boys and 30 men in main choir. 250+ boys overall.
Airborne transmission	The largest indoor space in Berlin. Floor to ceiling air conditioners fitted. Shortened rehearsal times with breaks for the air to clear.
Age and ethnicity	Normal complement: 60 boys aged 10 – 14. 30 men 5 boys and 5 men with small group of period instruments
Proximity to others	Large, circular cathedral. ("the largest indoor space in the city of Berlin") All rehearsals held in the cathedral itself or outside on steps. No rehearsal rooms used. Singers spaced well apart (2-3m circle between each) in circular formation (see illustrations below). Floor markers and one way system in use.
Contaminated surfaces	Enhanced cleaning regime. Superfluous furniture removed, singers retain own copies.
Quarantine	Singers instructed not to attend if they have covid-like symptoms and asked not to attend if they feel unwell.

It perhaps merits comment that the choir chose a circular formation, which is not recommended as the singers will be facing each other. However, the voluminous space of the cathedral together with the large diameter of the circle presumably acted as mitigations. It should also be mentioned that the Staats und Domchor should not be confused with the adult Berlin Cathedral Cantory, as several writers and press reports have done. An outbreak amongst members of the Cantory rehearsing for Paul McCartney's *Liverpool Oratorio*, did occur on 9th March.

Münchner Chorgemeinschaft, Munich

The choir had rehearsed twice after resuming on 15th June. Conditions in Bavaria clearly differed from those is Berlin. Whereas the Berlin choir reported good support for the arts, Munich reported that unless ticket revenues quickly returned to pre-covid levels the sector would be threatened. Across Bavaria the choral sector was specifically targeted with instructions. During June, rehearsal was permitted, but masks were required to be worn, singers to be spaced a minimum of 2m apart with 10 minute ventilation breaks for the room after every 20 minutes' singing. Berlin, by contrast, had been left more to their own devices, reporting that choral singing is subsumed within more general phased returns to normality that they needed to interpreted for their sector.

Control measures implemented by the *Münchner Chorgemeinschaft*, Munich

Time of year	April-May
Location	Bavaria, 538 miles inland. 48° N, 12° W, elevation 524m
Cross-contamination	Not reported, though this was an adult amateur choir.
Airborne transmission	Fairly large room. Doors and windows left open.
Age and ethicity	15 mature adults, 32 elderly (over 20). Only small, selectd groups attending. Parts rehearsed separately.
Proximity to others	Singers asked not to attend if feeling unwell
Contaminated surfaces	Circle of 1 – 2m round each singer

Australia

Brisbane Cathedral (St. John's)

At the time singing resumed, there had been only 102 deaths attributable to the SARS-CoV-2 virus in the whole of Australia, a rate of 0.4 per 100 000 head of population, as opposed to 58.8 per 100 000 in the UK at that time. This is an almost meaningless statistic, given the size and average population density of Australia. At the time Queensland (itself a large state, 667 900 miles[2)] had experienced no new cases in the previous seven days with only two known positive cases remaining. Nevertheless, the choir exercised a high degree of precaution, the conductor reporting that "we have no certainty that we are doing the 'right thing' (and actually understand that there is no such thing) so the responsibility weighs heavily on our shoulders." Masks were attempted with the adult singers who chose to abandon them. The boy choristers attend the Anglican Church Grammar School and stopped singing at the same time as this school closed. The cathedral itself did not close, being considered a "place of work". Initially, five people were allowed in the building, so services were streamed by a quartet, increasing to an octet drawn from the cathedral chamber choir when the permitted number rose to 10. The boys first performed again on 25th June, recording a service to be broadcast via Youtube on 28th June after rehearsing three mornings per week in school and once per week in the cathedral (see illustration).

Control measures implemented by choirs of St John's Cathedral, Brisbane

Time of year	June/July (NB Winter in Australia. Mean temp 16° June, 15° July)
Location	Brisbane -28° N, 153° E. State capital of Queensland, Australia. Population density: 345/km^2
Airborne transmission	Large cathedral in hot climate. Open doors and enhanced air circulation normal. No additional arrangements practical.
Age and ethnicity	10 boys (1) 6 young adults, 14 mature adults selected from chamber choir (2)
Proximity to others	4 m^2 space worked out for each singer. Clear separation (2m apart minimum, see photograph)
Contaminated surfaces	Seats and stands are disinfected before and after every rehearsal. Enhanced cleaning regime. Normal music desks and stands not used. Singers keep own music copies.
Quarantine	Asked not to attend if feeling unwell.

New Zealand

Auckland Cathedral

Unlike Brisbane, the cathedral in Auckland, like all other churches, shut down completely early in the pandemic (by 25th March). The government published early on a four-level alert system that was said by the cathedral's music director to be "very clear and effectively, though sensitively, enforced by the police." 25th March was the day that Level 4 alert (the highest) was enforced. Reduction to level 3 occurred on 27th April, level 2 on 13th May and level 1 on 8th. June. The cathedral reopened with six singers and a congregation of 100 during level 2. Level 1 (8th June) allowed churches to return to normal, including the use of choirs. Concerts had not been restarted by that date in Auckland although the music director felt it would not be long. In spite of the unusually clear directions from the government, however, he considered that he didn't "really know what the contagion risks really are", though he felt that New Zealand hadn't had had the large-scale confusion and inconsistency that appears to have dogged the UK, Europe and the USA." For this reason, tabular data are not presented.

The choirs were able to resume normal activity very soon after the census date for this study. The case makes for a particularly interesting contrast with Sweden, being perhaps the opposite end of a continuum regarding how much individuals and individual organisations had to make their own risk assessments and decisions.

Discussion and review: did the choirs get it right?

It must first be reiterated that the data presented above are a snapshot of conditions on the 6th June. Since that date, much has happened. Many more scientific papers have been published, renewed outbreaks have occurred (including in both Australia and New Zealand), governments have issued new instructions. These changes will be reflected in the second iteration of this study which is intended to take a snapshot of the situation in September 2020 when choirs resume from their summer breaks, probably facing rising R numbers as temperatures fall and hard to predict regional resurgences of contagion are reported if complacency sets in. That said, there are grounds to say that the choirs did get many things right. All implemented control measures that were anticipatory of the advice that is now being offered. None reported any infections. It would not be appropriate to claim that this alone justifies any changes in policy or advice, but by the same token, should policy be driven by nothing more than press reaction to the Amsterdam and Skagit "super-spreader" events?

It is important to draw a conceptual distinction between precaution and risk. In general, a decrease in precaution might be expected as scientific knowledge increases. High levels of precaution are exercised when there is a high degree of scientific uncertainty. This has been seen to be the case for most of the choirs. The Berlin choir, for example, exercised extreme precaution in reducing its numbers from 60 boys and 30 men to 5 boys and 5 men, and by rehearsing either outdoors or in the very large, ventilated space of the cathedral. Possibly they had been influenced by Berlin Cathedral Cantory event.

The same is not necessarily true of risk. Estimations of individual hazards may rise or fall according to the state of scientific knowledge. The most obvious example of this concerns aerosol transmission. At the time the first choirs stood, the WHO were adhering to their scientific brief of 26th March which claimed that "no airborne transmission had been reported". This position was maintained until 9th July against a considerable body of evidence that it was untenable. Lidia Morawska of the Queensland University of Technology was the lead author of a critical position paper in the journal *Environment International* (Morawska and Cao, 2020) and a more recent publication by Morawska and Milton (2020) gained the support of 239 signatories to a letter. It is worth noting that history is simply repeating itself here as the 2003 SARS outbreak also needed the invocation of alternatives to large droplet explanations that were unable to account for the infection of individuals without sufficiently close contact with known cases (Scales et al 2003). Four years later, Xie et al (2007) showed retrospectively that airflow patterns within buildings indicated airborne infection.

One of the signatories to the Morawska document, a consultant virologist at the Leicester Royal Infirmary, claimed on BBC Radio 4's PM programme that the WHO had been selective in their interpretation of evidence on order to maintain their own position (Tang, 2020). Allegations were made, either that the WHO was obsessed by over-medicalised conservatism that discounts other science, or that it feared stressing the importance of facial coverings because many developing countries will be quite unable to provide them for the whole populations (see Royal Society/British Academy, June, 2020). All this serves as a reminder that, though dispassionate objectivity is the constant goal of science, it is not always achieved. What is of particular interest at this juncture is that the first choirs standing were in some ways actually ahead of government advice in their precautionary response to the risks posed by airborne infection. For example, the Berlin senate issued guidance on the 12th August, three months after the Staats und Domchor had performed (see Table 3 below).

Two points stand out. The first is the emphasis on ventilation and air exchange, correctly anticipated by the choir. The second is the requirement to wear face coverings, not anticipated or adopted by the choir. The third is the absence from the senate guidance of several other measures taken by the choir that would reduce the risk of singers standing in contaminated air (see above). There have been several significant research projects that have released findings between the two dates. A much cited but arguably overly simplistic experiment on airflow by Kahler and Hain (2020) produced somewhat misleading results that perhaps set some choirs' understanding of ventilation and flow backwards, whilst the somewhat weightier study by Asadi et al (2020) on the relationship between phonation intensity and aerosol production generated an angst right across the sector in most countries.

The high levels of angst are almost certainly attributable to the fact that the Asadi study did not specifically address the issue of singing. It had been thought likely that aerosol production by singing would lie towards the high end, perhaps on a par with or exceeding that of shouting or loud talking, but in the absence of specific information, high levels of precaution predominated and certainly influenced the judgements of Public Health England.

Table 3
Choir actions on 8th May compared with Senate instructions on 12th August

Berlin Senate 12th August	Staats und Domchor 8th May
The room must be ventilated regularly, ideally by cross-ventilation	The largest indoor space in Berlin.
Rows of common singing must have an impulse ventilation (ideally cross ventilation) of at least 15 minutes	Floor to ceiling air conditioners fitted.
Continuous external ventilation (e.g. windows on tilt or fully open) should be provided from the beginning of the rehearsal or the event to the end.	All rehearsals held in the cathedral itself or outside on steps
After the end of a rehearsal in which 60 minutes of singing have taken place, the room must be ventilated crosswise for 30 minutes, after which the room must remain empty for two hours. Before the start of the next rehearsal, again, cross-ventilate for 30 minutes.	Rehearsal rooms not used. Shortened rehearsal times with breaks for the air to clear.
the minimum distance of 2 metres must be maintained in all directions.	Singers spaced well apart (2-3m circle between each) in circular formation.
A mouth-and-nose cover is required during rehearsals and performances for singers and the audience. However, it is strongly recommended that singers and the audience wear the mouth and nose protector for the entire duration of the event.	*Face coverings not worn*

Further complications arise from ongoing confusion between studies that address the behaviour of aerosols (flow dynamics) and studies that address the production of aerosols. Echternach and Kniesburges (2020) set up experiments specifically to identify the drift of aerosols in singing as opposed to the projection of particles in simple air flow models such as that of Kahler. This study addressed primarily the question of aerosol behaviour as opposed to production, though it gave some indication of the number of particles that might be generated, confirming earlier speculation that strongly emphasised consonants would project aerosols further. A significant finding concerned the wearing of masks, concluding that these did significantly, though not completely mitigate the flow of aerosols. The authors were reluctant, however, to recommend masks for professional singers. They did show that the risk was significantly smaller towards the side of a singer than towards the front, noting that the radial model of distancing (i.e. a 2m+ circle round each singer) might be revised. They particularly stressed the need for a constant supply of fresh air to prevent aerosol accumulation indoors.

Mapping of infection risk on the probability scale through the Wells-Riley equation was carried out during the second phase of the Colorado-Boulder study (Miller et al, 2020). This showed a significant effect for the wearing of well-fitting masks, leading the authors to conclude that these should be compulsory for a return to singing in schools. The study also placed a strong emphasis upon rehearsal length and air change. Rehearsals should not exceed 30 minutes in length, and a time interval corresponding to however long it takes to achieve a complete air change should intervene before the next use of the room (Miller, 2020).

The specific angst associated with the Asadi study has been addressed by Dirk Mürbe and colleagues in Germany (Mürbe et al, 2020) and in the UK by the PERFORM project collaboration led by Pallav Shah of Imperial College London, and popularly associated with co-investigator Declan Costello (Gregson et al, 2020). This study demonstrated that at the quietest volumes, neither singing nor speaking were significantly different to breathing, but at the loudest volumes (90-100dB), a significant difference between singing and speaking could be observed. The authors stressed that the largest changes they observed were nevertheless between the loudest and quietest volumes irrespective of the type of vocalisation (greater than one order of magnitude). Differences between singing and shouting, though statistically significant, were small enough for the authors to conclude that guidelines could be produced in which volume, duration of vocalisation, number of participants and the environment in which the activity occurs could be mitigations. No attempt was made to quantify the risk or provide a means of assessing the efficacy of the suggested mitigations, but the data and results were sufficient to convince PHE that there is no justification for treating singing as a uniquely hazardous type of vocalisation. Against this must be considered that some English conductors appear to have been excessively influenced by social media and press hyperbole, one rather brashly and naively stating "it all depends on Declan Costello". Neither should it be over-looked that the study confirmed the possibility that any individual singer might be an unknown "super-spreader". It remains the case that it all depends on the ability of choirs to implement a range of mitigations that differ little in principle from the mitigations necessary for any activity in which there is collective indoor vocalisation.

Finally, another study that is awaiting peer review has been undertaken for the Association of Professional Musicians in Sweden. Noting the work that had been undertaken in other countries, this study recommended the following controls for singing in Sweden:

- joint singing in closed up rooms should not exist
- If rehearsals are happening, the volume of the room must be as big as possible, with very good ventilation possibilities. Air must be replaced, not recirculated.
- The duration of a rehearsal must not exceed 15 minutes, and the empty room must be properly aired out
- Unventilated rehearsal rooms should be shut down. Ventilated rooms could possibly be used, given a few hours between users.

(SYMF, 2020)

Whilst clearly broadly in agreement with the emerging consensus that all indoor gatherings in which voices are used (for whatever purpose) must be time limited and require large, well ventilated spaces, a rather higher degree of precaution is recommended than was exercised by the Stockholm Boys Choir. Sweden seems, by this criterion, currently to be travelling in the opposite direction to the UK.

Conclusions

For all the painstaking work that has been carried out in large studies such as the Colorado-Boulder collaboration, the question of how to express and quantify risk remains. James Weaver, Director of Performing Arts and Sports for the US National Federation of High Schools stated that

> We are not using a live virus, we are not infecting participants, we are not allowing participants to be infected while doing labratory experiments so something that we can't answer is, you know, if the play, will they be infected, we can't tell you that (Weaver, 2020).

Arguably, the first choirs standing *did* use a live virus in that they took the risk that the live virus would not be present in their spaces in sufficient quantity to cause an infection – but it could have been.

They were able, as a result, to say that if they sing, they will not be infected. That, fundamentally, is the point of an empirical study and it is the basis of familiar statistical risks such as that of death in an air accident. Of course, no ethics committee would sanction the deliberate construction of a study that would intentionally expose participants, including children, to a live virus. Nevertheless, it was the judgement of the choir directors and managers that the risk of this was acceptably low that kept the children acceptably safe. It was this judgement that counted, not a clinical, hermetic exclusion of the virus and it has been clear that an extremely high degree of precaution was exercised. Judgement was expressed in intention to act on a set of control measures informed by whatever understanding was available at the time. Whilst the present author felt obliged to uphold the position that choral singing was "high risk", these choirs in their various locations and circumstance took the position that choral singing with stringent controls was "acceptable risk", even for children. It is the stories of these choirs, not a number, that gives substance to the meaning of "acceptable risk".

The experimental studies that have been published since the first choirs stood have moved in a clear direction. Provided that controls relating to limitations on numbers of singers, time of rehearsals, and above all ventilation and air change are implemented, the level of precaution has indeed reduced in proportion to the increase in scientific knowledge. The fact that the first choirs standing anticipated most of these controls might be taken as a demonstration that some trust might be placed in choir directors to manage risk. This does not eliminate risk, however, but it is empirical study, not experiment, that will remain the final arbiter as is the case with transport safety. As choral singing resumes in the UK, an empirical study is by default taking place. We all hope that the result will be "no infections reported" from which the conclusion "if they sing, they won't be infected" can be drawn.

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