EDUCATION

Predictors of laparoscopic simulation performance among practicing obstetrician gynecologists

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BACKGROUND: While simulation training has been established as an effective method for improving laparoscopic surgical performance in surgical residents, few studies have focused on its use for attending surgeons, particularly in obstetrics and gynecology. Surgical simulation may have a role in improving and maintaining proficiency in the operating room for practicing obstetrician gynecologists.

OBJECTIVE: We sought to determine if parameters of performance for validated laparoscopic virtual simulation tasks correlate with surgical volume and characteristics of practicing obstetricians and gynecologists.

STUDY DESIGN: All gynecologists with laparoscopic privileges (n = 347) from 5 academic medical centers in New York City were required to complete a laparoscopic surgery simulation assessment. The physicians took a presimulation survey gathering physician self-reported characteristics and then performed 3 basic skills tasks (enforced peg transfer, lifting/grasping, and cutting) on the LapSim virtual reality laparoscopic simulator (Surgical Science Ltd, Gothenburg, Sweden). The association between simulation outcome scores (time, efficiency, and errors) and self-rated clinical skills measures (self-rated laparoscopic skill score or surgical volume category) were examined with regression models.

RESULTS: The average number of laparoscopic procedures per month was a significant predictor of total time on all 3 tasks ($P = .001$ for peg transfer; $P = .041$ for lifting and grasping; $P < .001$ for cutting). Average monthly laparoscopic surgical volume was a significant predictor of 2 efficiency scores in peg transfer, and all 4 efficiency scores in cutting ($P = .001$ to $P = .015$). Surgical volume was a significant predictor of errors in lifting/grasping and cutting ($P < .001$ for both). Self-rated laparoscopic skill level was a significant predictor of total time in all 3 tasks ($P < .0001$ for peg transfer; $P = .009$ for lifting and grasping; $P < .001$ for cutting) and a significant predictor of nearly all efficiency scores and errors scores in all 3 tasks.

CONCLUSION: In addition to total time, there was at least 1 other objective performance measure that significantly correlated with surgical volume for each of the 3 tasks. Higher-volume physicians and those with fellowship training were more confident in their laparoscopic skills. By determining simulation performance as it correlates to active physician practice, further studies may help assess skill and individualize training to maintain skill levels as case volumes fluctuate.

Key words: gynecologic surgery, laparoscopy, simulation, virtual reality simulation

Introduction

High-risk fields such as aeronautics use simulation to maintain credentialing of its members. The industry has accepted the intense responsibility of pilots and uses simulation to assure that they achieve minimum standards to keep passengers safe. Surgeons have been slow to adopt this type of policy even though the risks are potentially higher and more immediate. Once credentialed, very little exists to assure the maintenance of surgical skill. This lack of quality control is only heightened in the field of gynecology where a high percentage of its members are low-volume surgeons. It is possible that surgical simulation may provide the oversight that is otherwise greatly lacking.

Simulation training has been established as an effective method for improving laparoscopic surgical performance in surgical residents.[1-6] Training and assessment virtual reality (VR) curricula in minimally invasive surgery and endoscopy are already being adopted in the general surgery culture for both novice and experienced surgeons. As a result, simulation training programs, such as the Fundamentals of Laparoscopic Surgery (FLS) endorsed by the Society of American Gastrointestinal and Endoscopic Surgeons and the American College of Surgeons, are now being incorporated into general surgery residency training programs to improve technical and nontechnical proficiency in the operating room.[7-9] However, little has been studied on the use of simulated laparoscopic surgical training in attending surgeons, particularly in obstetrics and gynecology. Although the American Board of Surgery does require that FLS be completed for board certification, potential exists to use laparoscopic simulation curricula both for Continuing Medical Education and for request or maintenance of surgical privileges at local institutions. The process to validate the use of simulation in maintenance of surgical privileges is a long one. In the current study, we sought to determine if there is an association between a variety of demographic, surgical volume, and self-perception data with simulation performance in attending gynecologic surgeons as a first step in establishing the usefulness of simulation training in a population of attending surgeons.

Materials and Methods

This study was conducted as part of a mandatory quality improvement project

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that includes 5 academic medical centers in New York City, their risk management advisors (FOJP Service Corporation), and their professional liability insurer (Hospitals Insurance Company). The goal of the initiative is to develop a method by which to assess, improve, and maintain laparoscopic skill levels for attending gynecologic laparoscopic surgeons, and ultimately develop criteria by which to use simulation in the credentialing and privileging process for gynecologic laparoscopic surgery. All gynecologists with laparoscopic privileges from each institution were required to complete a questionnaire and laparoscopic surgery simulation assessment. Within the questionnaire, consent was obtained to use their deidentified information and test results for study purposes. All physicians had the opportunity to decline use of their deidentified data for research purposes. The study was deemed exempt by the institutional review board at all 5 institutions.

The LapSim (Surgical Science Ltd, Gothenburg, Sweden) laparoscopic simulator was selected for use in this study based on its face validity and haptic feedback.[10] The physicians performed 2 introductory tasks to orient them to the LapSim simulator, followed by 3 basic skills tasks: enforced grasp peg transfer, lifting/grasping, and cutting. These specific tasks were selected because they were shown to correlate with performance in the operating room and require the use of both dominant and nondominant hands.[11] The performance measures assessed in all 3 tasks included total time (in seconds), efficiency scores (left/right instrument path length in meters, and left/right instrument angular path in degrees), and error scores (percent misses and mean drops per transfer for the enforced grasp peg transfer task; tissue damage count for the lifting/grasping task; and tissue damage count and rip failure percent for the cutting task). Of the many performance measures recorded by the VR simulator, these were shown to correlate to blinded objective assessment of parallel performance measures in operating room procedures.[12] Physicians were required to complete 2 repetitions of the skills tasks. We opted to analyze only the second-attempt data to allow for physician learning curve on a new VR system. We believed additional attempts would only introduce a repetition bias.

Each physician was guided through the assessment in a standardized manner by a simulation technician at each site. Surveys were administered both before and after the simulation protocol. The presimulation survey gathered self-reported physician characteristics including years in practice, fellowship training (maternal-fetal medicine, reproductive endocrinology and infertility, family planning, gynecologic oncology, urogynecology, or minimally invasive gynecologic surgery), and handedness (left vs right) along with self-reported clinical skills measures such as perception of laparoscopic skills (scale of 1-10, with 10 being best) and average monthly laparoscopic and/or robotic case volume category (0-1; 2-5; 6-10; ≥11). The postsimulation survey collected anonymous feedback on the simulation experience, including clinical relevance and logistical considerations such as ease of scheduling and session length.

We used linear and Poisson regression models to examine the association between simulation outcome scores (time, efficiency, and errors) and self-rated clinical skills measures (self-rated laparoscopic skill score or surgical volume category), while controlling for site, and the provider characteristics described above. Linear regression was used to model all outcomes except tissue damage count; for this outcome, Poisson models were applied. Only outcome scores from the second simulation trial were analyzed. All analyses were done using software (SAS, Version 9.4; SAS Institute Inc, Cary, NC).

Results

In all, 357 physicians participated in the quality improvement initiative; of these, 347 agreed to allow their simulation performance data to be used for the current study. The included physicians had an average of 14.4 years in practice (range 0-50 years) and 34.8% were fellowship-trained specialists. The majority (90.2%) were right-handed. Selected physician characteristics gathered from the presimulation survey are reported in Table 1.

TABLE 1
Physician characteristics, N = 347

Characteristic	Value
Years in practice	14.4 (10.4)
Fellowship training completed, n = 345	120 (34.8%)
Left-handed	34 (9.8%)
Vision correction required, n = 340	249 (73.2%)
Past or current video game playing	183 (52.7%)
Robotics training	74 (21.3%)
Self-rated laparoscopic skill	6.8 (1.7)
General coordination	7.3 (1.7)

Mean (SD) or freq (%).

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The mean self-rated laparoscopic skill level was 6.8 (SD 1.7) of 10. The majority (54%) of physicians reported performing an average of 0-1 laparoscopic or robotic procedures per month. Only 7% of physicians reported an average of ≥11 procedures per month. The true surgical volume of a random sample of 20% of the attendings participating in the study was evaluated and found to coincide within 20% of the self-reported volume.

Physician performance on time, error, and efficiency scores for each simulation task are reported in Table 2.

The effect of surgical volume and self-rated laparoscopic skill on the simulation outcomes is presented in Tables 3 and 4, respectively. Each table displays the regression parameter estimates and *P* values specifically for these predictors, while also controlling for site, years in practice, fellowship training, and handedness.

The average number of laparoscopic procedures per month was a significant predictor of total time on all 3 tasks ($P = .001$ for peg transfer; $P = .041$ for lifting and grasping; $P < .001$ for cutting). Each category >0-1 procedures per month (2-

TABLE 2
Physician performance on virtual reality simulation tasks, N = 347

	Peg transfer		Lifting and grasping		Cutting	
Outcome	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Total time, s	221.2 (69.2)	99.2–466.6	96.5 (37.8)	39.9–386.5	110.8 (40.6)	43.3–315.0
Error scores						
Mean drops/transfer	0.4 (0.3)	0–1.4	—	—	—	—
Tissue damage	—	—	9.2 (9.1)	0–59.0	8.7 (11.9)	0–73.0
Efficiency scores						
Left path length, m	4.0 (1.7)	1.7–12.3	2.6 (0.8)	1.3–7.0	1.5 (0.9)	0.3–5.7
Right path length, m	4.3 (1.8)	1.4–13.8	2.4 (1.0)	1.2–13.1	1.7 (1.0)	0.6–11.4
Left angular path, degrees	851.7 (374.6)	312.5–3051.5	478.6 (177.5)	261.2–1636.0	325.2 (208.0)	50.7–1484.5
Right angular path, degrees	934.5 (400.6)	257.7–3061.3	448.4 (249.7)	188.9–3540.4	364.0 (226.9)	101.6–2821.0

Second attempt only.

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5, 6-10, and ≥11) was associated with an average decrease in total time, compared to the 0-1 category, ranging from approximately 24-40 seconds for the peg transfer task, 6-14 seconds for the lifting and grasping task, and 17-30 seconds for the cutting task. For efficiency scores, average monthly laparoscopic surgical volume was a significant predictor of right instrument path length ($P = .018$) and right angular instrument path ($P = .0152$) in the peg transfer task, and all 4 efficiency scores in the cutting task ($P = .001$ to $P = .011$), but was not a significant predictor of any efficiency outcomes in the lifting/grasping task. Surgical volume was a significant predictor of errors in the lifting/grasping task and the cutting task ($P < .001$ for both), but not in the peg transfer task. Regardless of significance, an average improvement in the outcome score (eg, faster time, fewer errors, greater efficiency) was seen in all models for each category >0-1, and the improvement increased as the surgical volume category increased.

Self-rated laparoscopic skill level was a significant predictor of total time in all 3 tasks ($P < .0001$ for peg transfer; $P = .009$ for lifting and grasping; $P < .001$ for cutting). It was also a significant predictor of nearly all efficiency scores and errors scores in all 3 tasks, with the exception of right path length and right angular path in the lifting and grasping task. For all models, higher self-rated skill scores are associated with an average decrease (improvement) in outcome scores.

In the anonymous postsimulation survey, 58.1% agreed or strongly agreed that the technique simulations were realistic, and 60.1% of physicians agreed or strongly agreed that the simulation session would be helpful in their clinical practice (Appendix Tables 1 and 2). Scheduling of the assessment was convenient for 88.1% of physicians and 91.0% thought the length of session was about right. More than three quarters (78.0%) reported that the simulation activity was enjoyable.

Comment

Simulation is gaining acceptance as a method of technical skill training and assessment in a variety of surgical specialties. Most physicians who participated in this study were low-volume surgeons, performing on average 0-1 laparoscopic or robotic procedure per month. In addition, the most commonly performed procedures are those of generally low complexity: diagnostic laparoscopies or laparoscopic adnexal surgeries. Gynecology is unique within the surgical specialties in that a large percentage of attending physicians within the field perform a small number of surgical procedures each year. Gynecology has a greater need to provide methods by which its members can maintain surgical skills. In the future, simulation may have a role in improving and maintaining surgeon technical skill as case volumes fluctuate, especially for the low-volume surgeon.

All 3 tasks have some value in the objective assessment of laparoscopic skills. In addition to total time, there was at least 1 other objective performance measure that significantly correlated with surgical volume for each of the 3 tasks. Tissue damage was significantly correlated in both the lifting/grasping task and cutting task. Left and right instrument and angular instrument path lengths were not always correlated with handedness, as one would expect, however in the cutting tasks all 4 of these measures were significantly correlated with monthly case volume. In future VR simulation studies, the cutting task may be the most comprehensive basic skills task to include as an assessment of laparoscopic skills.

In our study, physician self-perception of laparoscopic skills correlated with nearly every objective performance measure, indicating that most attending physicians were accurately able to self-assess their skills. This is in contrast to many studies that showed weak and no association between physician self-rated assessment and external assessments, such as a systematic review of physician

TABLE 3
Regression parameter estimates and *P* values for average monthly laparoscopic procedure volume as predictor of task outcomes, when also controlling for site, years in practice, fellowship training, and handedness

	Parameter estimates for average monthly laparoscopic procedure volume			
Outcome	2–5 vs 0–1/mo	6–10 vs 0–1/mo	≥11 vs 0–1/mo	*P* value
Peg transfer task				
Total time, s	−24.32	−27.91	−40.38	.0009[b]
Mean drops/transfer	−0.04	−0.07	−0.07	.5757
Left path length, m	−0.30	−0.42	−0.60	.1502
Right path length, m	−0.36	−0.68	−0.96	.0183[b]
Left angular path, degrees	−55.32	−83.57	−116.78	.2710
Right angular path, degrees	−83.68	−169.09	−200.88	.0152[b]
Lifting and grasping task				
Total time, s	−5.49	−17.01	−13.52	.0410[b]
Tissue damage, count[a]	0.74	0.62	0.65	<.0001[b]
Left path length, m	−0.15	−0.21	−0.14	.2733
Right path length, m	−0.18	−0.28	−0.16	.2647
Left angular path, degrees	−28.79	−47.89	−39.63	.2679
Right angular path, degrees	−40.52	−74.88	−60.99	.2402
Cutting task				
Total time, s	−17.08	−22.50	−29.81	<.0001[b]
Tissue damage, count[a]	0.78	0.63	0.28	<.0001[b]
Left path length, m	−0.27	−0.39	−0.67	.0006[b]
Right path length, m	−0.22	−0.39	−0.57	.0070[b]
Left angular path, degrees	−39.96	−83.09	−127.41	.0076[b]
Right angular path, degrees	−41.94	−90.21	−130.20	.0105[b]

Linear regression used, except where specified.

[a] Poisson regression used. Parameter estimates interpreted as percentage of reference group tissue damage count; [b] Statistically significant.

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self-assessment compared to objective measures of competence across a wide variety of specialties that concluded that physicians have limited ability to accurately self-assess.[13] In our study, higher-volume physicians and those with fellowship training were more confident in their laparoscopic skills. There is an evolving emphasis on integrating continued self-assessment, self-directed learning, and data from objective physician assessment, with feedback and reflection in professional development contributing to the provision of higher-quality health care.[14] This will be an area for further exploration in subsequent phases of our project and will help guide the provision of nonpunitive feedback to our physicians.

The strengths of our study include the large-scale and multi-institutional approach. This study is unique in that it correlates surgical training and practice to the simulator performance of practicing obstetrician gynecologists. This is also the largest and most uniform collection of laparoscopic simulation data from practicing physicians. The majority of simulation literature has small sample sizes and focuses on trainee performance. Criticism may exist regarding the decision to use an expensive VR simulator to develop this assessment protocol. Although box trainer training and assessment protocols exist, such as the FLS program, they have many limitations we believe preclude the cost savings. The FLS program demonstrated efficacy for training purposes, however there are few data to support its validity as an assessment tool.[15] The FLS proficiency standards are based on the performance of 2 expert surgeons; however, in reality, it tests basic proficiency, not true expertise.[16] In addition, time is heavily weighted and error penalties have a negligible effect on the overall score. Objective measures such as economy of movement and tissue damage, shown in our study to correlate to surgical volume and in other studies to correlate with operating room performance, cannot be tracked in a box trainer model.[10] The VR simulator allows for skills-focused training, which can be useful for specific gynecologic surgeries that vary in complexity. In a study that compared bariatric and nonbariatric surgeon performance on VR simulation procedures, there was a clear statistical difference in skill-specific tasks.[17] Finally, the VR simulator also allows for collection of large amounts of objective data using validated basic skills tasks.

In a practical sense, while simulators are very expensive, the true cost of an assessment tool must include the cost of human time. If we are able to correlate simulation performance to true surgical performance, it would be possible to have regional simulation centers where attendings could be required to undergo regular evaluations. The alternative would require observation, either direct or recorded. The cost in human hours to validate this type of assessment and then roll it into practice is prohibitively high and not practical given the low number of cases by the majority of surgeons. The same would be true if using FLS as the measure of proficiency. It is important that we proceed with our goal to establish a tool to maintain a minimum level of quality in our surgeons in a manner that is both effective and efficient.

Proficiency standards in simulation protocols are often defined by expert performance. One multicentered study in Europe determined that proficiency should be defined as expert performance plus 2 SD, meaning the goal is to achieve a similar performance as experts at the 95th percentile.[18] Given the significant difference in case volume and complexity, one can expect a difference in the skill level of general gynecologists vs expert gynecologic surgeons. We have identified numerous outcome measures that correlate with surgical volume.

We hypothesize that an expected level of performance can be established based on simulator performance. It is possible to use these simulator data to identify surgeons who may require additional training. As an example, we set 2 SD above the mean (the higher the score, the poorer the performance) as a cut-off in performance level; 66 physicians from our study fall into this category (19%). A total of 23 are above the cut-off if using >1 performance measure (6.6%), and only 2 participants if using at least 1 performance measure in each task (0.6%). These suggested cut-offs may help identify physicians needing additional simulation practice or more frequent assessment to improve and maintain surgical skills. There were a small percentage of high-volume and fellowship-trained physicians scoring above this cut-off, supporting initial testing for all physicians, regardless of volume and training. Incorporating performance-based consequences will ensure that all physicians perform their best. It is possible that if yearly simulation performance and individual surgical volume remain consistent, we may be able to show that the combination of high initial simulation performance and high surgical volume can allow for exclusion from yearly testing. Additionally, by determining performance as it correlates to active physician practice, there is an opportunity to assess skill and individualize training to maintain skill levels as case volumes fluctuate.

Overall, physicians had a favorable response to the assessment and many agreed their skills would improve with structured simulator practice. VR simulation training is most effective when the opportunity exists to consolidate skills acquired on the trainer in the clinical setting and with the use of short practice sessions interspersed with longer rest periods (distributed practice), since skills deteriorate with

TABLE 4
Regression parameter estimates and *P* values for self-rated laparoscopic skill level as predictor of task outcomes, when also controlling for site, years in practice, fellowship training, and handedness

Outcome	Parameter estimate for self-rated laparoscopic skill level	*P* value
Peg transfer task		
Total time, s	−11.00	<.0001[b]
Mean drops/transfer	−0.03	.0117[b]
Left path length, m	−0.20	<.0001[b]
Right path length, m	−0.22	<.0001[b]
Left angular path, degrees	−46.49	<.0001[b]
Right angular path, degrees	−45.64	.0002[b]
Lifting and grasping task		
Total time, s	−3.00	.0085[b]
Tissue damage, count[a]	0.94	<.0001[b]
Left path length, m	−0.06	.0165[b]
Right path length, m	−0.03	.2850
Left angular path, degrees	−14.66	.0054[b]
Right angular path, degrees	−10.13	.1894
Cutting task		
Total time, s	−5.77	<.0001[b]
Tissue damage, count[a]	0.91	<.0001[b]
Left path length, m	−0.12	<.0001[b]
Right path length, m	−0.11	<.0001[b]
Left angular path, degrees	−26.35	<.0001[b]
Right angular path, degrees	−26.08	.0001[b]

Linear regression used, except where specified.

[a] Poisson regression used. Parameter estimates have been exponentiated; [b] Statistically significant.

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disuse.[19] This implies that sporadic clinical opportunities due to lower case volumes would also lead to deterioration of skills. There may also be a role for VR simulator practice immediately prior to a laparoscopic procedure in the operating room, as a warm-up. A small randomized prospective study showed a significant improvement in blinded objective structured assessment of technical skills median scores with preoperative simulation warm-ups.[20] We hope to incorporate a VR simulation assessment such as this one into ongoing and focused professional practice evaluations to allow for nonpunitive assessment of laparoscopic skills and to facilitate distributed practice. If performance drops below the set passing score, additional VR simulator practice may be suggested to maintain skills.

Other VR construct validity studies have shown that VR simulator performance correlates with level of training and/or novice, intermediate, or expert level skills. In this initial phase of this project, we have successfully demonstrated construct validity for practicing obstetrician and gynecologists in these selected VR simulation tasks, in that improved task performance correlates with higher-volume surgeons between low- and high-volume surgeons. This study was not structured to assess predictive validity, the ability for psychomotor skills tasks to show skill transference from simulator to performance in the operating room. This has been established for novice surgeons in training but not fully established for practicing physicians with varying skill level, fellowship training, and case volumes. In the future, we plan to continue this quality assessment initiative and to analyze the performance measures of procedural VR simulation tasks, such as a simulated adnexal surgery or hysterectomy, and correlate them not only to case volume, but also to blinded OSATS evaluations for these specific procedures in the operating room, thereby assessing predictive validity. The establishment of a simulation program to evaluate and credential attending surgeons is a long process. We have accomplished the first stage by demonstrating a correlation between surgical volume and simulation scores on basic tasks. The next phase will evaluate simulated procedures to determine if the same correlation exists or is possibly stronger. If that is the case we would then compare these simulation scores to checklist operative assessments such as objective structured assessment of technical skills or global rating scale scoring. Finally we would evaluate to see if these simulation scores related to better patient outcomes, which is the ultimate goal of this type of research. By gathering performance information in the operating room as well as on various basic skills and procedural tasks on the VR simulator, we hope to develop a robust validated simulation process that will certify our physicians for laparoscopic privileges and help them maintain their technical skills over time. ■

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APPENDIX TABLE 1
Average monthly laparoscopic or robotic procedure volume by case type

Laparoscopic/robotic procedure	Average no. of cases/mo None	1–3	4–6	7–9	≥10
Diagnostic laparoscopy or laparoscopic tubal sterilization	132 (38.0%)	186 (53.6%)	16 (4.6%)	4 (1.2%)	9 (2.6%)
Laparoscopic salpingectomy for ectopic pregnancies, laparoscopic ovarian cystectomy, or bilateral salpingo-oophorectomy	101 (29.1%)	206 (59.4%)	30 (8.7%)	3 (0.9%)	7 (2.0%)
Laparoscopic supracervical or total hysterectomy	236 (68.0%)	67 (19.3%)	25 (7.2%)	8 (2.3%)	11 (3.2%)
Laparoscopic myomectomies or robotic surgery	280 (80.7%)	44 (12.7%)	11 (3.2%)	6 (1.7%)	6 (1.7%)

Values are freq (%).

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APPENDIX TABLE 2
Anonymous postcourse survey responses

Questions	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I believe this session will help me in my clinical practice	75 (21.7%)	133 (38.4%)	80 (23.1%)	35 (10.1%)	23 (6.7%)
I found this simulation activity enjoyable	109 (31.5%)	161 (46.5%)	46 (13.3%)	18 (5.2%)	12 (3.5%)
I think format of this session was appropriate for material taught	101 (29.2%)	177 (51.2%)	53 (15.3%)	9 (2.6%)	6 (1.7%)
Technique simulations were realistic	42 (12.1%)	159 (46%)	73 (21.1%)	52 (15%)	20 (5.8%)
Available dates and times were convenient	135 (39%)	170 (49.1%)	25 (7.2%)	9 (2.6%)	7 (2%)
		Too short	About right	Too long	
I think length of session was:		14 (4.1%)	315 (91%)	17 (4.9%)	
		Easy	Neutral	Difficult	
How difficult was it for you to find time for this session?		109 (31.5%)	155 (44.8%)	82 (23.7%)	

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