Evidence summary to inform safe return to campus in the context of COVID-19

Professor Trisha Greenhalgh, Professor Aris Katzourakis, Dr Tristram Wyatt, University of Oxford and Dr Stephen Griffin, University of Leeds.

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Summary

SARS-CoV-2 (the virus which causes COIVD-19) spreads predominantly through the air. It is transmitted mainly in crowded and unventilated indoor spaces among unvaccinated people, though vaccinated people can still transmit the disease and catch it from others. Measures to reduce transmission should reflect the mode of transmission. The most effective ones are:

- Vaccination
  - ✓ Aim for at least 90% coverage
  - ✓ Make it easy to get a jab
- Everyone should wear masks
  - ✓ At all times when indoors, especially in crowded settings
  - ✓ Masking protects others ("source control"), protects the wearer and models safe behaviour
  - ✓ Make sure the mask fits well and has no gaps at the side (no "chin masks")
  - ✓ Respirator (FFP2 or N95) masks are more effective than cloth or medical masks
  - ✓ Do not remove masks when speaking or singing
  - ✓ Ideally, take lunch and other refreshment breaks (when masks are removed) outdoors
- Space people out (reducing the chance of cross-infection)
  - ✓ Physical distancing—but there is no magic "safe" distance to space desks
  - ✓ Reduce class size with blended learning options (students may choose to connect virtually)
  - ✓ Use cohorting (keep students in small groups with no cross-mixing)
- Measures to clean the air
  - ✓ Ventilation: windows wide open (preferably all the time, or at least during regular breaks)
  - ✓ If using natural ventilation, ask management to supply CO_2 monitors, measure levels regularly and aim for <700 ppm
  - ✓ Use CO_2 levels in classroom air strategically to negotiate with management
  - ✓ Filtration: inbuilt filtration systems (MERV13) or portable air filters (HEPA)
  - ✓ Aim for 4-6 air changes per hour
- Testing, tracing and isolating
  - ✓ Frequent LFD testing (and tracing and isolating infectious individuals) if incidence is high
- Clinically vulnerable people should
  - ✓ Be supported to work from home and connect remotely as much as possible
  - ✓ Wear respirator masks when on campus
  - ✓ Speak to Occupational Health for further advice

Some widely promoted measures are ineffective and could distract or falsely reassure us:

- ☒ There is <u>no direct evidence that sanitising hands prevents transmission</u> of COVID-19 (but absence of evidence is not proof of ineffectiveness, and general hygiene measures include clean hands)
- ☒ There is <u>no evidence that taking temperatures</u> before entering the classroom prevents transmission
- ☒ There is limited evidence that <u>fomites (phones, paper money, discarded masks) are not a major route of transmission</u> (but avoiding too much passing of objects is a sensible precaution)
- ☒ There is evidence that <u>plastic screens do not reduce transmission</u>
- ☒ There is evidence that <u>face screens/shields are ineffective</u> at reducing transmission

SARS-CoV-2 and university life

As Independent SAGE has recently pointed out, the UK is currently (Autumn 2021) experiencing high and rising levels of COVID-19 cases, and almost all are the highly contagious delta variant [1]. Whilst young people are less likely to develop severe acute disease than older people, some will be hospitalised and a few could die; persistent symptoms ("long Covid") is a risk in a proportion of those infected. All universities and colleges now have the infrastructure to implement rapid and frequent testing. Vaccination rates in UK are generally high (though not yet in the 18-24 age group, and some vulnerable groups are unable to receive the vaccine or mount an effective immune response to it). Universities have experience of running most courses online and supporting students to isolate when necessary. There is, however, an appetite to return to face-to-face modes of teaching as well as socialising and sport.

The science of classroom transmission

There is strong and consistent evidence that the main—and perhaps the only significant—mode of transmission of SARS-CoV-2 is *through the air* [2, 3]. Indeed, super-spreader events (in which one or a few people infect large numbers of others)—including choir practices, funerals, conferences, gym sessions and other mass indoor events—are the *main drivers of the pandemic* [4].

Higher education includes many preconditions for such super-spreader events, including living and eating communally, lectures and seminars, sports training and competition, arts and singing performances, and socialising.

Some indoor events show no COVID-19 transmission, even when infected people are present, while others are shown in retrospect to have been super-spreader events; this phenomenon is known as heterogeneity or *overdispersion* of transmission dynamics, and is highly relevant to our efforts to control the virus in schools and universities [5]. Whilst the highest risk of airborne viral transmission occurs with coughing and sneezing, speaking and singing are also high-risk activities [6, 7].

A landmark paper on minimising risk of airborne transmission (written before effective vaccines had been discovered) used the US Centers for Disease Control and Prevention's "hierarchy of controls" (Figure 1) [8]. In the sections which follow, we consider all the measures in the hierarchy of controls plus vaccination. We begin with vaccination, masking and administrative controls as these are things which individual university employees may be able to influence. We then discuss engineering controls (ventilation and air filtration).

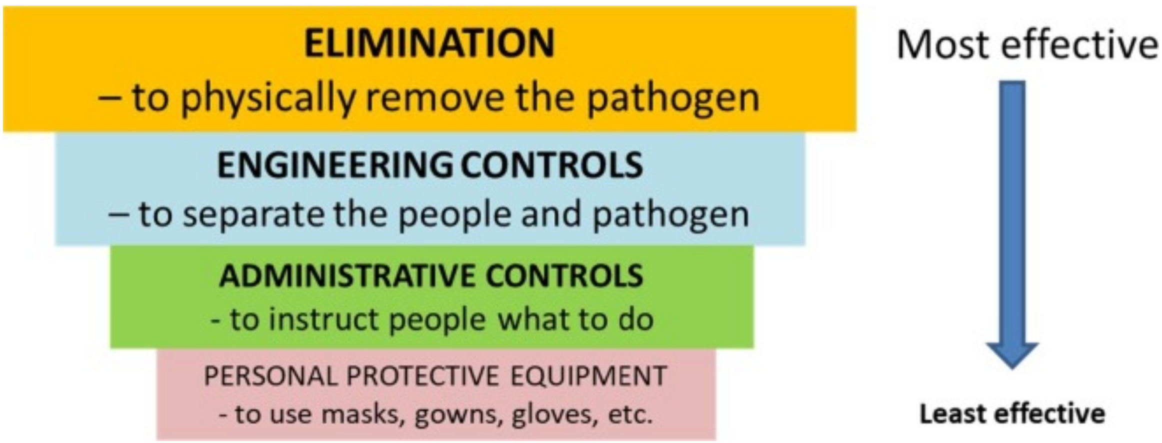

Figure 1: the hierarchy of controls for an infectious pathogen (reproduced from [8] under Creative Commons licence)

Encourage vaccination—and make it easy

Vaccines have been a game-changer for COVID-19; they dramatically reduce the incidence of symptomatic disease and risk of transmission of the virus to others; breakthrough infections in vaccinated persons are rare and generally mild [9].

A recent BMJ review concluded that the most important single intervention for preventing on-campus transmission is vaccination [10]. These authors suggest (based on a preprint modelling study [11]) that if 90% of staff and students are fully vaccinated, campuses can safely reopen without other measures. However, this 90% target is currently rarely met (as of end September 2021, only 59% of 18-24s were fully vaccinated – see https://coronavirus.data.gov.uk), and the 90% cutoff is perhaps questionable in any case. An individual interacting with another group of people in a university setting has no way of knowing what proportion of them are vaccinated. Vaccine hesitancy among student age groups is often due to perceived low vulnerability and the "inconvenience" of attending for a jab [10], so one key measure for improving safety could be to *make it very easy for people to get a vaccination* on campus.

Everyone should wear masks

Masking of the public has been controversial but the science is actually fairly straightforward. Masking has two main effects: reducing emission of the virus by the wearer ("source control"), and protecting the wearer from virus emitted by others [12, 13]. It also has a third potential effect—reminding us that we are still in a pandemic and signalling to others that we are taking *their* safety seriously [14].

Reviews of a wide range of evidence (including laboratory studies and natural experiments) have shown that, broadly speaking, masks are effective—but by no means perfect—for source control [12, 13]. Masks reduce the amount of virus that gets into the air, and hence the probability that someone else in the room will be infected [15]. Wearing a mask reduces viral emissions from coughing and sneezing approximately 20-fold [16], but around half of all people who transmit the virus have no symptoms at the time (i.e. they are not coughing or sneezing but simply *exhaling* the virus in aerosols) [17]. Different materials for cloth masks have very different filtration properties [18]; a well-fitting mask with no leaks round the side is crucial [19]. A double-layer neck gaiter (bandana) and a medical mask both reduce emission of aerosols by around 60%, but respirator (FFP2 or FFP3, N95) masks are much more effective, blocking up to 99% of aerosols [20]. Note that face visors reduced aerosol emission by only 5%—i.e. they are ineffective [20].

Some people say that randomised controlled trial (RCT) evidence is the only "robust" way to test the impact of masks. This is untrue, because most such RCTs are designed only to test the hypothesis that the mask protects the wearer over a short period. Actually, masks work *mainly* by protecting other people, and even a non-statistically significant effect on transmission dynamics (e.g. in lectures) can lead to very large effects over time.[1]

Should masks be mandated rather than just encouraged? We think so. If everyone is wearing a mask, source control will be high and double-layer cloth masks will be adequate for most healthy people. To *protect the wearer* effectively from airborne virus when others in the room are unmasked, a higher grade of filtration is needed, hence in the absence of near-universal use of source control masks, individuals may be left with little choice but to consider respirators [12]. Those who are clinically vulnerable (hence requiring masks for self-protection) should use respirators. Perhaps the most persuasive argument for masks in the university context is that if everyone wears one, there is a much lower risk that teaching will need to return to online as a result of rising case numbers. In one recent CDC report, US schools without mask mandates in July-August 2021 were 3.5 times more likely to have COVID-19 outbreaks than schools with mandates [21].

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[1] Double the number 1, and keep going. 1 becomes 2, then 4, etc. After 10 doubles, you get 512. After 10 more doubles, you get 262144. Now instead of doubling, multiply by 1.9 instead of 2 (a tiny reduction in growth rate). After 20 cycles, the total is only 104127. Hence, if masks reduce transmission by even a tiny bit (too tiny to be statistically significant in a short RCT), population benefits are still huge. If Covid-19 rates double every 9 days, an intervention which made them increase by only 1.9 every 9 days would mean that after 180 days, cases would be down by 60%.

We recommend that masks are worn continuously indoors and not removed for speaking or singing [6, 7]. The suggestion in some universities that masks should be worn only until people are seated but may be removed thereafter makes no scientific sense. Indeed, because of the airborne nature of the disease, masking is *more* important when in a classroom learning setting (indoors, with others, and with some people talking) than when moving between classrooms (especially if walking alone, outdoors and in silence). Likewise, rules in gyms that masks should be worn when walking between equipment but not when exercising *on* the equipment are nonsensical since heavy breathing during exercise will increase emission of viral particles [22, 23].

The benefit of mask wearing by all is not dependent on the size of a group, so suggestions that masking is needed only above a certain occupancy threshold means that unmasked smaller groups would carry a preventable risk (and also provide a false sense of security).

A major risk setting for transmission of COVID-19 is lunch and tea breaks, since masks must be removed for eating and drinking, and because people often sit at close quarters and talk. To reduce transmission, refreshment breaks should ideally be taken out of doors. If this is not possible, physical distancing should be increased and silence maintained while unmasked. Socialising in breaks could occur, for example, during the walk to the café (while masked) but not while eating.

A few people have a medical reason not to mask (e.g. neurodiverse); in some universities they may obtain a lanyard to indicate they are exempt.

Space people out (physical distancing, joining remotely, cohorting)

Physical distancing (also known as social distancing, but it's better to say physical distancing since we can still be sociable in the remote environment) is effective at reducing droplet transmission, since droplets fall to the ground within a few feet due to gravity [24]. Physical distancing also protects against *airborne* transmission, since most airborne particles are spread via close contact, especially when a person is in the direct stream of someone else's exhaled breath (think of smelling the garlic on someone's breath—you might be able to smell it across the room but it's much stronger at close range) [3].

Many university guidelines stipulate a specific physical distance such as 1 or 1.5 metres to space desks apart. This is scientifically naïve. A "safe" distance cannot be calculated precisely, since a) airborne particles spread throughout a room within about 30 minutes (and can remain even after the room has been vacated), hence *time spent indoors* must also be factored in; b) if nobody is wearing a mask, viral emission is considerably greater (hence, close contact is more risky—and conversely if everyone is masked, it's less risky); c) singing or loud talking increases viral transmission (hence, again, close contact is more risky); d) even wide separation will not protect fully against the turbulent jets emitted when a symptomatic person coughs or sneezes [24].

Figure 2 below summarises this information in a semi-quantitative way [24]; a paper offering a quantified version of this diagram is under review [25].

What to do if you are given a rigid separation distance to impose? Most importantly, don't be reassured by this desk-separation theatre! Take account of the *multiple influences on transmission risk.* Separating desks is good, but also—and more importantly—you should encourage people to get fully vaccinated, keep masks on, and speak quietly rather than loudly (and if they've nothing important to say, here's another reason to stay silent).

The fewer people who are physically present in the room, the lower the risk of transmitting the virus. This is partly because desks can be more spread out, but it's also because fewer breathing humans will be exhaling virus into the air. If you can, provide a blended learning option where those who wish to join the lecture or seminar remotely are supported to do so (especially if they or a household member are clinically vulnerable). Staggering the start dates of students does not appear to reduce transmission [26].

There is no evidence that introducing Perspex screens (or other barrier) reduces the risk of transmission and the benefit that is conferred by a greater distance, and they may interfere with the effective circulation of clean air [8]. Such barriers should not be a substitute to distancing or engineering controls (ventilation and air filtration – see below).

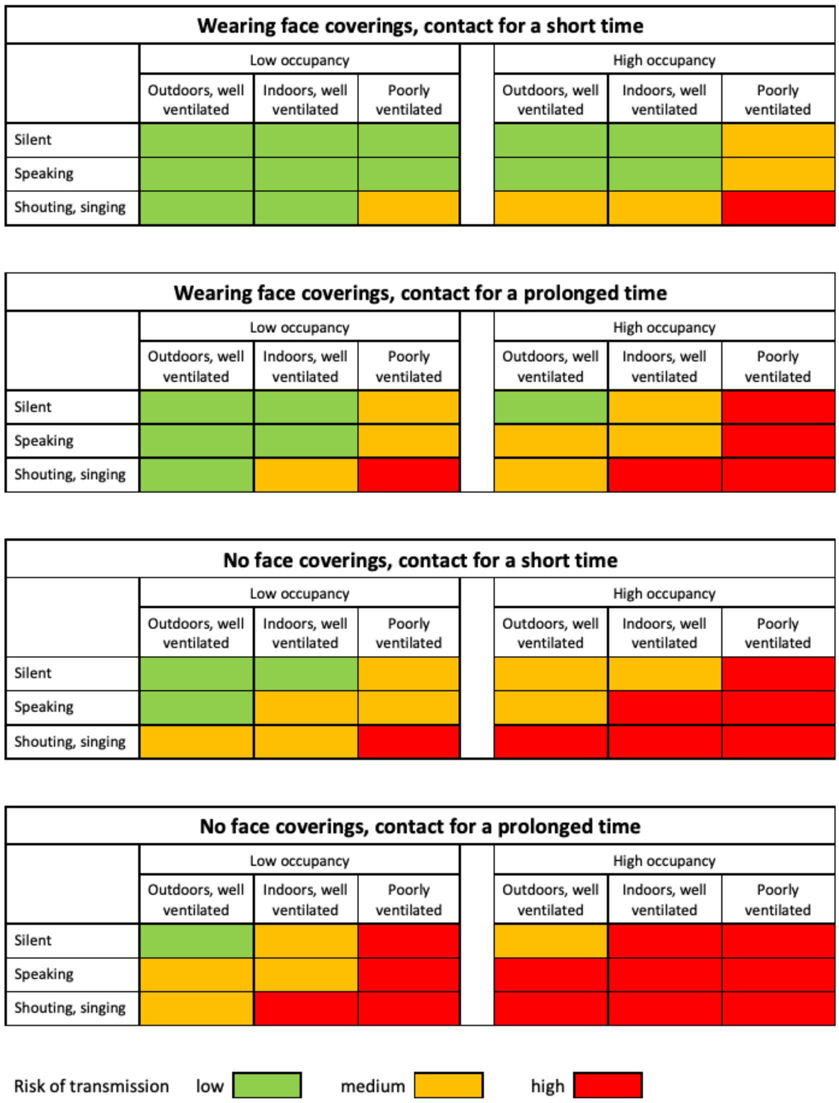

Figure 2: Risk of SARS-CoV-2 transmission in different settings, assuming people are asymptomatic (reproduced from [24] under Creative Commons licence)

Ensure adequate ventilation

We all know that good ventilation helps clear the virus from indoor spaces, but what counts as good ventilation? In one modelling study (currently a preprint [27]), the most effective single intervention for reducing aerosols was natural ventilation through the full opening of six windows all day during the winter—a measure which led to a 14-fold decrease in cumulative dose of aerosol. This was more effective than universal use of surgical masks (which led to an 8-fold decrease). In the spring and summer, natural ventilation with windows fully open all day was less effective (2-fold decrease in cumulative dose). In the winter, partly opening two windows all day or fully opening six windows at the end of each class produced an approximately 2-fold decrease in cumulative dose of aerosols. In that study, opening windows during breaks only had minimal effect (≤ 1.2-fold decrease). In sum, ventilation appears highly effective—but if you can't open windows more than a crack, you'll need to find a different way of cleaning the air.

Mechanical ventilation occurs through extractor fans (such as those in domestic kitchens and bathrooms) or ceiling fans (often used as an alternative to air conditioning in hot climates). Such measures are rarely adequate on their own for ventilating public buildings, but a fan can help natural ventilation (it should be adjusted carefully to direct air out of the room, not back into it).

If indoor spaces are fitted with air conditioning systems, it is important to ensure that air which is removed is not recycled unfiltered (or inadequately filtered) back into that space—a surprisingly common design feature in some university buildings [8].

Air quality in ventilated spaces can be approximated by measuring carbon dioxide (CO_2) levels, since this is present in higher concentrations in exhaled air than in outdoor air. The higher the CO_2 level in a room, the more exhaled air (and hence, potentially, the more virus) there is. Before the pandemic, indoor air quality standards were generally set around the goal of avoiding CO_2 poisoning (which can lead to "sick building syndrome" with symptoms such as headaches a sense of stuffiness) and also of clearing body odours and other smells.

Whilst CO_2 levels can be used to approximate the risk of COVID-19 transmission [28], they are only a proxy for this risk. With that caveat, some authors have suggested that CO_2 levels might be used strategically in negotiations with employers [29]. Figure 3 shows some suggested cut-off levels for denoting "low risk" (below 700 ppm), "medium risk" (700-800 ppm), "high risk" (800-1000 ppm) and "very high risk" (>1000 ppm). Measures to address moderate risk include opening classroom doors and windows, opening windows between classes, and reducing number of students in the classroom. If levels indicate "high risk" despite these measures, infrastructure changes (such as mechanical or portable air filters) are needed.

	RISK LEVEL			
	LOW	MODERATE	HIGH	VERY HIGH
CO2 peak concentration or class time average concentration	< 700 ppm	700-800 ppm	800-1000 ppm	> 1000 ppm
Recommended action	No action needed	A If A active, do B If B active, do C If C active, do D	A and B If both active, do C then D If all active, do E	A and C If both active, do D If all active, do E

A: door always open

B: windows open for 10 min at lunch break

C: windows open for 10 min at end of each teaching hour

D: change setting (e.g. windows open longer, reduce number of students per class)

E: infrastructure changes needed (e.g. inbuilt or portable filtration system)

Figure 3: Risk classification scheme for CO_2 levels in indoor air (adapted from [29] under Creative Commons licence).

Note that the cut-off values for unacceptable CO_2 levels in the above figure differ from those in many official documents (e.g. from UK Health and Safety Executive, who recommend 1500 ppm). This is because the higher cut-off values were set historically for an entirely different purpose.

Use air filtration and sterilisation when needed

When it is not possible or desirable to use ventilation (e.g. for energy efficiency reasons) to maintain clean air, measures known as engineering controls are needed. There are two main kinds: an inbuilt mechanical filter (for which standards are expressed as the minimum efficiency reporting value (MERV) [30]) or a portable air cleaner fitted with a HEPA (high-efficiency particulate air) filter. Such filtration systems have been designed to remove particles of many different kinds and sizes (e.g. dust, pollen, smoke, bacteria, viruses).

The SARS-CoV-2 virus—approximately 100 nanometres (0.1 μm) in diameter— is smaller than most airborne particles, so it is important to check that the system installed is efficient in the 0.1 to 1 μm range. Of note to those in charge of supplying clean air to old-fashioned university or school buildings is this warning: *"most central mechanical systems were not designed for HEPA filters. Instead, these systems use filters on a different rating scale, minimum efficiency reporting value, or MERV, and typically use a low-grade filter (eg, MERV 8) that captures only approximately 15% of 0.3- to 1-µm particles, 50% of 1- to 3-µm particles, and 74% of 3- to 10µm particles. For infection control, buildings should upgrade to MERV 13 filters when possible, which could capture approximately 66%, 92%, and 98%, of these sized particles, respectively"* [30].

Portable air filtration units fitted with HEPA filters are highly effective at removing aerosols in the 0.1 to 1 μm range [31-34]. In the Villiers study described above, one HEPA filter was as effective as two windows partly open all day during the winter (2.5-fold decrease in cumulative dose of aerosols) while two HEPA filters were more effective (4-fold decrease) [27]. A combination of interventions (masks along with natural ventilation *and* HEPA filtration) were the most effective, producing a 30-fold decrease in cumulative aerosol dose [27]. Aerosol scientists have begun to develop and test home-made, low-cost box fans fitted with HEPA filters as a quick and effective solution for improving mechanical ventilation in poorly-ventilated spaces [35].

Ultraviolet light (from sunlight or radiation lamps) has been shown to destroy SARS-CoV-2 in numerous studies [36], which is probably a key reason why the virus shows seasonal variation. This mechanism holds potential for enhancing safety in indoor spaces where risk of transmission is particularly high (e.g. hospitals, gyms). In a small before-and-after study published as a preprint, a combination of HEPA filtration *and* ultraviolet light sterilisation was highly effective at removing bioaerosols (including but not limited to SARS-CoV-2) in a COVID-19 surge ward and intensive care unit in one hospital [32].

Electronic air cleaning systems, for example those which use ozone, are of no proven efficacy in reducing COVID-19 transmission [37]; they currently have no place in preventing transmission of SARS-CoV-2. Air filtration does not remove CO_2, so CO_2 monitors cannot be used to monitor the quality of filtered air.

In the longer term, universities should consider the need for a *paradigm shift* in the design and ventilation of buildings, to improve air quality standards and ensure that all indoor spaces meet these through adequate ventilation, filtration or sterilisation [38].

For further information on air cleaning in the context of COVID-19, see an earlier report from SAGE (Scientific Advisory Group on Emergencies), September 2020 [39].

Test, trace and isolate while COVID-19 incidence is high

In the context of high incidence of COVID-19 and an unvaccinated or partially-vaccinated student population, frequent testing of asymptomatic staff and students along with contact tracing and support to isolate has been shown to reduce on-campus transmission substantially [26]. While lateral flow device (LFD) tests can detect asymptomatic cases and break chains of transmission, this measure depends on the efficacy of efforts to track and trace contacts and maintain and enhance the isolation of infected individuals. Anyone who is symptomatic should isolate immediately and take a gold-standard polymerase chain reaction (PCR) test, irrespective of the status of their LFD test. Universities should ensure clear and consistent communication on this matter as confusion still abounds.

Anyone with symptoms, even if they are perceived to be "just a cold", should isolate immediately, and a negative LFD should never override the more accurate PCR test (see below). Note that the most common symptoms of delta infection (headache, fatigue, runny nose, sore throat, sneezing) are different from the standard triad of cough, fever and shortness of breath which are still widely used to prompt PCR testing. Hybrid teaching options greatly facilitate immediate isolation, and students and staff with symptoms that may be due to COVID-19 should be supported to engage remotely if they are well enough to do so. Track and trace efforts are constrained by the specifics of the system. Universities may have additional information that can be harnessed to provide a further layer of safety. In the UK for example, individuals sharing a confined space for extended periods of time, for example, may not be contacted by the official Track and Trace system but could be identified via attendance lists.

Some authors have questioned the validity and expense of mass asymptomatic testing in populations where incidence of COVID-19 is low, due to the very large number of tests required to detect small numbers of positive cases [40]. A recent modelling study suggests that as vaccination rates rise and the incidence of COVID-19 falls, the cost-benefit balance of frequent testing becomes less favourable [11]. However, at the time of writing the UK is a long way from a low-incidence state and we strongly recommend maintaining asymptomatic testing. Below, we explain some of the science behind the tests.

Lateral flow devices (LFDs), which detect the presence of virus antigen in the nose and throat using a swab sample tested in a flow device (like a pregnancy test) [41]. Multiple types of LFD test are available, and they are designed to test people (perhaps repeatedly) who are not displaying overt COVID symptoms. LFD tests are all highly specific i.e. they are very unlikely to give a positive result if the person is not infected. But LFD tests are not particularly sensitive (i.e. less able to detect very small quantities of the virus) compared with the gold standard PCR (polymerase chain reaction) tests. This means that testing negative on an LFD is not a "green light" i.e. it does NOT guarantee that the individual is not infected with SARS-CoV2, so they should continue to practice mitigations as advised. On the other hand, testing *positive* on an LFD means it is highly likely the person *is* infected (it is a "red light", indicating that they are potentially infectious). Such individuals should self-isolate immediately, report the positive test, and order a confirmatory PCR test as soon as possible. A positive LFD test should trigger a call from the Track and Trace service.

Whilst LFD tests are used mainly in people without symptoms, they are actually more likely to be positive if the infected person is symptomatic (probably because such people have higher levels of the virus) [42]. However, people with a positive LFD may well be infectious despite lack of symptoms—hence the value of these tests in identifying infectious cases (who should then isolate) and reducing the chance of a super-spreader event on campus. LFD tests also tend to reflect past infection (they are more likely to be positive 2 weeks after the onset of symptoms than on the day symptoms appear) [42].

In sum, the on-site LFD testing established at many UK university sites appears to be evidence-based (though not scientifically perfect) and its regular, frequent use is recommended while the incidence of COVID-19 remains high. Those with symptoms also need a PCR test.

Clinically vulnerable staff and students

Universities and colleges have a duty of care to their staff and students. They must provide a safe environment for learning, teaching, and working. If a person has a condition or risk state which makes them vulnerable to COVID-19 and its complications, the institution must take account of this. Increased vulnerability to COVID-19 occurs in people who are immunosuppressed (including those on medication which suppresses the immune system, and pregnant women), those with certain long-term conditions, older age groups, some minority ethnic groups and those who are overweight. These risk groups were considered in detail in the IndySAGE report [1].

The evidence supports a policy of vulnerable groups (whether staff or students) being supported to work from home if possible while the incidence of COVID-19 is high. If they must enter indoor spaces they should be advised to wear a respirator mask for self-protection, and it is particularly important for others in the room to wear a mask to maximise source control. If clinically vulnerable people are required to enter indoor spaces, those spaces should be adequately ventilated (confirmed using CO_2 levels) or have high-quality air filtration systems (MERV13 or HEPA) installed.

Interventions for which there is no evidence ("hygiene theatre")

There is no scientific evidence to support taking temperatures, sanitising hands before entering the classroom (though washing hands when they are dirty and after going to the lavatory is of course a general hygiene measure), restricting the sharing or exchange of fomites (i.e. potentially contaminated objects such as pens, paper, books or other study materials), wearing face visors, or separating desks with plastic screens. Such "hygiene theatre", which links to a discredited hypothesis that the virus is spread mainly or exclusively by droplets [43], could potentially distract us from measures which do work.

In relation to sanitising, hand hygiene is recognised good practice for the prevention of many infectious diseases, so it should not be dismissed or discouraged (but equally, should not be over-emphasised). In relation to fomite transmission, a large Brazilian study detected no SARS-CoV-2 virus on over 400 samples of mask fronts, cell phones, paper money or card machines during a wave of the pandemic [44]. In other words, there is some evidence *against* the importance of fomite transmission. However, since the mode of transmission remains contested, it would seem sensible to discourage widespread sharing of pencils, books and other objects among students.

Conclusion

The key to effective prevention of COVID-19 is acknowledgement of its predominantly airborne mode of transmission. Many widely-promoted measures—hand sanitising, strict 1- or 2-metre distancing, fomite precautions—wrongly assume an exclusively droplet mode of transmission assume and are therefore ineffective. Droplet thinking also dominates the thinking of senior management, many staff and students.

Acknowledging the importance of airborne transmission should lead to policies such as: a) masking at all times while indoors, with encouragement to wear higher-grade respirators for best protection (especially if clinically vulnerable); b) continuing attention to physical distancing but in a way that does not assume that a particular interval between desks makes the space "safe", and using additional measures (joining remotely, cohorting, frequent breaks) to reduce crowding and time spent indoors; c) a greater focus on engineering controls (ventilation and/or filtration of air). In addition, university and college staff should encourage and facilitate vaccination, attend to testing and tracing, and be ready to instigate tighter controls (e.g. return to online teaching) if case numbers rise.

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