Ambulatory Clinic Exam Room Design with respect to Computing Devices to Enhance Patient Centeredness

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Structured Abstract

Purpose: Challenges persist regarding how to integrate computing effectively into the exam room, while maintaining patient-centered care. Our objective was to evaluate a new exam room design with respect to the computing layout, which included a wall-mounted monitor for ease of (re)-positioning, in both a laboratory simulation study and pilot field study.

Scope: A total of 28 primary care providers (17 male, 11 female) completed the laboratory simulation study at the University of Louisville's Center for Ergonomics. For the pilot field study at the Phoenix VA Health Care System, we enrolled 11 primary care providers into our study and observed 18 of their patient encounters. Six of the primary care providers (10 patient encounters) were from a community-based outpatient clinic with the new exam room design, and five primary care providers (eight patient encounters) were from the main facility and annex, with the older exam room design.

Methods: In a lab-based experiment, providers used prototypes of the new and older "legacy" outpatient exam room layouts in a within-subject comparison using simulated patient encounters. We measured efficiency, errors, workload, patient-centeredness (proportion of time the provider was focused on the patient), amount of screen sharing with the patient, workflow integration, and provider situation awareness. In a subsequent pilot field study, we conducted observations and interviews with primary care providers and their patients from three locations within the Phoenix VA Health Care System, in a pilot study comparing the new exam room design standard with the older legacy exam rooms.

Results: For the laboratory simulation study, there were no statistically significant differences between the exam room layouts for efficiency, errors, or time spent focused on the patient. However, when using the new layout providers spent 75% more time in screen sharing activities with the patient, had 31% lower workload, and gave higher ratings for situation awareness (14%) and workflow integration (17%). When using the new exam room layout in the pilot field study, providers spent a greater proportion of time focused on the patient, spent more time in screen-sharing activities with the patient, and had a higher degree of self-reported situation awareness. Overall, our results from both the laboratory simulation study and the field study were supportive of the new exam room design. Providers seemed to be unwilling to compromise their focus on the patient when the computer was in a fixed position in the corner of the room and, as a result, experienced greater workload, lower situation awareness, and poorer workflow integration when using the old "legacy" layout. A thoughtful design of the exam room with respect to the computing may positively impact providers' workload, situation awareness, and time spent in screen sharing activities.

Key Words: Human-computer interaction, Computer workstations, Mental workload, Exam room design; Exam room computing; Patient centeredness

Purpose

Although much research has been conducted on the impact of the electronic health record (EHR) and health information technology (IT) on provider-patient interaction, challenges persist on how to effectively integrate these tools into healthcare environments, while maintaining patient-centered care. Many providers have been concerned that incorporating health IT and computer use into patient visits negatively impact the provider-patient relationship. However, integrating computerized applications into the patient visit, while maintaining patient-centeredness, may help enhance, rather than negatively impact, this relationship. For example, rather than maintaining a focus on the computer monitor instead of the patient, the computer and monitor can viewed as a third party that can mediate between the provider and patient. In other words, there is an awareness of the 'triadic' relationship between provider, patient, and computer/electronic health record (EHR). This technology-enabled collaborative view opens new doors for integrating health IT into clinical workflow. We designed a multi-method study to enhance the exam room layout, with respect to the exam room computing, to improve clinical workflow and patient-centeredness in the Veterans Health Administration (VHA). The Specific Aims were:

Aim 1: Prototype and evaluate a redesigned exam room layout with respect to the exam room computing and compare the redesigned layout to a current, typical exam room layout in the Veterans Health Administration (VHA).

Aim 2: Refine the redesigned exam room layout, implement it in a live clinic setting, and compare it to currently designed exam rooms in a Veterans Affairs (VA) Medical Center.

Scope

Although much research has been done on the impact of the electronic health record (EHR) on the provider-patient interaction in ambulatory care, challenges persist on how to effectively integrate the electronic health record (EHR) into patient visits and clinical workflow, while maintaining patient-centered care.[1-2] Many providers have been concerned that incorporating health information technology (IT) and computer use into patient encounters will negatively impact the provider-patient relationship.[3-6] Integrating EHRs into the patient visit, while maintaining patient-centeredness, may help enhance, rather than negatively impact, the provider-patient relationship, and ultimately enhance patient safety. Safe healthcare is considered a main component of healthcare that is meaningfully patient-centered.[7] Also, multiple studies demonstrate that patient-centeredness can improve outcomes of care.[8-11] Moreover, patients who are involved in decision making and management for their care experience better outcomes than those who are not.[12,13]

The additional complexity introduced by the EHR creates new challenges for provider-patient communication. Research by Frankel and colleagues examined a clinic where an EHR had been utilized in the back office for 10 years and had recently become available in the exam room. Their work demonstrated that the addition of the EHR made verbal and nonverbal provider-patient communication more complex and, at times, challenging.[14] Computers were often placed where wiring was available, irrespective of where other furniture and instruments were located in the exam room. Such placement often resulted in situations in which the provider was forced to sit with his or her back to the patient in order to enter information.

Similarly, Ventres and colleagues found that the positioning of the computer affected communication; this group also found that the very presence of a computer altered the flow of provider-patient encounters.[15] In another study, Margalit et al. found that patient-centered communication was inversely related to the amount of EHR use during a medical encounter.[16] These effects on verbal and nonverbal communication are concerning given their potentially negative impact on patient-centered communication and ultimately on patient outcomes. Some providers have adapted by using paper printouts when with the patient to maintain focus on the patient rather than on the computer monitor.[17,18]

Pearce and colleagues have studied the impact of the exam room computer on provider-patient relationships.[19,20] They classified providers as having a "unipolar" or "bipolar" body orientation with respect to the computer.[19] Providers with a unipolar orientation had the lower pole of their body oriented toward computer; whereas those with a "bipolar" orientation changed their orientation back and forth between as patient and computer. The authors further classified patients as "dyadic", focused on provider to the exclusion of computer; or "triadic", meaning they included the computer during their discussions with the provider. In a subsequent study, Pearce and colleagues demonstrated that patients used three signaling behaviors in relation to the computer on the provider's desk (screen watching, screen ignoring, and screen excluding) to influence the behavior of the doctor.[20] Patients were able to draw the provider's attention to the computer and even used the computer to challenge doctor's statements. More recently, Kumarapeli and de Lusignan found that patients looked at the computer twice as much when it was within their gaze and that the EHR is used for a consistent proportion of the visit.[21] They recommended that providers who want to promote screen sharing should change their room layout. Future research is needed to generate specific recommendations for layout to promote these sharing behaviors.

The US Department of Veterans Affairs (VA) is preparing new standards for the design of the exam rooms throughout the Veterans health Administration (VHA), in part to consider how exam room layout and computing should support the new Patient Aligned Care Team (PACT) model embraced by the VHA. There is a tremendous amount of variation in the current designs of the exam rooms across the approximately 150 VA Medical Centers and associated Community-Based Outpatient Clinics (CBOCs) that comprise the VHA.[1] To date, only a few studies have focused on how computer use affects interactions between providers and patients in VA settings.[1,22,23] McGraph and colleagues examined nonverbal communication in relation to EHR use during the patient visit. They found three different office spatial designs: 'open,' 'closed' and 'blocked'.[22] In the 'open' orientation, the physician was orientation toward the patient, even when using the computer. With the 'closed' orientation, physicians had their back turned to the patient while using the computer. In the 'blocked' orientation, the physician was orientation toward the patient but the computer monitor obstructed the view between the physician and patient. The 'open' arrangement put physicians in a position to establish better eye contact and physical orientation than did the other configurations. Rouf and colleagues found that patients seeing VA resident providers, compared to those seeing more experienced VA physicians, were more likely to agree that the computer adversely affected the amount of time the physician spent talking to, looking at, and examining them.[23] More recently, our research team performed a study on VA exam room computing at three geographically dispersed VA Medical Centers.[1] Our study revealed several variations in, associated barriers to, and facilitators of EHR use corresponding to different units of analysis: computer interface, team coordination/workflow, and organizational. Our findings helped inform the design of the intervention for this proposal, including physical layout of the exam room with respect to the computing, as well as the notion of designing to accommodate maximum variation of workflow preferences of the providers before, during, and after the patient visits.

The health IT intervention for this study is a redesigned physical layout of a VA exam room with respect to the exam room computing. The new exam room design includes a wall-mounted monitor on an armature system for ease of (re)positioning, as well as a table for workspace that is easy to move and that can rotate against the wall or rotate outward to form a consult surface for a keyboard or printed materials that can be shared with the patient and family members. In the past, computers were introduced into the legacy exam rooms with the desk and computer fixed to the wall in a way that encouraged the provider to turn their back to the patient while using the EHR. The Veterans Health Administration (VHA) and VA Office of Construction & Facilities Management decided that the new exam room design should minimize the dependency of a built-in desk, which seemed to facilitate a "move-in and occupy" mindset. The new exam room design is intended to free providers to move from one exam room to another.

Our research objective was to evaluate the new exam room design, specifically in comparisons to the older legacy design, using both laboratory simulation and field study methods. To achieve Aim 1, we conducted a "human in the loop" simulation study in the Center for Ergonomics laboratory space at the University of Louisville to pilot test a redesigned exam room layout with respect to the exam room computing. To achieve Aim 2, we conducted a field study based upon actual patient visits in a live clinic.

Methods

Simulation Study

Participants. A total of 28 healthcare providers (17 male, 11 female) completed the study, with the mean age being 31 (range: 26-59). Using a convenience sampling method, four attending physicians, 23 resident physicians, and one nurse practitioner were recruited. In total, 26 of the 28 providers used the Department of Veterans Affairs (VA) Computerized Patient Record System (CPRS) as their EHR often or occasionally; the majority of the providers were resident physicians who had previously rotated through the VA and had used CPRS. Eight providers currently utilize a wall-mounted armature system in the exam room, five providers currently utilize a stationary desktop, six utilize a laptop, seven do not utilize a computer in any capacity, one utilizes a computer on wheels, and one provider did not provide a response. All providers had experience working with patients in an outpatient examination room, with 24 providers being employed through the University of Louisville, two through an independent family practice, one through the Baptist Health Center, and one from the Louisville VA Medical Center.

New exam room design. Our redesigned exam room layout with respect to the computing is based on the VA's new exam room design standard. The redesigned exam room includes a mobile computing work station with an armature system and a moveable table that can rotate against the wall or rotate out to form a consult surface for a keyboard or printed materials that can be viewed with the patient. Historically, computers were introduced into the exam rooms with the desk and computer fixed to the wall in a way that potentially encouraged the clinician to turn their back to the patient while using the EHR. The VA Office of Construction & Facilities Management decided that the new exam room design should minimize the dependency of a built-in desk, which seemed to encourage a ‘move-in and occupy’ mindset. The new exam room was designed with built-in efficiency, encouraging the provider to move from one exam room to another, which is consistent with the new team-based models of care where members of the healthcare team rotate to the patient in a single location. We simulated this new exam room design in our laboratory, as well and the older exam room design with a computer on a desk against a wall.

Experimental design. We used a single-factor, within-subjects experimental design. The single factor was ‘Type of Exam Room Layout’ with two levels (A, B), one representing a current, typical exam room layout (A), and the other representing the redesigned layout, where the EHR/computer is designed to be more easily incorporated with the provider-patient interaction (B). The presentation order of designs A and B were counterbalanced to account for potential crossover effects. Dependent measures addressed efficiency, errors, workload, patient-centeredness, screen sharing, workflow integration, and situation awareness. Table 1 lists and defines the outcome measures, and describes what data collection tool or method was used for each.

Table 1. Outcome measures for comparing a current, typical exam room layout with the redesigned layout during lab simulation study.

Outcome measure	Definition	Measuring tool / method
Efficiency	Efficiency completing scenarios with the given exam room and computing layout.	Time to complete test scenarios
Errors	Deviations or omissions from the given clinical scenarios.	Completeness of each clinical scenario.
Workload	The difference between the amount of resources available within a person and the amount of resources demanded by the task situation	NASA Task Load Index (TLX)[24]
Patient-centeredness	Time the provider is focused on the patient compared to the computer	Eye gaze
Amount of screen sharing with the patient	Time spent sharing information from the EHR and related software programs where both the provider and patient are viewing the computer monitor	Time spent during screen sharing activities.
Workflow integration of computer/EHR	Degree to which new technology is tailored such that it fits into the clinician’s workflow process for delivering patient care	Workflow Integration Survey (WIS)[25]
Situation Awareness	Perception and comprehension of elements in the environment; projection of their status in the future[26]	Situation Awareness Rating Technique (SART)[27]

For efficiency, errors, patient-centeredness, and screen sharing, data were collected by using video recordings and screen captures from Morae software (version 3.3.4, TechSmith Corporation, Okemos, MI). Specifically, time to complete a scenario (efficiency) was measured through a task-timing function with video recordings, while errors were measured by evaluating screen captures of the provider's CPRS inputs and video recording from two cameras. One camera facing the provider and patient, and the other attached atop the exam room computing device, respectively captured screen sharing and patient-centeredness. Data for the NASA-TLX was collected via a computer-based survey with a scale of 1-100. The WIS and SART were paper-based measurements based on a scale of 1-5 and 1-7, respectively.

Procedure. Providers were brought to the Center for Ergonomics laboratory and they read an IRB-approved informed consent form. A brief overview of the study was described to the provider followed by a five-minute guided familiarization session with the EHR used for the study, the VA's CPRS. Upon completion of the familiarization session, the first testing session began by working through one of two potential scenarios and layouts. Care was taken by the facilitator not to refer to the exam room layouts as "old" and "new", which instead were referred to as "first" and "second". Once the session was completed, or the 20-minute time limit was met, the provider left the simulation area to complete the paper-based SART and WIS, as well as the computer-based NASA-TLX. The provider was brought back into the simulation area to complete the second session using the alternative layout (i.e., the provider's second simulated scenario and layout was different that the first). Similar to the first event, once the scenario was completed, or the 20-minute time limit was met, the provider left the simulation area to complete the SART, WIS, and NASA-TLX. Finally, the provider was guided through a semi-structured debrief session to gather any final thoughts pertaining to the study. After the debrief session was concluded, the provider was compensated and dismissed. The entire session was designed not exceed 90 minutes in total.

Simulation scenarios. We used similar outpatient visit scenarios for the provider to complete using both room layouts (A and B). These scenarios were reviewed and revised by a physician consultant to ensure a sufficient level of realism. Fictitious patient records for our scenarios were entered into the demo version of CPRS and populated with the scenario data, including historical and current vitals, a previous progress note, and medication list. A member of the study team played the part of the patient. The patient actor asked for similar actions from the provider regardless of the layout and scenario. That is, regardless of the scenario or layout, the patient actor gave the provider a list of current medications and asked to see a history of vital readings from previous visits (blood pressure or respiratory rate depending on the specific patient scenario) to show interest in looking at their EHR record. The scenarios only differed in 'surface-level' aspects such as fictitious patient name, similar chief complaint, similar co-morbidities, similar medications, etc. However, the scenarios required providers to complete the same tasks, including creating a progress note, sharing lab results with the patient, medication reconciliation, ordering / renewing medications, and other common tasks associated with a primary care visit. Providers were asked to complete the clinical tasks; no instructions were given to the providers regarding patient-centeredness and screen sharing. The presentation order of the two patient scenarios was counterbalanced across layouts A and B (in addition to the layouts being counterbalanced across providers). In other words, the first provider used layout A with scenario 1, then layout B with scenario 2. The second provider used layout B with scenario 1, then layout A with scenario 2. The third provider used layout A with scenario 2, then layout B with scenario 1. The fourth provider used layout B with scenario 2, then layout A with scenario 1. This counterbalancing scheme was repeated for the next 24 providers.

Layouts A and B. Layout A included a simple computer and 19-inch monitor setup on a desk at the nearest electric outlet with no respect to the locale of the patient, patient table, or other needed medical tools. Layout B included an all-in-one computer (19.5-inch monitor) attached to a wall mount that moves the screen along three axes allowing for optimal screen positioning that can be adjusted depending upon the scenario. Placement of the wall mount was determined based upon where the most open space was located in the exam room to not limit the potential movement of the screen along any axis. This is consistent with the VA's new exam room design standard, which is the basis for Layout B. Both simulated exam rooms were of high fidelity with regard to the exam room computing device, room layout, and furniture pieces. However, we did not include many smaller items that are typically in exam rooms, such as a blood pressure monitor, opthalmoscope, supply cart, etc.

Analysis. Analysis was done with an A vs. B comparison of the current, typical exam room layout and the redesigned layout with statistical analyses performed to compare the measures in Table 1 across the two types of exam room layouts. Each provider completed the NASA-TLX, WIS, and SART instruments twice, once for each of the two layouts. The SART instrument for situation awareness contained 10 items that were rated on a Likert-type scale from 1-7. Each of the 10 items map to three subscales for 'understanding', 'demand', and 'supply'. A composite SART score for situation awareness (SA) was calculated using: $SA = U - (D - S)$, where: U = summed understanding; D = summed demand; S = summed supply. Paired t tests were used to compare outcomes between the two layouts when parametric assumptions were met, and Wilcoxon Signed Rank tests were used otherwise. Statistically significant differences between layouts were concluded using a significance level of 0.05.

Debriefing responses were recorded for all 28 providers. The debrief interviews were first transcribed from audio recordings. Then, responses from the debrief interview transcripts were reviewed by a member of the study team for recurrent themes across providers. A second study team member reviewed and verified the summary of interview responses for repeating patterns within the full study sample. Recurrent themes centered around layout preference, provider-patient interaction, and redesign recommendations.

The remote database supporting the demo version of CPRS was inaccessible during the last provider's session. Therefore, quantitative data for this provider was not included (i.e., the sample size was 27 for the statistical analyses).

Field Study

Study design. We conducted observations and interviews with primary care providers and their patients from three locations within the Phoenix VA Health Care System to compare the new exam room design standard with the older legacy exam rooms. One community-based outpatient clinic (CBOC) had recently implemented the new exam room design standard in the primary care rooms, which included a wall-mounted monitor for ease of (re)-positioning. The other two locations were the primary care clinics in the main, tertiary care facility and primary care clinics in an annex building close by. Both of these two locations had the older legacy exam rooms, with a desktop computer on a stationary desk, generally located in the corner of the room.

For this field study, two members of the study team conducted observations of provider-patient interactions and self-reported satisfaction with encounters in the new and legacy exam rooms in order to assess the impact of the new exam room designs. Over the course of one five-day work week, we collected data in both the new exam rooms, located in the CBOC, and legacy exam rooms, located at the main facility and annex. We spent 1-2 hours with each primary care provider, observing one or more patient encounters.

Participants. We enrolled 11 primary care providers into our study and observed 18 of their patient encounters. Six of the primary care providers (10 patient encounters) were from the CBOC with the new exam room design, and five primary care providers (eight patient encounters) were from the main facility and annex, with the older exam room design. Of the six providers from the CBOC, five were physicians and one was a nurse practitioner. Of the five providers from the main facility and annex, four were physicians and one was a nurse practitioner. Each of the providers had extensive experience in their respective primary care clinics.

Dependent measures. We collected measures of patient-centeredness (i.e., the extent to which the provider focuses on the patient vs. the computer), screen sharing, situation awareness, and workflow integration in both the new exam rooms and legacy exam rooms. We recorded time estimates in handwritten observations for time the provider was focused on the patient vs. the computer, as well as for time the provider spent in screen sharing activities with the patient. For workload integration and situation awareness, we used subjective rating instruments that providers could complete relatively easily (with minimal disruption) after the patient left the exam room. Each of these brief measures were strategically chosen to minimize disrupting the provider's work and flow of the clinic. We recorded handwritten estimates of time using a stopwatch application on a smartphone as we were not permitted to video-record the patient encounters for more precise estimates.

Debrief interviews. At the end of the patient visit, we conducted a semi-structured debrief interview with the provider and patient separately, to assess their satisfaction with each encounter. All 11 providers and nine patients agreed to be interviewed. For the purpose of this study, we defined satisfaction as the quality of the provider's and patient's experience during the patient visit within the exam room. Questions that were not encounter-specific were only asked once for each provider.

Provider interview questions included:

- What are your current work habits during patient visits related to the exam room computing?
- In what ways, if any, did the different layouts affect your interaction/communication with the patient?
- In what ways, if any, did the exam room layout affect your computerized tasks?
- In what ways, if any, did the exam room layout impact your willingness to share the monitor with the patient to review information on the screen?
- How would you modify the exam room layout design to better suit your needs?

Patient interview questions included:

- Did the computers in the exam room assist or distract from your conversation with the provider?
- Were you interested in viewing any information from the electronic health record on the computer monitor during your visit with the provider?

- Did the provider encourage you to view any information from the electronic health record on the computer monitor? If so, did you understand what you were viewing?

Analysis. The SART instrument for situation awareness contained 10 items that were rated on a Likert-type scale from 1-7. Each of the 10 items map to three subscales for 'understanding', 'demand', and 'supply'. A composite SART score for situation awareness (SA) was calculated using: SA = U – (D – S), where: U = summed understanding; D = summed demand; S = summed supply. The WIS instrument was for workflow integration and contained 12 items that were rated on a 5-point Likert-scale. An overall WIS score was derived as a mean across each of the 12 items. Full descriptions of the SART and WIS survey instruments are available in the literature.[25,27] Given the pilot nature of our study, and the small sample size, only descriptive analyses of the quantitative data are presented. The qualitative debrief interview data were reviewed for recurrent themes.

Results

Simulation Study

A summary of statistical results is provided in Table 2. There were no significant differences between layouts for measures of efficiency, errors, or patient centeredness. However, there were significant differences for time spent in screen sharing activities, as well as provider perceived situation awareness and workload between layout types.

Table 2. Results for Efficiency, Errors, Patient Centeredness, Screen Sharing, and Situation Awareness (n=27)

Outcome Measure	Layout A – Mean (SD)	Layout B – Mean (SD)	Statistical Test Used	*p*-value
Efficiency – Time to complete scenario (seconds)	604 (202.9)	585 (205.0)	Wilcoxon Signed Ranks Test	0.501
Errors – Number of Errors Committed	1 (0.9)	1 (0.9)	Wilcoxon Signed Ranks Test	0.529
Patient Centeredness (amount of time focused on patient in seconds)	139 (87.7)	128 (84.5)	Wilcoxon Signed Ranks Test	0.648
Patient Centeredness (Percentage of time focused on patient)	22 (9.2)	21 (8.5)	Paired T-test	0.482
Screen Sharing (Amount of time screen sharing with patient in seconds)	24 (20.5)	42 (35.8)	Wilcoxon Signed Ranks Test	0.022*
Situation Awareness	22 (6.9)	25 (5.7)	Paired T-test	0.017*

Note: * denotes statistical significance.

For workload, five out of six of the NASA-TLX subscales significantly differed between layouts (Table 3), though results for the mental workload subscale only approached significance.

Table 3. NASA-TLX Subscale Comparison of Layout A vs. B (comparisons using paired *t* tests; n=27)

NASA-TLX Subscale	Layout A - Mean (SD)	Layout B – Mean (SD)	*p*-value
Mental Workload	53 (28.7)	44 (25.9)	0.054
Physical Workload	35 (28.9)	16 (12.0)	0.003*
Temporal	53 (22.3)	40 (24.9)	0.030*
Performance	54 (25.1)	44 (28.7)	0.049*
Effort	55 (24.6)	38 (21.7)	<0.001*
Frustration	60 (29.8)	35 (25.4)	<0.001*
Overall Workload	52 (20.0)	36 (17.0)	<0.001*

Note: * denotes statistical significance.

Finally, three out of four subscales in the WIS were found to be significantly different between layouts (Table 4), as well as the total WIS scores, while differences in the paper workaround subscale approached significance.

Table 4: Workflow Integration Survey (WIS) analysis Layout A vs. B (n=27)

WIS Subscale	Layout A - Mean (SD)	Layout B – Mean (SD)	*p*-value
Navigation	3.5 (1.0)	4.0 (0.8)	0.008*
Usability	2.6 (1.2)	3.4 (1.0)	<0.001*
Paper Workarounds	3.3 (1.1)	3.5 (1.1)	0.057
Workload	2.6 (0.7)	3.1 (0.9)	0.002*
Total	3.0 (0.8)	3.5 (0.8)	<0.001*

Note: * denotes statistical significance.

Table 5 provides a summary of the themes revealed from analysis of the semi-structured debrief interviews. Two members of the study team agreed that the debrief interviews revealed interesting concepts related to three main themes: (1) layout preference; (2) provider-patient interaction; and (3) redesign recommendations. All providers indicated a preference for layout B due to the mobility associated with the wall-mounted armature system, and because the patient was within the provider's field of view. Similarly, providers indicated that layout B facilitated provider-patient interaction because the patient was in close proximity and the provider did not experience ergonomic discomfort to interact with the patient (i.e., providers turned and contorted their torso, neck, etc. to face the patient with layout A). Finally, providers described a couple of redesign recommendations for both layouts A and B. For layout A, they suggested moving the patient to a location within their field of view (i.e. next to the desk). For layout B, providers recommended the wall mounted armature system be fully adjustable in a vertical direction so they could stand if needed.

Table 5: Debrief Interview Responses; Themes and Subthemes (n=28)

Theme	Subthemes
Layout preference	Mobility Field of view
Provider-patient interaction	Spatial relationship to patient Ergonomic discomfort
Redesign recommendations	Patient location Adjustable work area

Field Study

Quantitative results. Table 6 displays a summary of the results for each of our measures. Providers spent a greater proportion of time focused on the patient, spent more time in screen-sharing activities with the patient, and had a higher degree of self-reported situation awareness. The legacy exam rooms were perceived as better facilitating workflow integration.

Table 6: Mean (SD) outcomes for quantitative measures

Measure	Exam Room Type	
	Legacy	New
Proportion of time focused on patient	39.4 (19.8) %	43.6 (25.2) %
Proportion of time focused on computer	58.4 (19.3) %	53.4 (23.4) %
Time spent in screen sharing activities with patient	0 (0) min	1.9 (3.7) min
Situation awareness (composite SART score)	21.3 (4.6)	29.3 (6.3)
Workflow integration (composite WIS score)	4.4/5 (0.5)	3.7/5 (0.4)

Note: Providers spent about 2-3% of time focused on items other than the patient or computer (e.g., paper printouts).

Provider debrief interviews. We found two themes from provider responses using the new exam room layout: (1) several providers noted how difficult it is to adjust the monitor up and down (e.g., "*It's hard to adjust the monitor if the provider wants to stand without putting in a work order – it's bolted at a single level for sitting*."); (2) several providers expressed enthusiasm for how easy it was to swivel and share the screen with the patient using the wall-mounted monitor with the armature system.

Patient debrief interviews. Patients at clinics with both exam room layouts were positive about the provider using the computer during the patient encounter and perceived the computer to be helpful in general. However, patients interviewed at the clinic with the new exam room layout expressed an interest in seeing what was on the computer screen, whereas most patients interviewed at the clinics with the legacy exam room layout specifically expressed that they were not interested in seeing what was on the computer screen.

Discussion – Simulation Study

The academic literature supports several practices for promoting provider-patient interaction with the use of exam room computing.[28] Recommended behavioral and communication practices, as supported by evidence, are: (1) using the computer to facilitate conversation; (2) adjusting room design; (3) maintaining eye contact with the patient while typing; (4) separating typing and patient interaction; (5) talking to the patient while gazing at the computer; (6) using a postural style that allows the clinician to face the patient most of the time; (7) inviting the patient to look at the screen before the patient asks; and (8) informing the patient about the functions and role of the computer. Adjusting the exam room design was the focus of our study, as it is both strongly supported by available research evidence and also related to other evidence-based strategies for promoting provider-patient interaction.

Recommended exam room design practices include arranging the computer so that the patient can simultaneously view the record, and using computers that allow for easy repositioning of the screen.[29,30] Adjustable and moveable furniture have also been reported to facilitate orienting the room layout to be more patient-centered.[28] The new exam room design used here incorporated these recommended design practices, and our findings support the notion of 'using the computer to facilitate conversation', an evidence-based strategy for promoting provider-patient interaction with the use of exam room computing.[28] The new exam room design seems to facilitate this strategy. The new design, with the ability to easily reposition the monitor and easily move the workspace furniture, may also facilitate other evidence-based practices for promoting provider-patient interaction such as: maintaining eye contact with the patient while typing; using a postural style that allows the provider to face the patient most of the time; and inviting the patient to look at the screen before the patient asks.[28]

Efficiency, errors, and patient centeredness. Objective measurements of efficiency, errors, and patient centeredness (percentage of time focused on the patient) did not differ between layouts. These results are, to the best of our knowledge, unique with respect to related studies. One interpretation for the lack of a substantial difference in our study is that neither layout helps (or hinders) a provider's performance in these measures. However, the lack of a clear difference may have occurred due to the fact the provider did not have to rely more or less on the EHR based on the scenario. Moreover, the provider could have gathered much of the needed information by interacting with the patient and not with the EHR, meaning the EHR was used as more of an assistive tool to try and facilitate conversations between the provider and patient. Since the EHR was not used as a crutch for the provider's performance, the provider could dictate how much EHR use would be incorporated in the patient visit. The amount of such use is variable, and thus may have led to the lack of significant differences in time, number of errors, and amount of time focused specifically on the patient.

Workload. We believe the current study is the first to measure changes in perceived workload with different exam room layouts. Layout B was more favorable in terms of perceived physical workload, temporal workload, performance, effort, and frustration. Despite the performance results of the NASA-TLX favoring layout B, performance measures (time and errors) showed no significant differences. However, some of the comments given during the debriefing match these findings. Providers complained about the amount of physical movement and general discomfort encountered while using layout A. The most common complaints were about having to turn around constantly to shift attention between the EHR and patient, twisting at the waist to look over their shoulder to check on patient while interacting with the EHR, and having their back turned towards the patient. Constantly adjusting the body posture to accommodate the EHR and patient is a logical explanation for the less favorable physical workload ratings for layout A. Additionally, providers mentioned they felt rude by having their back turned to the patient and layout A would have been easier if they took paper notes. This supports the NASA-TLX scores in regards to the high frustration scores for layout A. The temporal workload, effort, and frustration subscales were significantly lower with layout B, likely because of the personalization of the layout B, which accounts for various patient locations to assist with EHR and patient attention shifting.

Screen sharing. To our knowledge, this is the first study to measure difference in the time spent in screen sharing activities between exam room layouts. Layout B led to a larger amount of time screen sharing compared to layout A. Similar to the NASA-TLX subscales, the cause of the increased amount of screen sharing in layout B is likely to be the wall-mounted system. With layout B, the computer is fully adjustable, potentially making the providers more willing to share the screen with the patient. With layout A, the only way to effectively share the screen with the patient was by relocating the patient and moving him/her to the screen, whereas with layout B the screen can be adjusted and moved to the patient by the provider. This not only promotes the increased amount of screen sharing, but also likely promotes patient centeredness. However, during the debriefing, providers expressed concern about the potential of a patient seeing information the provider did not intend to share.

Workflow. The WIS instrument, or similar workflow integration assessment tools, have not been used in previous studies of exam room layout. The three WIS subscales of navigation, usability, and workload, as well as overall WIS scores, indicated a significant difference between layouts, with Layout B having better scores. Moreover, providers rated Layout B higher, meaning that they believed layout B was easier to incorporate into their clinical workflow rather than layout A. The debrief interviews are helpful for interpreting these results. Providers mentioned that layout A involves having their back to the patient and thus made interacting with the EHR and the patient very difficult. In contrast, with layout B, focusing between the EHR and the patient was nearly seamless, involving a simple shift in eye gaze. This easy shift in attention allowed providers to make changes in the EHR and talk to the patient with ease without having to change positions, which may have led to layout B having a more favorable WIS score. The one subscale of the WIS that was not statistically different was 'paper-based workarounds', but trended towards significance. The lack of difference for this subscale may be the result of the simulation environment; provider did not have access to any paper materials aside from a one-page overview of the patient scenario and a list of medications provided by the patient. Transposing this study to a real-world scenario, it is possible that over time certain paper-based workarounds would be developed.

Situation awareness. Our assessment of changes in providers' situation awareness with different exam room layouts is, we believe, novel in the existing literature. There was a higher perceived level of situation awareness with layout B. Situation awareness was most likely facilitated in layout B again because of the flexibility of the wall mount. The mounting system allows for the provider to have the patient in their peripheral vision. This gives the provider freedom to change eye gaze from the EHR and patient quickly, but also enables the provider to visually sense a disturbance with the patient when focused on the EHR and vice versa. With layout A, if a provider needs to visually check the patient, they would need to either move their body to put the patient within eye gaze, or move the patient next to them.

Debrief interviews. Debrief interview results were organized into major themes of layout preference, provider-patient interaction, and redesign recommendations. Providers preferred layout B because it facilitated (1) conversation; (2) maintaining eye contact with the patient while typing; (3) talking to the patient while gazing at the computer; and (4) using a postural style that allows the clinician to face the patient most of the time. This is consistent with several practices for promoting provider-patient interaction with the use of exam room computing outlined by Patel et al. (2017), including using the computer to mediate conversation. Indeed, layout B here, which included the wall-mounted monitor for ease of (re)-positioning, allowed for a "joint focus of attention"[31] that seems to allow the provider to better manage the medical encounter. Just as an aviation pilot relies on an external field of view as well as the instrument panel during complex coordinated actions, the medical provider can achieve the same joint focus of attention with the patient and the EHR when the layout allows for positioning of the computer monitor in close proximity with the patient.

Summary. Although there were no significant differences in performance measures between the layouts (i.e., efficiency, number of errors, and patient centeredness), providers experienced lower workload, better workflow integration, more screen sharing, and greater perceived situation awareness with layout B. Providers seemed unwilling to compromise their focus on the patient when using layout A and thus experienced greater mental and physical workload and lower situation awareness. In other words, a thoughtful design of the exam room layout with respect to layout B (and potential future modifications of layout B) may not result in improved physician performance or patient centeredness. However, our results support that manipulating the design and placement of exam room computing can reduce physician's perception of their overall workload, including physical demand, temporal demand, performance, effort, and frustration. Our results also suggest that a more thoughtful design may also improve their perceived situation awareness, as well their perceived integration of the computing with their clinical workflow in terms navigation, usability, and workload. These results, in terms of the specific measures used, are unique compared to previous studies.

Performance may not increase among physicians due to a more purposeful exam room computing set-up (layout B) from an objective point of view, but reducing the physicians perceived workload and increasing situation awareness with a more thoughtful computing arrangement can lead to an increase in patient centeredness and perhaps even patient care. This can mainly be achieved through screen sharing by inviting the patient in on care decisions as they relate to the information on the EHR screen and giving the patient a feeling of greater involvement.

This study has some limitations that should be noted. Due to the challenges of recruiting physicians to participate in a laboratory simulation away from their clinics, convenience sampling was used and the majority of the participants were resident physicians, whose practices may not generalize to all primary care providers. Although some of the providers had previous experience using a wall-mounted armature system, which may have introduced some learning bias, there was a good deal of variety in overall previous experiences with exam room computing set-ups across the providers. Limitations of the current study also existed with the patient scenarios. The scenarios did not require the provider to conduct a full physical exam, which would be more common for providers when conducting a patient visit. However, this was omitted because the focus of the study was on the computing arrangement and patient centeredness, not the provider's ability to conduct a physical examination. Additionally, certain nuances of the provider-patient interaction, such as mutual eye gaze of the provider and patient on the computer monitor, were not considered as part of patient centeredness, but should be incorporated in future studies. Another limitation was that one of the study team members played the role of the patient in each patient visit, could possibly have introduced bias during the study sessions. This was done because hiring an independent patient actor was cost prohibitive for the study. However, the study team member who played the patient was the senior member of the study team and took great care to be consistent across layout types and providers, and not compel the provider to share the screen with them by following a pre-determined patient file and pre-planned responses. Also, in both patient scenarios the patient was interested in viewing trends of their blood pressure or respiratory rate values over a period of time. This was purposefully designed into the scenarios to encourage the provider to share the screen at least once while using layouts A and B. In reality, there are patients who may not be interested in viewing the screen at all, which potentially limits the generalizability of the current laboratory simulation.

Finally, it would be interesting to see how layout A and B compare performance-wise over the course of an entire work day. Future research should look to conduct studies of provider-patient scenarios over the course of an entire work day in a real-world clinical environment. More specifically, future work should focus on the effects of the different layouts on performance, patient centeredness, workload, workflow integration, and situation awareness over the course of multiple patient interactions, to determine more realistic outcomes of the different layouts. Additionally, future studies could introduce a patient scenario where providers are required to reference imaging data (X-rays, CT scans, etc.) to better understand the role of the computing device in a more complex patient visit. Based on the study findings, we argue that layout B would be preferred based on the lower amount of perceived workload, greater perceived levels of situation awareness, and greater workflow integration. This may lead to providers feeling less fatigued towards the end of the day. The conclusion about layout B as preferred, however, is based solely on the study findings and does not take into account cost or other organizational factors.

Discussion – Field Study

Providers who used the new exam room design spent a greater proportion of time focused on the patient, less proportion of time focused on the computer, and more time spent in screen-sharing activities with the patient, as compared to the legacy exam room design. This suggests that the new exam room design, with a wall-mounted monitor on an armature system for ease of (re)-positioning and easily moveable workspaces, resulted in a greater degree of patient centeredness. Furthermore, providers who used the new exam rooms had greater situation awareness than those who were in the legacy exam rooms. These results imply that the ability to adjust the position of the monitor and to keep it within the view of the patient enhanced situation awareness as related to information sources (the patient and EHR) and potentially the ability to integrate them.

An unexpected result was that providers rated workflow integration higher in the legacy exam rooms. The workflow integration instrument included aspects of navigation, functionality, ease of use, workload, and paper-based workarounds. It is possible that most of these elements were not highly related to the layout of the exam room, but instead were more related to the interaction of the provider and computer. Clear conclusions about workflow integration need to be tentative, however, given the small sample size here. In our laboratory simulation study, with a larger sample size, we found evidence that the new exam room design produced a higher degree of workflow integration as compared to the legacy exam room design.

In the debrief interviews, providers valued the ability to easily swivel and share the screen with the patient in the new exam room design. Similarly, patients expressed an interest in viewing what was on the computer screen in the new exam rooms as compared to the legacy exam rooms, where the screen was not easily viewable to the patient. These findings support the notion of 'using the computer to facilitate conversation', the #1 ranked strategy for promoting provider-patient interaction with the use of exam room computing, according to a systematic review of the literature.[28] The new exam room design seems to facilitate this strategy. The new design, by virtue of the ease of (re)positioning the monitor and easily moving the workspace furniture, may also facilitate other evidence-based practices for promoting provider-patient interaction such as: sustaining eye contact with the patient while typing; using a physical posture that allows the provider to face the patient most of the time; and inviting the patient to look at the screen before the s/he asks.[28]

There are limitations to this field study, which should be taken into account when interpreting the results. We had hoped to recruit more providers and patients to participate; however, recruitment was more challenging than we had anticipated and our sample size was relatively small. Therefore, we only present descriptive analyses without inferential statistics. Furthermore, there are potential uncontrolled factors in the field that may impact comparison between the new exam room design implemented at the CBOC and the legacy exam rooms implemented at the main facility and annex building. For example, the type of providers and/or patients may differ, even though all facilities belonged to the same health care system. The main facility and annex were located in a downtown urban setting, whereas the CBOC was located in a suburban setting. We are preparing a grant application to conduct a similar, larger study that will address these limitations of sample size and settings.

Conclusions

In the laboratory simulation study, although neither layout was significantly different in terms of objective performance measures (efficiency, errors, and proportion of time focused on the patient), results show that layout B was the preferred exam room computing layout. Additionally, providers experienced reduced workload, increased situation awareness, and better integration with clinical workflow using layout B when compared to layout A. Layout B also encourages a greater amount of screen sharing activities, consistent with the evolving paradigm of the computer and EHR being a third party and serving as a mediator between provider and patient.

In a field comparison of new and legacy exam room designs, providers spent a greater proportion of time focused on the patient, spent more time in screen sharing activities with the patient, and had a higher degree of situation awareness when using the new exam room layout with a wall mounted monitor on an armature system for ease of (re)positioning and a moveable workspace furniture. However, the legacy exam rooms received higher workflow integration scores. Provider and patient debrief interviews also supported the new exam room design. Providers valued the ability to easily reposition the monitor and share it with the patient and patients expressed more interest in what was on the monitor in the new exam room design. Overall, our results from both the laboratory simulation study and the field study were supportive of the new exam room design.

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List of Publications and Products

1. Weiler DT, Satterly T, Rehman SU, et al. Ambulatory clinic exam room design with respect to computing devices: A laboratory simulation study. IIE Trans Occup 2018; In Press.

2. Saleem JJ, Weiler DT., Satterly T, et al. Field investigation of ambulatory clinic exam room design with respect to computing devices: A pilot study. In Proc Hum Factors Ergon Soc Annu Meet 2018; In Press