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RESEARCH REPORT

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Investigating the impact of remote neuroanatomy education during the COVID-19 pandemic using online examination performance in a National Undergraduate Neuroanatomy Competition

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Abstract

Neuroanatomy is a notoriously challenging subject for medical students to learn. Due to the coronavirus disease-19 (COVID-19) pandemic, anatomical education transitioned to an online format. We assessed student performance in, and attitudes toward, an online neuroanatomy assessment compared to an in-person equivalent, as a marker of the efficacy of remote neuroanatomy education. Participants in the National Undergraduate Neuroanatomy Competition (NUNC) 2021 undertook two online examinations: a neuroanatomically themed multiple-choice question paper and anatomy spotter. Students completed pre- and post-examination questionnaires to gauge their attitudes toward the online competition and prior experience of online anatomical teaching/assessment. To evaluate performance, we compared scores of students who sat the online (2021) and in-person (2017) examinations, using 12 identical neuroradiology questions present in both years. Forty-six percent of NUNC 2021 participants had taken an online anatomy examination in the previous 12 months, but this did not impact examination performance significantly ($p > 0.05$). There was no significant difference in examination scores between in-person and online examinations using the 12 neuroradiology questions ($p = 0.69$). Fifty percent of participants found the online format less enjoyable, with 63% citing significantly fewer networking opportunities. The online competition was less stressful for 55% of participants. This study provides some evidence to suggest that student performance is not affected when undertaking online examinations and proposes that online neuroanatomy teaching methods, particularly for neuroradiology, may be equally as effective as in-person approaches within this context. Participants perceived online examinations as less stressful but raised concerns surrounding the networking potential and enjoyment of online events.

KEYWORDS
medical education, neuroanatomy, online education, student perceptions, student performance

INTRODUCTION

The coronavirus disease-19 (COVID-19) pandemic saw the provision of anatomy education transfer from traditional in-person laboratory-based teaching to the use of remote online teaching resources.[1] Off-campus practices resulted in many faculties adopting online teaching strategies. However, unlike many educational disciplines, the delivery of anatomical education has conventionally relied more heavily upon in-person, cadaver-based teaching sessions.[2] More specifically, the COVID-19 pandemic exposed several specific vulnerabilities in the delivery of neuroanatomy education due to a reliance on in-person teaching and the inherent historical challenges of teaching and learning neuroanatomy.[3] These challenges include a specific fear surrounding learning neuroanatomy (termed "neurophobia") due to perceptions of the subject material being particularly complex,[4] but also a lack of suitably trained teachers to provide students with high-quality, small-group neuroanatomy teaching that helps prevent overcrowding of intricate specimens.[5]

Despite predominantly face-to-face based anatomy education, online learning resources have long been used by many institutions to supplement medical student's learning.[2] This approach, termed "blended learning," refers to the supplementation of traditional didactic educational approaches with technology-enhanced learning resources. Popular examples include the likes of Acland's Anatomy videos[1,2,6] and Dr Krebs' clinical neuroanatomy site.[7] Closer to home, members of our own research group regularly produce content related to the neurosciences for our own YouTube channel, Soton Brain Hub, to help support medical student's anatomical education, amassing over 44,000 subscribers and 4.5 million total views to date.[8] These blended learning practices have been increasingly implemented within many branches of medical education, but appear to be particularly efficacious when deployed in addition to the anatomical curriculum.[3] This is of relevance, as medical students have previously been shown to perceive neuroanatomy as the most challenging topic in the undergraduate anatomy curriculum, leading to increased implementation of blended teaching methods to augment their learning.[4] In a new era of blended learning, the development of communities of practice, both locally and more further afield, has been particularly emphasized, whereby a balance of power can be struck between staff and students to co-create learning resources.[2,9]

Throughout the COVID-19 pandemic, medical schools across the UK and globally adopted various online learning strategies to ensure the continual and sustainable delivery of neuroanatomy education.[10] Previous studies have outlined the importance of synchronous remote teaching, fully embracing new pedagogies, and providing equitable access to new online learning resources.[4,10–12] Moreover, clear communication, transparent expectations, and constructive alignment have been identified as core elements of the success of online anatomical education and the development of a community of practice.[10] Such online resources have previously been referred to as complementary parts of a comprehensive neuroanatomy teaching curriculum[13] and have been shown to enhance student learning.[12] However, many limitations, such as resource availability, technical capacity and overall accuracy, and reliability may hinder the sustainable integration of these new teaching methods.[10,12]

The University of Southampton has run the National Undergraduate Neuroanatomy Competition (NUNC) for the past 10 years (http://www.natneurocomp.com). The NUNC is an annual extracurricular event for undergraduate medical students across the UK and Ireland that has attracted over 1000 participants since its founding in 2013. The competition consists of two main components: neuroanatomically themed examinations and keynote talks from experts in the field. The examinations consist of a clinically orientated multiple-choice question (MCQ) paper and an anatomical spotter examination. The purpose of the NUNC is to encourage participants to foster an interest in neuroanatomy and the neurosciences and to enable them to demonstrate commitment and excellence in the field to support their portfolios. In 2021, COVID-19 prevented the NUNC from running an in-person event. Consequently, the competition was forced to adopt an online format for the MCQ and anatomy spotter examinations which presented an opportunity for an investigation into online teaching and learning practices.

Due to the rapid uptake of online neuroanatomy learning resources,[14–16] many were implemented before having their feasibility and potential advantages/disadvantages appropriately evaluated due to the unpredictable nature of the COVID-19 lockdown measures. Additionally, there remains a relative lack of subjective and objective data exploring the usefulness of these new modalities.[11] Changes to the way in which anatomy was assessed were also necessarily introduced, including converting summative examinations to formative, in-person to online, and using digital 2D images instead of a traditional in-person spotter.[16]

Thus, the current evidence base would benefit significantly from a qualitative assessment of students' perceptions of these new learning modalities and an objective evaluation and comparison of knowledge gain and academic performance when being taught by online methods compared to traditional in-person teaching modalities.[17] This is especially important for online neuroanatomy teaching methods, as the inherent challenges that the subject presents to both teach and learn make it susceptible to be the first to suffer from new, emergency, and potentially sub-standard methods of teaching/assessment. Additionally, to the best of our knowledge, no

in-depth assessment of the impact of online versus in-person teaching methods on medical student performance in neuroradiology has been performed. We deemed an assessment of the efficacy of both pedagogical approaches in the context of neuroradiology an important area to investigate further given the requirement for future clinicians to be able to interpret neuroimaging confidently, and accurately, even at early stages in their clinical careers.

Hence, in this study, we aimed to use a well-established NUNC to assess student performance in, and attitudes toward, an online neuroanatomy assessment when compared to an in-person equivalent, as a surrogate marker of the efficacy of remote neuroanatomy education during the COVID-19 pandemic, with a specific sub-focus on neuroradiology performance.

MATERIALS AND METHODS

Ethics statement

Ethical approval for this study was granted by the Faculty of Medicine Ethics Committee, University of Southampton (ERGO ID: 9351), before commencement.

NUNC assessments

The assessments used for in-person NUNC events have traditionally consisted of a neuroanatomically themed MCQ paper and anatomical spotter examination (named Parts A and B). These were all equally weighted. MCQs were designed to cover the entire neuroanatomical spectrum and comprised both clinically and anatomically themed questions. The anatomical spotter contained questions requiring participants to identify, explain the function of, and correlate the clinical importance of neuroanatomical structures on human cadaveric specimens that were dissected in-house by members of the NUNC team. These specimens revealed both simple and complex structures, including those related to the brainstem and deep white matter tracts. The spotter also required participants to identify structures on, and clinically interpret, neuroimaging (e.g., CT scans, MRI, and X-rays). All questions used in the NUNC examinations underwent extensive external peer review for the purposes of quality assurance. Much of the content assessed in the NUNC examinations extended beyond the scope of the typical medical school curriculum.

In 2021, the online format of the competition changed the way the assessments needed to be delivered. The content and structure of the MCQ paper remained unchanged, however the anatomical spotter required adjustments. The traditional in-person spotter with cadaveric prosections was replaced with high-resolution images of the same specimens with digitally imposed arrows in place of pins to guide participants to structures they were required to identify, and participants were able to zoom in on the images if they wished. The online examinations were delivered using the proctored examination platform Synap (Synap Learning Limited, Leeds, UK).

Participant experience questionnaire

All NUNC 2021 participants were informed about the aims of the current study. Consenting participants were asked to complete matched questionnaires before and after participating in the online competition to assess their expectations and experiences of the competition and online teaching/assessment. These questionnaires were developed in accordance with the protocol outlined by Jenn and were piloted on a small cohort of medical students.[18] Both questionnaires were delivered via the online proctored examination platform. The pre-examination questionnaire was delivered to participants the week before the competition. This had the additional benefit of allowing participants to gain familiarity using the platform before the competition (i.e., how to advance through the questions, select answers, and flag questions for review). The post-examination questionnaire was also delivered via the online platform and was distributed immediately following the completion of the NUNC examinations.

The pre-examination questionnaire consisted of 36 questions related to the participants' expectations of participating in the online competition, their experience of online teaching up until their involvement in the competition, and their preparation methods for the event (Appendix 1). The post-examination questionnaire consisted of 24 questions related to participants' actual experience participating in the competition, their overall confidence when answering questions using the online platform, and any details surrounding issues that may have arisen (Appendix 2).

Sixteen questions in our pre-examination questionnaire and 15 in our post-examination questionnaire were scored using a Likert Scale.[19] The remaining questions consisted of short answer responses and MCQs. A small number of free text questions allowed for additional context and detail. The paired questions in the pre- and post-examination questionnaires were used to investigate whether participants' expectations for an online event correlated to their actual experience. Participant experience of the online event was determined by comparing answers to the pre-examination questionnaire with the post-examination questionnaire. All data collected in both questionnaires was fully anonymized.

Performance analysis

Descriptive statistics were performed for each outcome using SPSS Statistics 26 (IBM, 2018). To assess the impact of online neuroanatomy teaching on examination performance, the performance in each of the NUNC 2021 assessments (MCQ examination and anatomy spotter parts A and B) was plotted against the student's previous exposure to online examination and proportion of online anatomical education in the previous 12 months leading up to the competition. Data for NUNC 2021 performance versus previous exposure to online examination was non-parametric (Shapiro–Wilk, $p < 0.05$) and so were displayed as a box and whisker plot

(median + interquartile range) and analyzed using a Mann–Whitney *U*-test. Data for NUNC 2021 performance versus proportion of online anatomical education was parametric (Shapiro–Wilk, $p > 0.05$) and so were presented as a clustered bar chart (mean ± standard deviation) and analyzed via a one-way ANOVA with post hoc Bonferroni's multiple comparisons.

To compare the 2021 online cohort with the 2017 in-person cohort, we analyzed 12 questions that had been in both the 2021 and 2017 NUNC examinations. All 12 questions were based on neuroradiological imaging. The neuroradiological images used in 2021 and 2017 were identical and were chosen as they would provide a like-for-like comparison between participant performance in the two cohorts. The 2021 and 2017 results for these questions were compared using an independent sample t-test as the data were deemed to be parametric (Shapiro–Wilk, $p > 0.05$). The 2021 answers were assumed to represent answers following an increase in online neuroanatomy teaching and an assumed increase in remote learning compared to 2017 due to the COVID-19 pandemic. A relative difference, two-tailed, post hoc power calculation was performed for comparison between 2017 ($n = 109$) and 2021 ($n = 104$) neuroradiology question scores. Equal allocation to each study arm (2017 and 2021) was assumed and alpha statistic was set at 0.05. The traditional null hypothesis significance level of 95% was used. A minimum detectable effect of 50% was chosen following a heuristic approach in keeping with current literature and author consensus. A 50% change in performance was deemed sufficient in demonstrating educationally relevant change. Post hoc analysis generated a power of 0.8823 (88%).

For all statistical tests in this study, $p < 0.05$ was accepted as a marker of statistical significance.

RESULTS

Ninety-eight participants completed the pre-examination questionnaire, 97 participants completed the post-examination questionnaire, and 86 participants completed both questionnaires.

The impact of previous online anatomy assessment on NUNC examination performance

Forty-five (46%) NUNC 2021 participants had sat an online anatomy assessment in the previous 12 months. This did not significantly impact their examination performance in the NUNC MCQ examination, Part A, or Part B of the spotter examination ($p > 0.05$) (Figure 1).

The impact of online anatomy teaching on NUNC examination performance

Many NUNC 2021 participants had much of their anatomy teaching online in the 12 months preceding the competition (July 2020 to July 2021). Excluding those who did not have any anatomy teaching in their curriculum in the past year (i.e., clinical category students, $n = 28$), 49 (70%) participants had >75% of their anatomy teaching online. Only 9 (13%) participants had <50% of their anatomy teaching online. No significant differences were observed between examination performance in any of the three NUNC examinations and the proportion of online anatomy teaching experienced by participants in the previous year ($p > 0.05$) (Figure 2).

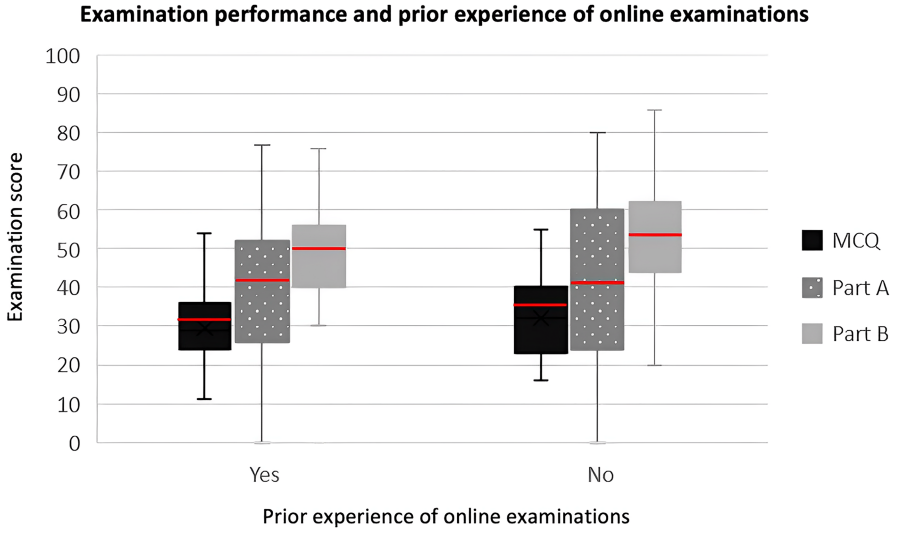

FIGURE 1 A clustered box and whisker plot demonstrating the relationship between experience of partaking in prior online anatomy examinations and subsequent raw examination score in each of the three NUNC examinations. These data were deemed to be non-parametric (Shapiro–Wilk, $p < 0.05$) and so are displayed as a box and whisker plot (red line depicts the median, boxes depict the interquartile range, and whiskers depict maximum and minimum values). Data were analyzed using a Mann–Whitney *U* test. MCQ; multiple-choice questions, Part A/B; sections of the spotter examination.

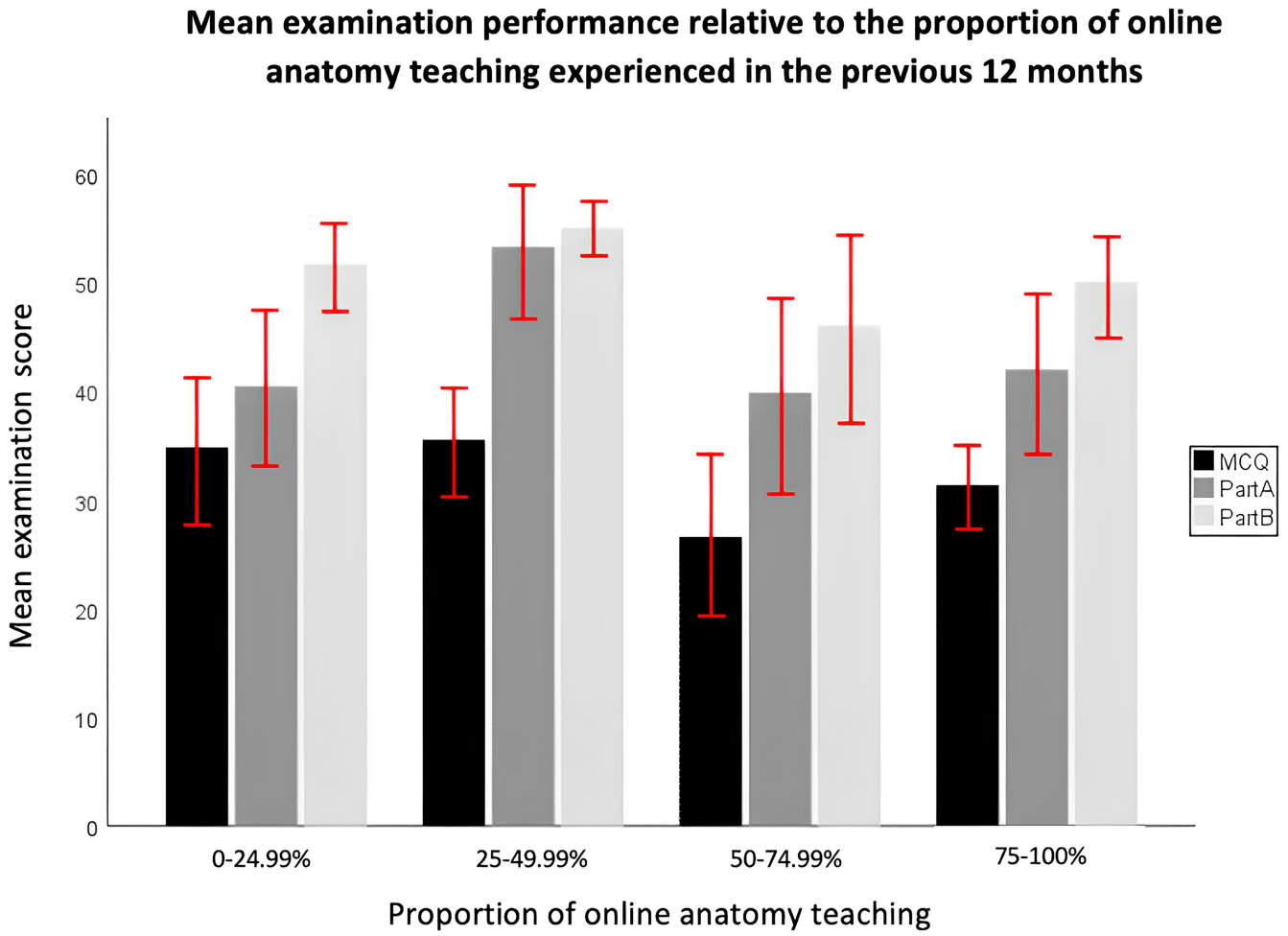

FIGURE 2 A clustered bar chart demonstrating the relationship between the proportion of students' anatomy teaching that took place online and the mean score in each of the three NUNC examinations. These data were deemed to be parametric (Shapiro–Wilk, $p > 0.05$) and so are displayed as a clustered bar chart (bars depict the mean examination score, and error bars represent the standard deviation). Data were analyzed using a one-way ANOVA with post hoc Bonferroni's multiple comparisons.

When comparing participants' performance in the 12 identical neuroradiology questions, we observed no significant difference in the mean score between 2017 (in-person) and 2021 (online) cohorts ($p = 0.69$).

Event experience

The pre- and post-examination questionnaire responses are summarized in Table 1. Fifty (58%) NUNC 2021 participants expressed that they expected the event to be less or significantly less enjoyable than if it were in-person, which was confirmed by 43 (50%) participants in the post-examination questionnaire This reduction could be explained by more participants rating the online event as "more enjoyable" or "significantly more enjoyable" in the post-examination questionnaire (pre: 6% and 0%; post: 10% and 3%).

Forty (46%) participants were concerned that the online format would provide "significantly fewer opportunities" to network with other delegates. This was confirmed as an issue by 54 (63%) participants in the post-examination questionnaire. Forty-seven (55%) participants found the examination less stressful than an in-person equivalent.

In our pre-examination and post-examination questionnaires, free-text questions highlighted some of the main concerns expressed by participants. Five felt that the online format may have lowered the status of the event and their motivation to study for it, with one student going as far as to say; "*I think the online format made it seem less serious and therefore I didn't revise as much as I would have for an in-person* examination." Most concerns were regarding technical issues due to the online nature of the assessment. Although these were dealt with quickly on the day, this may have advantaged those students with higher computer skills or those less affected by a delay. Other concerns raised by students included difficulties identifying the orientation of specimens from photographs. This was identified as a concern for several students in the pre-examination questionnaire ($n = 4$), with 50% of those who anticipated it being an issue confirming that it was in the post-examination questionnaire.

TABLE 1 Percentage of total responders selecting each item on the Likert scale for questions in the pre- and post-examination questionnaires related to expectations of an online event.

	Percentage of total responses (%)									
	1		2		3		4		5	
Question	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
How do you/did you think the online format will/did affect your enjoyment of the NUNC?	5	5	53	45	36	37	6	10	0	3
How do you/did you think the online format will affect/did affect how stressful the NUNC experience is/was for you?	11	13	37	42	25	22	23	19	4	4
How do you feel the online format of the NUNC will/did impact the opportunities to network with other delegates?	46	63	34	25	6	9	13	2	1	1
How do you think that an online format of the NUNC will/did affect your performance in the examination compared to if it was in-person?	4	13	30	29	51	39	13	14	2	5

Note: Full details of the labels assigned to the Likert scale are given here: How do you/did you think the online format will/did affect your enjoyment of the NUNC? 1 = significantly less enjoyable, 2 = less enjoyable, 3 = the same, 4 = more enjoyable, 5 = significantly more enjoyable; How do you/did you think the online format will/did affect how stressful the NUNC experience is/was for you? 1 = much less stressful, 2 = less stressful, 3 = the same, 4 = more stressful, 5 = much more stressful; How do you feel the online format of the NUNC will/did impact the opportunities to network with other delegates? 1 = significantly fewer opportunities, 2 = fewer opportunities, 3 = no impact, 4 = more opportunities, 5 = significantly more opportunities; How do you think that an online format of the NUNC will/did affect your performance in the examination compared to if it was in-person? 1 = significantly worse performance, 2 = slightly worse performance, 3 = no impact, 4 = slightly better performance, 5 = significantly better performance.

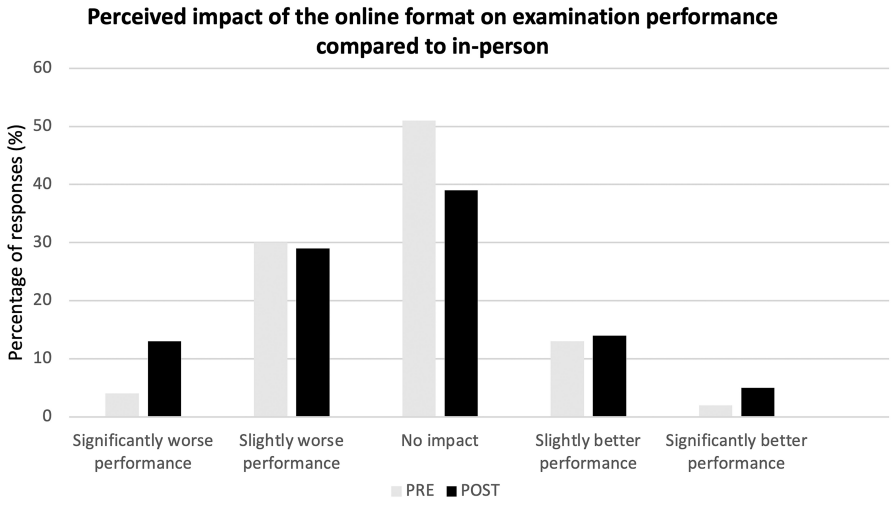

FIGURE 3 A clustered bar chart showing the responses to the questions "How do you think the online format of NUNC will affect/did affect your performance compared to if it was in-person?" from the pre- and post-examination questionnaires. Bars represent the percentage of responses for each individual category in the pre- and post-examination questionnaires.

Perceived impact

Before the event, 44 (51%) participants did not believe that the online format of the examinations would impact their performance in the examination. This was reduced to 34 (39%) participants in the post-examination questionnaire. Interestingly, after the event, more participants reported that they felt their performance was "significantly worse" (pre: 4%; post: 13%) because of the online format (Figure 3).

DISCUSSION

This study used the well-established NUNC to evaluate the impact of remote neuroanatomy education during the COVID-19 pandemic by examining online assessment performance in a national neuroanatomy assessment. In this study, 86 participants completed a pre- and post-examination questionnaire exploring event experience and attitudes to online teaching. Data pertaining to examination performance was also obtained.

We collected information on participants' prior experience with online neuroanatomy teaching. This study shows that less than 50% of all participants had sat an online anatomy examination in the preceding 12 months before the event, but that this did not significantly impact performance in any of the three NUNC examinations. We further report that of those participants who had previously been exposed to online anatomy teaching within their curriculum, 70% had greater than 75% of their anatomy teaching online. Despite this, we still observed no significant differences in examination performance between any of the three NUNC examinations and the proportion of online anatomy teaching experienced by participants in the previous 12 months. This suggests that the online teaching methods for neuroanatomy implemented during the COVID-19 pandemic may have been effective for teaching students even if the student experience might have suffered due to a lack of practical experience. This is a reassuring observation that suggests that the quality of online neuroanatomy teaching was likely of good quality despite the inherent teaching and learning challenges the subject presents to educators and learners alike. This finding is consistent with a recent study showing equivocal performance in a medical neuroscience assessment between students exposed to in-person learning versus adaptive blended learning.[3] Outside of the neurosciences, similar findings of equivalency (or sometimes even better) performance from students experiencing online only as opposed to traditional in-person teaching or hybrid approaches, have also been reported.[20–23]

The relationship between exposure to online education and non-inferior examination performance was further illustrated within our neuroradiology question sub-analysis. Here, no significant difference was observed between those in the 2017 cohort, who very likely had less exposure to online teaching, and those in the 2021 cohort who received a considerable proportion of their education in an online format in the past 12 months. These findings based on our neuroradiology sub-analysis are especially important given the need for future clinicians to be able to confidently interpret neuroimaging. Indeed, many will need to be able to do so regardless of what clinical subspeciality they work in, and a significant proportion of doctors will have roles within emergency departments where they will be required to reach accurate diagnoses in high-pressured, time-critical scenarios. The fact that non-inferiority to in-person was achieved via online teaching approaches, as suggested by our data, is especially reassuring in terms of knowledge acquisition, as it suggests that the current cohort of students who experienced this form of teaching (and future generations who may have a more hybrid approach combining both online and in-person teaching in a post-pandemic world) have or will encounter high-quality, effective teaching that will undoubtedly benefit them in their future clinical careers. There is also some evidence to suggest that medical students share this opinion.[24]

We investigated participants' expectations of the online NUNC before the event and their experience of these factors after the event. Despite a relative abundance of data surveying student experience with online anatomical learning,[16,24,25] there remains a relative lack of data detailing such experiences within medical schools across the UK. Regarding event experience, 58% of respondents expected the event to be "less" or "significantly less enjoyable" than if the event were in-person. Several key concerns were identified, including those regarding being able to orientate the specimens from the images used in the online examination. Previous studies have suggested that clear images allow orientation to be determined, although it could be augmented with multiple pictures and the ability to zoom.[26] Our post-examination questionnaire found a slight increase in positive attitudes toward the online event. A greater proportion of participants reported that the event was "more enjoyable" than an in-person event in the post-examination questionnaire. A few even said it to be "significantly more enjoyable." This may suggest that online teaching/assessment has the potential to provide an enjoyable and engaging educational experience. Despite these modest increases in positive attitudes, 50% of participants still reported that the online format was "less enjoyable" or "significantly less enjoyable."

Fifty-five percent of participants felt the online format was "less" or "much less stressful" than an in-person examination. This corroborates the findings from one study reporting that students displayed more positive attitudes toward online formal curriculum assessments when compared to an in-person equivalent.[27] However, several concerns unique to the online format that were a potential source of stress were raised, which may have contributed to the increase in feelings that performance was "significantly worse" because of the online format (pre: 4%; post: 13%). As previously mentioned, the potential for technical issues was a concern for participants. This has been found in previous studies, with concerns about technical problems being a significant source of student anxiety surrounding online examinations.[25,28] This highlights the need for clear protocols to manage technical issues in online examinations to mitigate student anxiety.[25]

Recent data published during the COVID-19 pandemic suggests that students thought online teaching and learning experiences lacked interaction and opportunities for collaboration.[24,29] Moreover, it has been widely reported that students do not deem online substitutive teaching methods comparable in preference to face-to-face sessions,[30–32] which is consistent with the findings from our pre-examination questionnaire. Students valued the networking opportunities provided by in-person events. Online events have great potential to enable large-scale events for delegates worldwide without the travel and logistical difficulties of an in-person event. However, to make the events more appealing to students, future events must consider how a community of delegates can be created to allow socialization and networking, as these are vital components of the experience.

Students have also previously reported they were much more likely to get distracted when working at home, resulting in difficulties with time management.[11] Thus, it could be argued that the student experience with online learning was not comparable to more traditional pre-pandemic education in this regard. Delineating the relationship between student perceptions and

their subsequent performance may determine whether such teaching methods warrant continued use.

Findings from the current study suggest that educators may begin to take reassurance that online neuroanatomy teaching during the pandemic, particularly within the neuroradiological context, might have been an effective method of sustaining a high standard of anatomical education. This study has demonstrated that the performance of NUNC 2021 participants did not vary based on the proportion of online teaching they had received during the previous 12 months. Additionally, their performance on a select number of identical neuroradiology questions was equitable to the 2017 in-person cohort. However, the positive findings from our performance data are offset by the drawbacks of the student experience. Moving forward, the authors believe that a hybrid approach to teaching is likely to be the best way to combine the technological advances we have seen in education during the pandemic and the numerous benefits of traditional teaching methods.

Limitations

Our neuroanatomy examination attracts a cohort of self-selecting, highly motivated students who are passionate about neuroanatomy. Therefore, it is likely that the performance of study participants may not be fully representative of the wider cohort of medical students who studied during the COVID-19 pandemic. Indeed, it has been suggested that adaptive blended learning has been very effective for high-performing medical students.[3] Further investigations are required to assess the impact of online teaching on academic performance in a wider cohort of students.

Our questionnaires did not collect detailed demographic data about the participants or their specific year of study. Those in the early pre-clinical years of their medical education are likely to have experienced more online teaching as traditional lecturesand seminar-based sessions, as these constitute a more significant proportion of their curriculum. Examination performance for these participants may have been affected by the level of online teaching to a greater extent than their peers in older years. However, we were able to eliminate those who had not had anatomy teaching that year when comparing the examination performance with the proportion of online teaching participants experienced in the last 12 months from our analyses to account for this. This excluded those in the later clinical years.

We singled out results from the neuroradiology questions in the spotter examination to compare performance between the 2017 and 2021 events. We assumed that any variation in these two groups would represent the impact of a greater proportion of online teaching in the 2021 cohort. As these are two different cohorts, the lack of variation in performance we found between them may not be related to the newer teaching formats being non-inferior but instead due to differences in the two groups.

Practice points

Our results demonstrate that while it comes with challenges, online teaching in neuroanatomy, particularly neuroradiology, can be an effective method of education for a group of highly motivated medical students. We believe that three key practice points can be taken from our study and applied to neuroanatomy teaching moving forward:

1. Online teaching can be an effective form of education and has many benefits. A hybrid approach to teaching, combining both online and in-person teaching, may help to modernize neuroanatomy education.
2. Online teaching lacks the social and networking component provided by in-person teaching and needs to be cognizant of intentionally creating networking and communication experiences.
3. The introduction of new education and assessment methods is likely to cause a degree of anxiety in students. Simple measures, such as clear protocol communication for resolving technical issues, are essential to mitigate student concerns.

CONCLUSION

Online remote teaching has been used universally as a substitute for face-to-face teaching during the COVID-19 pandemic. In the context of clinical neuroanatomy and neuroradiology, this investigation has demonstrated the potential of this approach to be a suitable and efficacious method of anatomy education for medical students. However, online teaching appears to have several drawbacks with regard to the student experience. As such, the implementation of changes that address these issues are essential if online approaches are to be used successfully alongside traditional in-person teaching modalities.

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CONFLICT OF INTEREST STATEMENT

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

DATA AVAILABILITY STATEMENT

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Faculty of Medicine Ethics Committee, University of Southampton, before the commencement of the study. This approval was filed under Ethics and Research Governance Online ID 9351. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

CONSENT FOR PUBLICATION

Not applicable. No participant-identifiable data is included in this manuscript. All data is anonymized.

PREVIOUS PRESENTATIONS

Elements of this work were previously delivered as an oral podium presentation by Calvin D. De Louche at the Anatomical Society Winter Meeting, University of Nottingham, UK in April 2023.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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