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Association between medical students' prior experiences and perceptions of formal online education developed in response to COVID-19: a cross-sectional study in China

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ABSTRACT

Objectives (1) Understanding the characteristics of online learning experiences of Chinese undergraduate medical students; (2) Investigating students' perceptions of ongoing online education developed in response to COVID-19 and (3) Exploring how prior online learning experiences are associated with students' perceptions.

Design Students' familiarity with online learning modes and corresponding perceived usefulness (PU) according to their previous experiences were investigated using an online survey. The survey also collected data on students' perceptions through their evaluation of and satisfaction with current online learning.

Setting In response to the educational challenges created by COVID-19, medical schools in China have adopted formal online courses for students.

Participants The questionnaire was sent to 225 329 students, of whom 52.38% (118 080/225 329) replied, with valid data available for 44.18% (99 559/225 329).

Methods Pearson correlations and t-tests were used to examine the relationship between familiarity and PU. Multiple linear regression and logistic regression analyses were used to determine the impact of prior learning experiences and its interactions with gender, area, learning phase and academic performance on students' perceptions.

Results Students' PU had a significant positive correlation with their familiarity with online learning modes (p<0.01). Students' evaluation of and satisfaction with their current online education were positively associated with their familiarity (β=0.46, 95% CI 0.45 to 0.48, p<0.01; OR 1.14, 95% CI 1.13 to 1.14, p<0.01) with and PU (β=3.11, 95% CI 2.92 to 3.30, p<0.01; OR 2.55, 95% CI 2.37 to 2.75, p<0.01) of online learning. Moreover, the higher the students' learning phases, the lower the associations between PU and students' evaluation of and satisfaction with ongoing online education.

Conclusions Medical students in China have experiences with various online learning modes. Prior learning experiences are positively associated with students' evaluation of and satisfaction with current online education. Higher learning phases, in which clinical practices are crucial, and high academic performance led to lower evaluation and satisfaction scores.

Strengths and limitations of this study

► A multisite, cross-sectional survey study was carried out across 90 medical schools in China with a large valid sample size (99 559).
► Descriptive statistics were used to offer first-hand empirical evidence demonstrating undergraduate medical students' perception of a large scale formal online education during COVID-19 period.
► A comprehensive statistical analysis was performed to provide an initial test of the influence of prior learning experiences on students' current perception and its interaction with gender, area, learning phase and academic performance.
► Although the medical students reported their prior online learning experience, the objective evidence of their previous exposure to and experiences with the online materials was not provided.
► The lack of investigating teaching modes adopted in the online courses for medical students and potential self-report bias in the survey may affect the results.

INTRODUCTION

Driven by continuous emergence of new technologies and the widespread adoption of the internet, online education has become a global phenomenon.[1] Online education, a subset of distance education, refers to pedagogical models that use information technologies to deliver instruction to learners in remote locations.[2] The development of information technologies has led to the development of a range of flexible online learning modes, such as massive open online courses (MOOCs) and small private online courses (SPOCs).[3] Online learning allows students to interact with learning resources, instructors and other students via laptops or mobile devices.[4] Students in higher education appreciate online learning for its potential to clearly and coherently structure learning

materials, to distribute information and to support self-regulated learning.[5] In general, there are two kinds of online courses: asynchronous online courses and synchronous online courses.[4] Both have been found to be at least as satisfying as traditional face-to-face instruction.[6 7] Blended learning, which combines offline and online activities, has been widely used in higher education,[8] for example, the application of flipped classrooms in medical education.[9]

In online education, students' learning experiences are primarily shaped by their interactions on online learning platforms with course content, other students and educators.[10] Accordingly, students' former experiences determines their familiarity with online learning modes, including the tools or platforms used for information transmission and interpersonal interaction.[11] Concerning students' completion in higher online education, success predictors include learning strategies, academic self-efficacy, academic goals and intentions, institutional or college adjustment, employment, supportive network and faculty–student interaction.[12 13] Compared with students' completion of online learning, students' perceptions of online learning have received less attention.[14] However, a significant direct effect has been found between students' satisfaction and retention of higher online learning.[15] Moreover, academic performance has been found to have a negative impact on students' evaluations of online courses, that is, students with a higher academic performance tend to yield a low level of evaluations.[7] Therefore, there is a need to pay more attention to students' perceptions of online learning to explore more details about the effectiveness of online education from the subjective view of students.

In addition to academic support from educators and the quality of instructional designs, students' intentions and attitudes towards online education play important roles in retention rates and final achievements in online learning.[3 10 15] Over the last three decades, the relationship between individual perceptions and actual use of new technologies, which is related to students' retention and achievements of online learning, has gained lots of attention especially as outlined in the technology acceptance model (TAM) of Davis et al.[16] According to TAM,[16] perceived usefulness (PU) and perceived ease of use are the two main factors that influence behavioural intentions towards new technologies, and they affect the actual use of the technologies. Based on TAM models, Venkatesh et al[17] found that gender, age, experiences and voluntariness are moderators of use intention of technologies. In assessing the above models, Choudhury and Pattnaik[18] reviewed the factors that were critical to success in online education and found that learners' perceived ease of use of technologies and PU of the online course determined learners' intention and, subsequently, the effectiveness of online learning.

With the integration of information technologies into undergraduate, graduate and continuing education, innovations in online learning have laid the foundation for a revolution in medical education.[2 19] Online education can enhance medical students' learning experience, support development, overcome geographical limitations, ease time constraints and offer greater flexibility.[20] However, there remain significant barriers to the development and implementation of online learning programmes for medical students and postgraduate trainees, including time constraints, poor technical skills, inadequate infrastructure, absence of institutional strategies and support, unsuitability for all disciplines, negative attitudes and negative perceptions.[13 21] Undergraduate medical students are less self-motivated than postgraduates and professional trainees, as they are always required to meet the criteria of their university's teaching committee.[22] Thus, greater attention to this group is warranted. For undergraduate medical students, online learning has been shown to be at least as effective as offline learning in terms of both theoretical knowledge and skills.[23] However, haptic awareness and immediate feedback from instructors are still lacking in online learning, which is especially important when students are learning complex practical skills.[24] As a rule, students in clinical medical education and clerkships need more experimental and clinical practice than those in general education and basic medical education.[25] From this point of view, although online learning appears to be at least as effective as face-to-face instruction, students still tend to treat online learning as a complement to traditional teaching methods.[2]

At the start of 2020, COVID-19, originating from Wuhan in Hubei province, began to spread throughout China. The Ministry of Education of the People's Republic of China banned most face-to-face instruction and launched a policy called 'Disrupted classes, undisrupted learning' to provide online learning to over 270 million students. Most students in China, including undergraduate medical students, attend formal online courses from their own homes. Given the variability in networks available to students taking online courses at home, we need to take students' home locations into consideration. In addition, students from lower socioeconomic backgrounds continue to be underrepresented in medical training.[26] Similarly, in China, the proportion of students from poor socioeconomic backgrounds in high reputation medical schools are lower than students from higher socioeconomic backgrounds.[27] Students living in more socially disadvantaged areas are more likely to have lower self-efficacy and learning performance in education, including medical education.[28 29] Thus, the Chinese government and medical schools are now confronted with novel challenges in the implementation of high-quality medical education, as they must adapt to a rapidly changing world and simultaneously meet the needs presented by these special circumstances.

In these circumstances, students' perceptions of online courses could be a crucial predictor of the ultimate effectiveness of online learning and could thus have implications for improving ongoing online courses. However,

subjective factors, especially the students' prior online experience, have received little attention in research on formal online medical education. Students' perceptions of ongoing online education, such as their evaluations of and satisfaction with online courses and platforms, might be influenced by their former online learning experience, especially at the beginning of the formal online education. Therefore, the main purpose of this study was to identify how undergraduate medical students' prior learning experiences are related to their perceptions of their current online courses. To explore this issue, we conducted a survey of Chinese clinical medical students at the beginning of the 2020 spring semester. We hypothesised that students' online learning experiences are related to their perceptions the online courses taken during the COVID-19 period. The three research questions were as follows.

1. What are the characteristics of the online learning experiences of Chinese undergraduate medical students?
2. How do students perceive ongoing online education?
3. What is the relationship between students' prior online learning experiences and their perceptions of online education?

METHODS
Context
A multisite, cross-sectional survey study was carried out across 90 medical schools in China with the support of the National Centre for Health Professionals Education Development. Due to the COVID-19 outbreak, the start times of the 2020 spring semesters of the medical schools that participated in the survey varied. All the involved medical schools voluntarily participated in the survey, which was administered via an electronic questionnaire 1 week after the implementation of online courses. All the selected medical schools should have complete online teaching plans and the schools involved should be nationally representative according to the regional distribution and the type of medical schools. There are a total of 225 329 clinical medicine undergraduates in the 90 medical schools. From 21 February to 14 March 2020 period, 118 030 questionnaires were collected, and the response rate was 52.38%. We cleaned the collected data to guarantee its quality as measured by response time, medical school name and start time of online education. After data cleaning, the sample consisted of 99 559 students from 90 medical schools, with the sample efficiency of 84.35%. The final sample accounted for 24.36% of all Chinese clinical medicine undergraduates (408 764 in total). Among all the Chinese clinical medicine undergraduates, 38.89%, 35.84% and 25.27% came from the eastern, central and western regions of China. In China, there are two kinds of medical schools, namely, medical school as a free-standing health professional institution and medical school as a comprehensive university.[30] About 61.64% of the Chinese clinical medicine undergraduates are studying in comprehensive universities and the rest

38.36% are studying in free-standing health professional institution.[27] In this study, the percentages of samples that came from the eastern, central and western regions were 38.30% (38 134), 41.52% (41 341) and 20.17% (20 084), respectively; the percentages of samples came from free-standing health professional institution and comprehensive universities were 59.24% (58 982) and 40.67% (40 577), respectively. Thus, the regional distribution and the type of medical schools in the sample has a certain representativeness of the whole China.

Measures
Prior online learning experiences
Based on TAM models and empirical research,[16–18] we investigated two aspects of students' online learning experience: familiarity with and PU of online learning. Familiarity refers to students' existing experiences about online learning. PU refers to the degree to which a student believes that online education would enhance his or her learning performance according to their existing experiences. First, we collected data on students' familiarity with different online learning modes. We adopted a detailed classification of learning modes according to medical schools' actual online teaching arrangements rather than using a simple asynchronous/synchronous classification.[4] There were six modes of online learning in the survey: (1) live broadcast courses; (2) MOOCs; (3) SPOCs; (4) recorded broadcast courses; (5) online education platforms (eg, Blackboard) and (6) blended learning, which combines online and offline learning (eg, flipped classroom). The six items constituted a 3-point scale (unfamiliar, neutral and familiar) were used to determine students' familiarity with online learning. Meanwhile, we used another 3-point question to investigate students' PU of these modes according to their previous experiences (useless, neutral and useful).

Perceptions of ongoing online education
To explore students' perceptions of their ongoing online education, we collected data on their evaluation of and satisfaction with their current courses. Based on prior studies,[10–12 15] we asked the medical students to evaluate ongoing online education in terms of teaching preparation, instructors' responsibilities, platform service, teaching arrangements, learning assessment, learning-related interaction and learning resources. Besides, an item was used to ask students' overall satisfaction with ongoing online education. The eight items related to students' perceptions of online education were rated using 5-point Likert scales (1=strongly disagree; 2=disagree; 3=neutral; 4=agree; 5=strongly agree).

Demographic information
The survey also collected demographic information, including gender, the area of their home location (rural or urban), learning phase and academic performance. In China, there are four learning phases in undergraduate medical students training[25]: general education, basic

medical education, clinical medical education and clerkship rotation. In the general education phase, students learn diverse skills that every person should master to lead a productive life and be a knowledgeable citizen. In basic medical education, they learn knowledge related to their own major and must meet certain requirements. Students in clinical medical education study and practice medicine in their courses. As a crucial stage in medical schools, clerkship rotation in a teaching hospital is a bridge to connect medical theory and clinical practice. The survey also asked students to report their academic performance based on their completed undergraduate study, namely which performance group they were in (top 10%, 10%–25%, 25%–50%, 50%–75% and bottom 25%). All question items involved in this study are listed in the online supplemental file.

Statistical analysis

Descriptive statistics were used to depict characteristics of medical students, including gender area, learning phase and academic performance. Students' familiarity with and PU of online learning were the two main independent variables. Familiarity with the six learning modes was measured with six items, that were each given a score ranging from 0 to 2 (unfamiliar=0, neutral=1, familiar=2). Pearson correlations were used to examine the correlations between familiarity with different online learning modes and PU of online learning. The overall familiarity with online learning, a continuous variable, was calculated by adding the scores of the six items. Additionally, because of the low percentage of 'useless' responses in PU, we merged 'useless' and 'general' into a 'not-so-useful' category, with a value of 0, and set the value of 'useful' as 1. An independent sample t-test was used to explore whether students' overall familiarity with online learning varied with different PU groups. As a measure of effect size,[31] Cohen's d was calculated (with 0.2 indicating a small effect, 0.5 a medium effect and 0.8 a large effect).

Evaluation and satisfaction were the two dependent variables related to students' perceptions of online education. The means and SD of the eight perception items were calculated. A composite score was generated for the overall evaluation of online education for each student by summing the Likert responses of the seven evaluation items. Cronbach's α was used to assess the internal consistency of the seven items (desirable values of >0.70 to 0.80).[32]

Multiple linear regression and logistic regression were used to analyse the impact of prior learning experiences on perceptions of the ongoing online education. Gender, area, learning phase and academic performance, which represented students' demographic information, were covariates in the regressions. For the subsequent regression analysis, the learning phase was set as a categorical variable (general education=1, basic medical education=2, clinical medical education=3, clerkship rotation=4), as was academic performance (top 10%=1, 10%–25%=2, 25%–50%=3, 50%–75%=4, bottom 25%=5). We included

dummy variables for both the learning phases and academic performance in the logistic regression. Coefficients (β) or ORs, 95% CIs, and p values were calculated for the corresponding results in the logistic regression. In addition, by setting the interaction items in the regression models, we further defined the influence of learning experiences on different groups of students. Specifically, based on the degree of correlation between PU and familiarity and the β or OR values, we added interaction terms between PU and the covariates for students' evaluation of and satisfaction with online education in regression analysis. To control for the differences between institutions and the missing variables at the institution level, we used institution fixed effects in all models.

The statistical analysis was performed using STATA V.14 with p<0.01 defined as statistically significant.

Patient and public involvement

No patient involved.

RESULTS
Participants

In total, 118 030 medical students responded to the survey (response rate of 52.38%), and the final sample consisted of 99 559 students (sample efficiency of 84.35%). The characteristics of the study participants are noted in table 1. The sample included 61.08% female students and 38.92% male students. Regarding the home location, 41.72% of the students came from rural areas, and the other 58.28% were from urban areas. The students were distributed across the learning phases as follows: general education (14.84%), basic medical education (43.22%), clinical medical education (31.01%) and clerkship rotation (10.94%). According to the self-reported results, 14.2% of the students thought they ranked in the top 10% and 6.35% students regarded themselves as the bottom 10%. The percentages of 10%–25%, 25%–50% and 50%–70% were 38.30%, 41.52% and 20.17%, respectively.

Prior online learning experiences

Students' familiarity with different online learning modes and their PU are shown in table 2. More than 70% of the medical students had prior learning experiences with most of the online learning modes. Students were most familiar with recorded broadcast courses (36.84%) and MOOCs (35.00%), whereas more than half were unfamiliar with SPOCs (52.07%). As shown in table 2, 31.28% of students agreed that online learning could benefit their study based on their prior learning experience, but 64.97% were not satisfied with the effectiveness of online learning, and 3.75% regarded online learning as useless.

Table 3 shows the correlations between the seven variables. Considering multiple correlations analyses performed may cause the problem of multiple comparison,[33] we made the Bonferroni correction. Familiarity with all six online learning modes had significant

Table 1 Sample distribution and summary statistics for participants (N=99 559)

	Participants, n (%)	Nationally, %
Gender		
Female	60 815 (61.08)	54.96*
Male	38 744 (38.92)	45.04*
Area (home location)		
Rural	41 538 (41.72)	34.73*
Urban	58 021 (58.28)	65.27*
Learning phase		
General education	14 774 (14.84)	–
Basic medical education	43 026 (43.22)	–
Clinical medical education	30 869 (31.01)	–
Clerkship rotation	10 890 (10.94)	–
Academic performance		
Top 10%	14 138 (14.20)	–
10%–25%	22 302 (22.40)	–
25%–50%	35 687 (35.85)	–
50%–75%	21 112 (21.21)	–
Bottom 25%	6320 (6.35)	–

*Data source: China Medical Student Survey in 2019, a survey with nationally representativeness, conducted by National Centre for Health Professionals Education Development, authorised by Ministry of Education and National Health Commission.[27]

correlations with PU. Overall familiarity (mean=5.70) was calculated by summing the scores of the six familiarity items. For PU, we merged 'useless' and 'neutral' into 'not-so-useful' (68.72%). The values of 'useful' and 'not-so-useful' were set to 1 and 0, respectively. As shown in table 3, in terms of students' familiarity with online learning under different levels of PU, there was a significant difference between the 'useful' and 'not-so-useful' subgroups (mean difference=1.58, p<0.01, Cohen's d=0.53). Students who agreed that online modes were useful were more familiar with online learning (mean=6.79, 95% CI 6.76 to 6.82), whereas those students who perceived online learning as not so useful were less familiar with online modes (mean=5.21, 95% CI 5.18 to 5.23).

Perceptions of ongoing online education
To investigate medical students' perceptions of ongoing online education, we used eight items that were measured with a 5-point Likert scale (see table 4). The first seven items were related to students' evaluations of online education and the eighth concerned students' overall satisfaction with online education. Each perception item's mean and SD are provided in table 4.

Students evaluated instructors as highly responsible (mean=4.21>4) but considered the support and service of platforms to be insufficient (mean=3.72). The Cronbach's α of the seven items was 0.95, indicating a high internal consistency for the composite evaluation score. We used the composite evaluation as a continuous variable in the following regression analysis. As is shown in table 4, there was a moderate level of satisfaction with the ongoing online education (mean=3.82). In the subsequent regression analysis, we merged 'agree' (Likert score 4) and 'strongly agree' (Likert score 5) into a single category with a value of 1 (62.09%) and merged 'strongly disagree' (Likert score 1), 'disagree' (Likert score 2) and 'neutral' (Likert score 3) into a single category with a value of 0 (37.91%).

Impact of prior experiences on perceptions of online education
In the regression (see table 5), we found that both perceptions of usefulness (β=3.11; 95% CI 2.92 to 3.30; p<0.01) and high familiarity (β=0.46; 95% CI 0.45 to 0.58; p<0.01) had significant associations with a positive evaluation of ongoing online education. In addition, the interaction between PU and familiarity was significantly associated with students' evaluation of their ongoing online education (β=−0.08; 95% CI −0.10 to 0.05; p<0.01). It was found that both positive perceptions of usefulness (OR 2.55; 95% CI 2.37 to 2.75; p<0.01) and high familiarity (OR 1.14; 95% CI 1.13 to 1.14; p<0.01) are significantly

Table 2 Former experiences of online learning (N=99 559, n (%))

Familiarity with online learning modes	Unfamiliar	Neutral	Familiar
1. Live broadcast courses	26 063 (26.18)	47 294 (47.50)	26 202 (26.32)
2. MOOCs	22 026 (22.12)	42 692 (42.88)	34 841 (35.00)
3. SPOCs	51 844 (52.07)	35 918 (36.08)	11 797 (11.85)
4. Recorded broadcast courses	17 842 (17.92)	45 035 (45.23)	36 682 (36.84)
5. Online education platforms	35 517 (35.67)	43 975 (44.17)	20 067 (20.16)
6. Blended learning	28 555 (28.68)	48 402 (48.62)	22 602 (22.70)
Perceived usefulness	**Useless**	**Neutral**	**Useful**
7. According to previous experience, how useful is online learning to you?	3730 (3.75)	64 691 (64.97)	31 138 (31.28)

MOOCs, massive open online courses; SPOCs, small private online courses.

Table 3 Correlations of familiarity and PU (n=99 559)

Variables	−1	−2	−3	−4	−5	−6	−7
1. Live broadcast course	1						
2. MOOCs	0.325*	1					
3. SPOCs	0.336*	0.432*	1				
4. Recorded broadcast course	0.435*	0.339*	0.294*	1			
5. Online education platform	0.382*	0.298*	0.433*	0.410*	1		
6. Blended learning	0.350*	0.357*	0.413*	0.402*	0.497*	1	
7. PU	0.231*	0.192*	0.124*	0.242*	0.172*	0.169*	1

Familiarity under different PU	Mean	95% CI			Diff	T-test	P value	Cohen's d
Useful (31.28%)	6.79	6.76	6.82		1.58	79.6	0	0.53
Not-so-useful (68.72%)	5.21	5.18	5.23					

*Shows significance at the 0.01 level.

Diff, difference; MOOCs, massive open online courses; PU, perceived usefulness; SPOCs, small private online courses.

associated with increased satisfaction with their ongoing online education, but the interaction of PU and familiarity had no significant association with students' satisfaction. Male students had lower evaluations of (β=−0.63; 95% CI −0.70 to 0.55; p<0.01) and satisfaction with (OR 0.88; 95% CI 0.85 to 0.90; p<0.01) their ongoing online education than female students. Students from urban areas gave significantly high evaluations (β=0.17; 95% CI 0.10 to 0.25; p<0.01) and satisfaction (OR 1.08; 95% CI 1.05 to 1.11; p<0.01) scores than students from rural areas.

The regression results showed that students in higher education phases gave lower evaluation and satisfaction scores for their online education (table 5). Students in basic medical education (β=−0.52; 95% CI −0.64 to 0.41; p<0.01), clinical medical education (β=−1.36; 95% CI −1.48 to 1.24; p<0.01) and clerkship rotation (β=−2.10; 95% CI −2.26 to 1.95; p<0.01) gave lower evaluations of online education than those in general education (table 5). Similarly, students in basic medical education (OR 0.86; 95% CI 0.83 to 0.90; p<0.01), clinical medical education (OR 0.66; 95% CI 0.63 to 0.69; p<0.01) and clerkship rotation (OR 0.58; 95% CI 0.54 to 0.61; p<0.01)

expressed lower satisfaction than medical students in general education. In table 5, it can be found that the higher learning phase students are in, the lower evaluation and satisfaction the students had. Our analysis of the association between academic performance and evaluation found that students ranked 10%–25% (β=0.24; 95% CI 0.12 to 0.36; p<0.01), 25%–50% (β=0.41; 95% CI 0.30 to 0.53; p<0.01), 50%–75% (β=0.55; 95% CI 0.42 to 0.67; p<0.01) and in the bottom 25% (β=0.33; 95% CI 0.15 to 0.50; p<0.01) gave significantly higher evaluations of their ongoing online education than students in the top 10% of group. In contrast, students ranked 10%–25% (OR 1.12; 95% CI 1.07 to 1.17; p<0.01), 25%–50% (OR 1.18; 95% CI 1.12 to 1.23; p<0.01) and 50%–75% (OR 1.07; 95% CI 1.00 to 1.14; p<0.01) were significantly more satisfied with their online education than the students in the top 10% group.

We also explored the influence of prior learning experiences on students in different groups by adding interaction items with covariates. The regression results with the interactions are shown in table 5. Only the interaction of PU and learning phases was significantly associated with students' perceptions of online education. The

Table 4 Perception of ongoing online education (N=99 559)

Perception	Items	Mean	SD
Evaluation	1. The online education is well prepared	3.93	1.04
	2. The instructors take responsibility for students' learning	4.21	0.93
	3. The platform provides good support and service	3.72	1.14
	4. Teaching arrangements are clear and reasonable	3.96	1.03
	5. Assessment and evaluation of learning are clear	3.87	1.05
	6. Interaction, feedback and question answering are effective	3.79	1.07
	7. Online learning resources are sufficiently provided	3.90	1.03
Satisfaction	8. Overall satisfaction with ongoing online education	3.82	1.02

Possible responses: 1=strongly disagree; 2=disagree; 3=neutral; 4=agree; 5=strongly agree.

Table 5 Regression results (N=99 559)*

	Evaluation†				Satisfaction‡			
	β	P value	95% CI		OR	P value	95% CI	
Regression results								
PU	3.11	<0.01	2.92	3.3	2.55	<0.01	2.37	2.75
Familiarity	0.46	<0.01	0.45	0.48	1.14	<0.01	1.13	1.14
PU×Familiarity×	−0.08	<0.01	−0.1	−0.05	1	0.76	0.99	1.01
Male	−0.63	<0.01	−0.7	−0.55	0.88	<0.01	0.85	0.9
Urban	0.17	<0.01	0.1	0.25	1.08	<0.01	1.05	1.11
Learning phase (Base: General education)								
Basic med educ	−0.52	<0.01	−0.64	−0.41	0.86	<0.01	0.83	0.9
Clinical med educ	−1.36	<0.01	−1.48	−1.24	0.66	<0.01	0.63	0.69
Clerkship rotation	−2.1	<0.01	−2.26	−1.95	0.58	<0.01	0.54	0.61
Academic performance (Base: top 10%)								
10%–25%	0.24	<0.01	0.12	0.36	1.12	<0.01	1.07	1.17
25%–50%	0.41	<0.01	0.3	0.53	1.14	<0.01	1.09	1.19
50%–75%	0.55	<0.01	0.42	0.67	1.18	<0.01	1.12	1.23
Bottom 25%	0.33	<0.01	0.15	0.5	1.07	0.05	1	1.14
	R-squared=0.18 Prob >F =0.00				Pseudo r-squared=0.12 Prob >F =0.00			
Regression results of interaction with covariates								
PU	0.18	<0.01	0.16	0.21	3.43	<0.01	2.96	3.97
Familiarity	0.02	<0.01	0.02	0.02	1.14	<0.01	1.13	1.15
PU×Familiarity	0.01	0.05	0.01	0.01	1	0.82	0.99	1.01
Male	−0.03	<0.01	−0.03	−0.02	0.87	<0.01	0.84	0.9
PU×Male	-0	0.84	−0.01	0.01	1.04	0.29	0.97	1.11
Urban	0.02	<0.01	0.01	0.02	1.08	<0.01	1.05	1.12
PU×Urban	0.001	0.85	−0.01	0.01	0.97	0.36	0.91	1.04
Learning phase (Base: General education)								
Basic med educ	−0.03	<0.01	−0.04	−0.02	0.88	<0.01	0.84	0.92
Clinical med educ	−0.06	<0.01	−0.07	−0.05	0.71	<0.01	0.68	0.75
Clerkship rotation	−0.08	<0.01	−0.1	−0.07	0.69	<0.01	0.64	0.73
PU×Basic med educ	−0.02	0.03	−0.04	0	0.88	0.02	0.78	0.98
PU×Clinical med educ	−0.07	<0.01	−0.09	−0.05	0.68	<0.01	0.61	0.76
PU×Clerkship rotation	−0.1	<0.01	−0.12	−0.08	0.55	<0.01	0.48	0.62
Academic performance (Base: top 10%)								
10%–25%	0.01	0.21	0	0.02	1.13	<0.01	1.07	1.19
25%–50%	0.01	0.05	0	0.02	1.14	<0.01	1.09	1.2
50%–75%	0.02	<0.01	0.01	0.03	1.16	<0.01	1.1	1.23
Bottom 25%	0.02	0.03	0	0.03	1.05	0.2	0.98	1.13
Pu×10%–25%	−0.01	0.37	−0.03	0.01	0.97	0.62	0.87	1.09
PU×25%–50%	0	0.69	−0.02	0.01	1	1	0.9	1.11
PU×50%–75%	0.01	0.39	−0.01	0.03	1.05	0.36	0.94	1.18
PU×Bottom 25%	0.02	0.28	−0.01	0.05	1.06	0.46	0.91	1.06
	R-squared=0.14 Prob >F=0.00				Pseudo r-squared=0.12 Prob >F =0.00			

*Medical school fixed effects.
†Multiple linear regressions were used.
‡Logistic regression using the satisfaction of online education, dichotomised between Likert score 4 and Likert score 3.
PU, perceived usefulness.

association of PU with the evaluations of students in clinical medical education (β=−0.07; 95% CI −0.09 to 0.05; p<0.01) and clerkship rotation (β=−0.10; 95% CI −0.12 to 0.08; p<0.01) were significantly lower than that the effect of PU on general education. Compared with students in general education, the association between PU and the satisfaction of students in clinical medical education (OR 0.68; 95% CI 0.61 to 0.76; p<0.01) and clerkship rotation (OR 0.55; 95% CI 0.48 to 0.62; p<0.01) were significantly lower. According to the β and OR values, in general, the higher the students' education phases, the lower the association between PU and their perceptions of online education. In addition, as is shown in table 5, no other interactions had a significant association with students' evaluation of or satisfaction with their online education.

DISCUSSION

In this study, we explore how medical students' prior experiences with online learning are related to perceptions of formal online medical education. First, our study provides valuable insights into the characteristics of Chinese medical students' online learning experiences. Among the six online learning modes, the medical students in this study are most familiar with recorded broadcast courses and MOOCs and least familiar with live broadcast courses and online education platforms. This indicates that medical students in China are more frequently exposed to asynchronous online courses in which instructional materials are fully prepared in advance. In such courses, students can watch and playback the teaching videos anytime, which reflects self-regulated learning in medical education.[34] Medical students in China have fewer experiences with live broadcast courses and blended learning. This suggests that instructors in formal medical education prefer traditional teaching methods, such as face-to-face lectures and experimental teaching. Although online education has attracted global attention,[1] it is still not widespread in formal medical education in China. In addition, studies have shown that students' control of the digital learning processes affects the success of a blended learning environment.[8] This may explain why instructional designers tend to adopt approaches in which teaching efficiency can be mainly controlled by instructors. In addition, more than half of the students in this study are unfamiliar with SPOCs. Actually, SPOCs in classroom settings is one of the methods of blended learning.[3] Problems in the design, creation and implementation phases, such as pedagogical understanding and practical considerations of such novel modes, could be barriers to their adoption and to the effectiveness of online learning.[3 21] Therefore, to continuously and effectively improve online medical education, it is necessary to offer more support and training in both the instructional strategies of teachers and the self-management skills of learners.

In addition, according to prior online learning experience, students evaluated the usefulness of online education for their learning. A majority of the students think that online learning is not very useful (68.72%), which shows that previous online courses did not provide satisfactory experiences for most medical students. Furthermore, students' perceptions of the usefulness of online education is significantly associated with their familiarity with all the six online learning modes. More specifically, the students who think that online learning is useful are more familiar with all of the online learning modes. In other words, the more online learning experiences students have, the higher evaluation they have on online learning. These findings are not only consistent with the correlation between experiences and use intention proposed in previous research,[17 18] but also provide more generalisable conclusions about various online learning modes.

In this study, we offer first-hand empirical evidence demonstrating how such a large scale formal online education provided for undergraduate medical students carried out. During online education, medical students generally give high appraisals to the instructors in online education but feel that the platforms are inadequate. In addition, there remains room for improvement in teaching preparation and arrangements, learning resources and learning-related interactions. Interactions such as feedback, question answering and technical support are important factors for the engagement of students during online learning.[12 35] Therefore, more attention needs to be paid to improving technical support for platforms and academic-related interactions between instructors and students. Meanwhile, stakeholders (eg, teaching administrators, instructors and material designers) should attach importance to all the aspects of instructional design and learning resource development. Overall, the students engaged in online medical education have a moderate level of satisfaction. This might be influenced by the time at which we conducted the questionnaire survey, namely, the first week of these online courses. There is need for further exploration of students' subsequent evaluation of the courses.

Using logistic regression, this study reveals a positive association between prior online learning experiences and perceptions of current online education; that is, students who are more familiar with online modes or who perceive online learning as useful tend to express high evaluations and satisfaction with their current online courses. In addition, rural students are less satisfied than urban students with online learning. A supportive network is one of the predictors of success for students' completion of higher online education.[12] However, in rural areas, poor network quality might affect learning processes when students are attending these courses from home. Hence, to promote online medical education, infrastructure construction (eg, network, hardware and media resources) in rural areas requires attention. It is worth noting that male students gave lower evaluations and expressed less satisfaction with online learning than female students. Although gender has not been viewed as

a factor in learning effectiveness in most studies,[3 10 15] this finding could draw attention to the gender differences in online medical education from other perspectives; for instance, the gender difference in major choices and the online learning adaptation for different majors. Interestingly, our study found that the higher the self-reported academic performance, the lower the evaluation of the ongoing online education. This finding is in line with the study by Ebner and Gegenfurtner,[7] which showed a negative association between learning performance and satisfaction with online courses. This may be because it is difficult for online courses to meet all of students' personalised learning needs,[13] especially those who have high self-evaluations. Thus, instructors and teaching managers need to provide extra support and resources for individual learning when conducting formal online courses.

With respect to learning phases in medical education, students in higher education phases have lower evaluations of and satisfaction with online education. In the clinical medical education and clerkship rotation phases, there is a greater need for experimental and clinical practices than in the general education and basic medical education phases.[25] In online courses, the lack of haptic awareness and practical instruction could hinder the learning of complex practical skills. Furthermore, the interaction of PU and learning phases had a significant association with students' perception of online education. Specifically, the higher the students' learning phases, the lower the effect of PU on students' evaluation and satisfaction scores, indicating that in higher education phases, such as the clinical medical education and clerkship rotation phases, the impact of PU on students' attitudes towards online learning might be weakened by actual practice needs. To meet these challenges in online situations, there is a need to develop more suitable virtual clinical experimental systems for medical students. Fortunately, researchers have explored the potential of virtual learning systems for undergraduate medical students.[13 36] With respect to practical instruction, there is a need to further improve the development and application of virtual simulation platforms and the corresponding instructional training. Furthermore, for medical students in higher learning phases, blended learning modes based on online learning platforms (eg, Moodle) and integration of virtual simulation tools whereby the students could develop practical skills and receive immediate feedback are effective ways to appeal to advanced students.[37]

Several limitations to the present study should be noted. First, it does not investigate the modes used in the ongoing online courses, which may result in an incomplete understanding of students' perception of online education. Students' perceptions of ongoing online learning can vary with the various interaction modes.[10] In addition, only one item was used to investigate students' PU and satisfaction with online learning, which may affect the reliability of the results. Potential self-report bias in the survey may also affect the results, even though it could give the perspective of students' self-evaluation. For example,

according to students' self-reported academic performance, only 6.35% of the students regarded themselves as the bottom 10%. This may be because students tend to report higher performance than actual performance or high-performance students are more likely to respond to surveys. Also, there is biased responding because the gender ratio of valid samples in this study is different with the gender ratio of the whole national medical students. Another limitation is that we do not consider other factors, such as gender differences in the selection of majors or network service in rural versus urban areas. These factors may affect the findings. In addition, we find that there are particular challenges in conducting formal training in clinical practice via the Internet. The various individual needs of medical students require more attention. In future work, we will explore how online learning modes are related to medical students' learning experiences and academic performance and develop more specific suggestions for improving formal online medical education. Moreover, in terms of institution-level differences, there is much more work that could be done in future studies.

CONCLUSION

This study provides an overall analysis of the relationship between medical students' prior online learning experiences and perceptions of their ongoing formal online education. Medical students in China have learning experiences on six different online modes, although online education is still not widespread in formal medical education. Moreover, students' evaluations of and satisfaction with their ongoing online education are positively associated with their prior online experience. Moreover, instructional design, academic-related interactions and technical support for platforms require improvement are also associated with students' perceptions of online learning. In addition, gender, area, learning phase and self-reported academic performance are all related to students' evaluations of and satisfaction with their online courses. Specifically, the ongoing medical online learning is perceived less favourably by male students and students from rural areas; students in higher learning phases in which clinical practices are important, and high self-evaluation students. In addition, the higher the students' learning phases, the lower the association between PU and their perceptions of ongoing online education. More attention needs to be paid to students' practical and individual learning needs when conducting online medical education.

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