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Beyond the Task: Developing a Tool to Measure Workplace Characteristics That Affect Cognitive Load and Learning

Sarah Blissett

Sebastian Rodriguez
Thomas Jefferson University

Atif Qasim

Patricia O'Sullivan

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Sarah Blissett, MD, MHPE, Sebastian Rodriguez, MD, Atif Qasim, MD, MSc, and Patricia O'Sullivan, EdD

Abstract

Purpose

Educators lack tools to measure the workplace characteristics that learners perceive to affect learning. Without a tool that encompasses the social, organizational, and physical components of workplace learning environments (WLEs), it is challenging to identify and improve problematic workplace characteristics. Using echocardiography WLE, this study developed a tool to measure workplace characteristics that cardiology fellows perceive to affect learning.

Method

The Workplace–Cognitive Load Tool (W-CLT) was developed, which encompasses 17 items to measure workplace characteristics that could affect perceived cognitive load and learning. Exploratory factor analysis was used to identify the most parsimonious structure. A total of 646 cardiology subspeciality fellows were recruited from 60 cardiology fellowship programs to complete the survey between November 2020 and February 2021. Validity evidence was collected, guided by the unified model of validity.

Results

A total of 308 fellows (response rate, 49%) participated in the survey. The most parsimonious structure included 4 factors: (1) workplace-task, (2) workplace-environment, (3) workplace-orientation, and (4) workplace–teaching and feedback. All factors had high reliability (Cronbach $\alpha = 0.92$, 0.92, 0.96, and 0.94, respectively). Social, organizational, and physical components of WLEs were represented in the items. Workplace–teaching and feedback had moderate negative correlations with workplace-environment ($r = -0.41$, $P < .001$) and workplace-orientation ($r = -0.36$, $P < .001$). A moderate positive correlation was found between workplace-task and workplace–teaching and feedback ($r = 0.42$, $P < .001$). Workplace-task had weak negative correlations with workplace-environment ($r = -0.22$, $P < .001$) and workplace-orientation ($r = -0.23$, $P < .001$).

Conclusions

The W-CLT measures workplace characteristics that cardiology fellows perceive to affect their learning. The presence of social, organizational, and physical components emphasizes how workplace characteristics can enhance or impede learning. The W-CLT provides a foundation to explore how learning can be optimized in other WLEs.

Participating in clinical work is integral to learning in workplace learning environments (WLEs).[1–4] Workplace learning environments are complex environments where social interactions, organizational structure, and shared spaces shape and support learning through clinical work.[5] They offer opportunities to learn from clinical work through clinical outcomes, patient feedback, supervisor feedback, comparison to peers, and role modeling.[2,3] However, some characteristics of WLEs could counteract the opportunities for learning. For example, time pressures[6] and interruptions[7] could jeopardize learning in WLEs. Consequently, experts have made recent calls for immediate rigorous research and expanded scholarship to evaluate and improve WLEs to support learning.[5]

Cognitive load theory (CLT) provides a framework to understand how some characteristics of a workplace could improve learning, whereas other characteristics could impede learning. Cognitive load theory is an educational theory that outlines principles for maximizing learning through addressing the 3 subtypes of cognitive load to optimize use of our finite short-term memory.[8,9] The 3 subtypes of cognitive load are intrinsic load (IL), extraneous load (EL), and germane load (GL). Intrinsic load describes the mental effort required to complete the task. Task complexity and learner level are key factors that contribute to perceived IL, with learning and cognitive load optimized when learners engage in tasks that are matched to their knowledge or skill level. Extraneous load is any component that does not contribute to task completion, such as interruptions. Germane load is any processing that contributes to long-term storage of the information, such as elaboration of knowledge with a supervisor or through feedback. In applying these principles to optimize learning, IL should be managed, EL should be minimized, and GL should be promoted. In classroom and controlled

Please see the end of this article for information about the authors.

Correspondence should be addressed to Sarah Blissett, B6-117A, 339 Windermere Rd, London, ON N6A 5A5, Canada; telephone: (519) 663-3501; email: Sarah.Blissett@lhsc.on.ca.

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settings, key factors in optimizing cognitive load and learning are the task, the learner, and the supervisor.

Although CLT was originally conceptualized for classroom settings, scholars have recently focused attention on its applicability to WLEs.[10–13] In adapting CLT to the WLEs, we need to consider how perceived cognitive load should be measured within the complexities of a WLE. We must also consider the sources of cognitive load that exist beyond the clinical task, the learner, and the supervisor in WLEs. Tools to assess cognitive load in the WLE may need to incorporate the social, organizational, and physical components of WLEs so that educators can identify the workplace characteristics that affect cognitive load and learning. This tool could be used by educators to identify which aspects of the WLEs could be addressed to maximize learning in their context. For example, if there is a workplace characteristic that typically enhances learning but is not maximally present in their WLE (e.g., supportive resources), then an educator could implement strategies to increase that characteristic in their workplace to improve learning.

A tool with sound psychometric properties that accounts for the social, organizational, and physical components of WLEs does not currently exist. Current tools used to measure WLEs are predominantly focused on identifying the presence or absence of key components of the social, organizational, and physical components of WLEs,[14,15] with emphasis on autonomy, teaching, and social support.[16] These tools aim to capture the learning climate rather than to identify how a workplace characteristic could enhance or limit learning. Although tools designed for classroom-based instruction are available, they are likely insufficient for a WLE context. Overall global ratings of cognitive load (Paas scale[17]) and other classroom-based cognitive load scales that focus on the task and its instruction (Leppink scale[18]) may not capture the nuances of the additional contributors to cognitive load in WLEs. Similarly, logistic and feasibility challenges limit the use of eye-tracking techniques in WLEs. Accordingly, there has been expansion of task-oriented tools in WLEs, including colonoscopy[10] and inpatient consultations.[19] These task-oriented tools include individual learner's perception of complexity (IL),[10,19] instruction from supervisors (EL),[10] distractions (EL),[10,19] and invested effort in learning (GL);[10,19] however, they do not encompass the entirety of workplace characteristics that may enhance or impede learning.

The workplace characteristics identified in our previous work[20] may be appropriate to form the foundation for a tool to measure workplace characteristics that learners perceive to affect their learning. We previously explored workplace characteristics that learners perceived to affect cognitive load and learning in an echocardiography context within a cardiology training program at a single center.[20] Echocardiography is ultrasonography of the heart. We found that managing IL was challenging because cardiology fellows often struggle to identify tasks that are of the appropriate complexity for their learner level. Unlike a classroom setting, where task complexity is determined by the supervisor, fellows selected their own tasks in this context. Fellows used the indication for the echocardiography to determine whether it was of appropriate complexity; they desired more guidance on how to know whether the echocardiogram was the appropriate complexity and how to know when they could progress to interpreting more complex echocardiograms. There were multiple workplace characteristics that affected EL, including interruptions, time pressures, and technology. Fellows found it harder to interpret echocardiograms due to interruptions and unfamiliarity with the required reporting software. Germane load was promoted through discussions with attendings for feedback and teaching. When attendings were not available, some fellows compared their preliminary interpretations with final interpretations by attendings as a strategy to promote GL, but others did not, which resulted in decreasing the opportunity for promoting GL. We argue that these characteristics have broader relevance to other WLEs. We recognized that these items could inform the design of a tool to measure workplace characteristics that learners perceive to affect their cognitive load and learning.

Echocardiography WLEs provide a suitable model to design a tool to measure the workplace characteristics learners perceive to affect their learning. In the United States, images are frequently acquired by a technician and then interpreted by a cardiology fellow, echocardiography fellow, or cardiologist. Cardiology fellows predominantly learn this complex skill in a WLE. Cardiology fellows, echocardiography fellows, and attendings share a physical space, typically called a reading room. The reading room includes multiple computer workstations for image interpretation. On a social level, fellows interact with other fellows, supervisors, nurses, scheduling clerks, and technicians. The physical space, social components, and organizational structure share similarities with other WLEs encountered by residents and fellows, such as workrooms on inpatient units and operating rooms.

Using learner participants in echocardiography WLEs across the United States as a model, we designed a tool to measure the perceived effect of workplace characteristics on learning. Examining the results in this population will provide a foundation for a robust tool in other contexts to measure workplace characteristics that are perceived to affect cognitive load and learning.

Method

Study design

We conducted a psychometric study to design a tool, called the Workplace–Cognitive Load Tool (W-CLT), to measure cognitive load imposed by workplace characteristics of echocardiography WLEs and identify the workplace characteristics that enhanced or impeded learning. We used exploratory factor analysis to identify the most parsimonious factor structure for the W-CLT. We used the unified model of validity as described by Downing[21] to inform our validity arguments, incorporating evidence from content, response process, internal structure, and relationship with other variables. We did not collect evidence related to consequences. The current study was situated in a broader research program of learning echocardiogram interpretation in WLEs.[22] Importantly, this study has distinct aims and reports findings not included in the other studies of this larger program of research.

W-CLT development

We used the 7-step survey design process outlined by Artino et al[23] to inform the

design of the W-CLT. These 7 steps include (1) conduct a literature review; (2) conduct interviews or focus groups; (3) synthesize the literature review, interviews, and/or focus groups; (4) develop items; (5) conduct expert validation; (6) conduct cognitive interviews; and (7) conduct pilot testing. Steps 1 to 5 provide evidence of content validity. Steps 6 and 7 examine response process evidence.

Our literature review confirmed a gap in tools to measure the cognitive load of workplace characteristics. The literature search further informed development of the W-CLT. First, we identified literature on key components of WLEs,[5,15,24] including personal, social, organizational, and physical domains, that provided the broad structure of workplace characteristics. Second, we identified tools to measure cognitive load of specific tasks, including colonoscopies[10] and consultations.[19]

We used data from our prior work in step 2.[20] In prior work,[20] we interviewed cardiology fellows on the workplace characteristics that helped them interpret an echocardiogram (IL), made it more difficult to interpret an echocardiogram (EL), or helped them learn about interpreting echocardiograms (GL).

We synthesized the literature review and our prior interviews to develop the items. We designed items based on the workplace characteristics identified in our prior study,[20] including items related to IL (how they identified tasks of suitable complexity), EL (interruptions, orientation, time pressures, and technology), and GL (teaching attendings, echo fellows, asking questions, and reviewing final reports).

In designing the items, we defined the task as the interpretation of an echocardiogram. We did not specify the task as interpreting the echocardiogram within a workplace. This definition places workplace characteristics, such as reporting software and disruptions, as EL because the echocardiogram could be interpreted verbally, on paper, or in the electronic medical record without using the reporting software, and the echocardiogram could be interpreted without disruptions if not performed within a workplace environment.

Through designing the items, we realized that the W-CLT would differ from task-oriented tools.[10,19] We recognized the need to measure general experience with workplace characteristics rather than perceived load after a single task because we anticipated that a general approach could provide additional insights on the workplace characteristics. For example, rather than asking learners, "Please rate your agreement with the following statement regarding your experience during the procedure you've just completed: I felt distracted by the environment (i.e., my pager going off, environmental noise, layout of the room),"[10] our item was "phone calls detracted from my ability to interpret an echocardiogram." Our item was not specific to one instance but rather to the general experience with a workplace characteristic. Although both these items address distractions, we designed our items to reflect general experience with a workplace characteristic. We used a 5-point Likert scale as follows, with 1 indicating strongly disagree; 2, disagree; 3, neither agree nor disagree; 4, agree; and 5, strongly agree. We did not measure global ratings of cognitive load (e.g., Paas scale) because these ratings relate to a specific task, and we were examining the perceived cognitive load related to the WLE.

Participants

We recruited cardiology subspeciality fellows (n = 646) from 60 randomly selected Accreditation Council for Graduate Medical Education–accredited cardiology fellowship programs to complete our online survey (Qualtrics) between November 2020 and February 2021. We used an Excel random number generator (Microsoft Corp) to randomly select 60 programs from all 245 Accreditation Council for Graduate Medical Education–accredited cardiology programs. Participants had completed at least 1 echocardiography rotation before participation. No incentive to participate was provided.

Data collected

Data on gender, year of study, and self-reported race were collected. We did not collect data on training program to preserve anonymity. We collected responses to the 17 items on workplace characteristics that could affect perceived cognitive load. Additionally, we collected data on other aspects of the WLE that might affect perceived cognitive load, including where participants usually interpreted echocardiograms, how many people typically share the physical environment where they reported echocardiograms, if they were interrupted often, their familiarity with the software in their WLE, and whether receiving feedback was helpful.

Validity assessment of W-CLT

We used the principles of the unified model of validity to guide our assessment of validity.[21] We outline the features of our validity arguments below.

Content. Content validity refers to whether the tool measures what it intends to measure.[21] In designing the instrument, we took steps to incorporate content validity. We used literature reviews and consulted with experts when designing the items in the instrument. Three CLT experts (Drs. Justin Sewell, Sam Brondfield, and John Q. Young) reviewed the items to independently classify each item with a CLT subtype. We revised items if the experts could not map the item to a subtype or it was different from the research team anticipated. Other members of our research team (A.Q. and S.B.) reviewed the items to ensure they represented features common to most echocardiography WLEs.

Response process. Response process refers to data integrity, with emphasis on minimizing sources of error related to administration of the tool.[21] We conducted pilot work to ensure our response process was valid. We conducted cognitive interviews with 3 advanced echocardiography fellows to ensure the wording of the items had the intended meaning and the questionnaire was not too burdensome to complete.

Internal structure. Internal structure relates to psychometric characteristics of the tool, including reliability of factors.[21] We used exploratory factor analysis with principal components analysis for extraction with Kaiser varimax normalization (0.841; $P < .001$). We included 17 items. Factor loadings less than 0.4 were suppressed. We selected items with Eigen values greater than 1. For reliability, we calculated a Cronbach α for each factor.

Relationships to other variables. Relationships to other variables often include correlations, which can be confirmatory or counterconfirmatory.[21] We first calculated correlations between subscales of workplace-task, workplace-environment, workplace-orientation, and workplace–teaching and feedback. To do so, we created subscales by summing items for workplace-task, workplace-environment, workplace-orientation, and workplace–teaching and feedback. We then calculated Pearson correlation coefficients between all subscales as well as the following 3 correlations: workplace-environment and being interrupted often, workplace-orientation and unfamiliarity with software, and workplace–teaching and feedback and receiving feedback. On the basis of known associations among the cognitive load subtypes,[9,10,18] we anticipated positive correlations between workplace-task and workplace–teaching and feedback, negative correlations between workplace–teaching and feedback and workplace-environment, and negative correlations between workplace–teaching and feedback and workplace-orientation.

We did not anticipate that year of training would correlate with the subscales as task complexity and roles within the echocardiography WLE expand as training progresses. Furthermore, our general approach to item development included items from all stages of training rather than a cross-sectional measurement (e.g., items around orientation asked fellows to reflect on orientation at the early stages of learning to interpret echocardiograms). The study was deemed exempt by the University of California San Francisco Institutional Review Board.

Results

Response rate and demographics

The questionnaire was completed by 308 participants (response rate, 49%), with 72% identifying as male. The predominant male gender aligns with demographics of U.S. cardiology training programs.[25] Eighty-six participants (28%) were in their first year of cardiology training, 111 (36%) in their second year, and 111 (36%) in their third year. Aligning with backgrounds reported for U.S. cardiology trainees,[26] 38% as Asian, 8% as Black, 10% as Latinx, and 42% identified as White. Most participants (98%) interpreted echocardiograms in echocardiography reading rooms, with 60% in large reading rooms (6–10 people) and 38% in moderate-sized reading rooms (3–5 people).

Validity assessment of W-CLT

In applying the principles of the unified model of validity to guide our assessment of validity,[21] we outline results pertaining to our validity argument below.

Content. We incorporated the workplace characteristics identified in our prior qualitative work to inform the items. Furthermore, our research team applied their own expertise in CLT and echocardiography, as well as sought expertise from other content experts in designing and refining the items. Pilot testing and cognitive interviews also contributed to the content of the items.

Response process. Pilot testing improved wording of questions, reducing variance. We invited cardiology fellows from a broad spectrum of training programs across the United States to participate, using a user-friendly interface on Qualtrics.

Internal structure. The most parsimonious structure included 4 factors relating to the workplace characteristics: workplace-task, workplace-environment, workplace-orientation, and workplace–teaching and feedback. The 4 factors aligned with CLT subtypes (Table 1 and Figure 1), with workplace-task mapping to IL, workplace–teaching and feedback mapping to GL, and workplace-environment and workplace-orientation mapping to EL.

The 4-factor model accounted for 85% of the total variance (Table 1). Item loads were high: workplace-task, 0.813 to 0.899; workplace-environment, 0.739 to 0.895; workplace-orientation, 0.895 to 0.922; and workplace–teaching and feedback, 0.827 to 0.890. Reliability for items comprising each factor was high: workplace-task, 0.92; workplace-environment, 0.92; workplace-orientation, 0.96; and workplace–teaching and feedback, 0.94.

Relationships to other variables. Correlations among the factor subscales provide additional validity evidence because the direction of the correlations aligns with principles of CLT. On the basis of principles of CLT, we would expect higher IL to correlate with higher GL and higher EL to correlate with lower IL and lower GL. We found that IL scores (workplace-task) were positively correlated with GL (workplace–teaching and feedback) ($r = 0.42$, $P < .001$). Lower IL scores on workplace-task correlated with higher EL scores on both workplace-environment ($r = 0.22$, $P < .001$) and workplace-orientation ($r = -0.30$, $P < .001$). Similarly, higher EL ratings (workplace-environment and workplace-orientation) correlated with lower workplace–teaching and feedback scores (workplace-environment and workplace–teaching and feedback: $r = -0.41$, $P < .001$; workplace-orientation and workplace–teaching and feedback: $r = -0.36$, $P < .001$). Lower scores on workplace-orientation correlated with lower scores on workplace-environment ($r = 0.47$, $P < .001$), which would be expected given that both relate to EL.

Aligning with our hypotheses, higher scores on workplace-environment strongly correlated with "being interrupted often" ($r = 0.85$, $P < .001$), higher scores on workplace-orientation correlated with being "unfamiliarity with software" ($r = 0.53$, $P < .001$), and higher scores on workplace–teaching and feedback correlated with "receiving feedback" ($r = 0.54$, $P < .001$).

Discussion

We developed a tool, the W-CLT, that can be used to measure the workplace characteristics cardiology fellows perceive to affect their learning in echocardiography reading rooms. The 4 factors of the tool include workplace-task, workplace-environment, workplace-orientation, and workplace–teaching and feedback. Multiple sources of evidence support our validity argument for the W-CLT, including content, response process, internal structure, and relationships with other variables. In exploring these factors, we can gain insight into the WLEs, which then positions us to consider how this type of tool could be used in other workplace-based learning contexts.

The 4 factors provide insights into how educators could improve learning in WLEs. Many of the items in workplace-task and workplace–teaching and feedback are consistent with the CLT

Table 1

Factor Loadings and Communalities in an Exploratory Factory Analysis in a Study of a Tool to Measure Workplace Characteristics That Cardiology Fellows Perceive Affect Learning, November 2020 and February 2021[a]

Characteristic[b]	Factor loading	Communality	Component of the WLE
Workplace characteristics relating to the task (workplace-task)			
I often had guidance on which echos were appropriate for my learning level (i1)	0.899	0.906	Organizational
I was specifically told which resources to use to look up normal values, interpretive techniques, and calculations (i2)	0.853	0.905	Organizational
A useful strategy for me is writing questions for each echo to follow up with an attending or fellow (i3)	0.813	0.812	Personal
Workplace characteristics relating to the environment (workplace-environment)			
Interruptions got in the way of me effectively reading echocardiograms (ee1)	0.886	0.843	Physical
Telephone calls detracted from my ability to read an echocardiogram (ee2)	0.869	0.945	Physical
Inpatient teams detracted from my ability to read an echocardiogram (ee3)	0.895	0.885	Physical
Performing other echocardiogram-related procedures detracted from my ability to read an echocardiogram (ee4)	0.805	0.686	Organizational
Time pressures detracted from my ability to learn to read echocardiograms (ee5)	0.791	0.763	Organizational
Unfamiliarity with software unnecessarily consumed my time (ee6)	0.739	0.698	Organizational
Workplace characteristics relating to orientation (workplace-orientation)			
I was oriented in how to use the reporting system to measure dimensions and gradients before interpreting echocardiograms (eo1)	0.918	0.944	Organizational
I was oriented in how to use the reporting system to complete reports before interpreting echocardiograms (eo2)	0.922	0.972	Organizational
I was oriented in how to use the reporting system to view images before interpreting echocardiograms (eo3)	0.895	0.957	Organizational
Workplace characteristics relating to teaching and feedback (workplace–teaching and feedback)			
Echocardiography fellows enhanced my ability to read a TTE (g1)	0.827	0.724	Social
Having attending assigned to teaching enhanced my ability to read an echocardiogram (g2)	0.890	0.881	Organizational
Reading with attendings enhanced my ability to read an echocardiogram (g3)	0.876	0.909	Social
Checking back on reports after they were finalized by an attending enhanced my ability to read an echocardiogram (g4)	0.855	0.823	Personal
Receiving feedback enhanced my ability to read an echocardiogram (g5)	0.834	0.881	Social

Abbreviations: ee, workplace characteristics that affect extraneous environment (workplace-environment); eo, workplace characteristics that affect extraneous orientation (workplace-orientation); g, workplace characteristics that affect germane load (workplace–teaching and feedback); i, workplace characteristics that affect intrinsic load (workplace-task); TTE, transthoracic echocardiogram; WLE, workplace learning environment.

[a]Exploratory factor analysis was used with principal components analysis for extraction with Kaiser varimax normalization (0.841; $P < .001$). Factor loadings less than 0.4 are suppressed.

[b]Parenthetical lowercase letters and numbers map to the items in Figure 1.

principles used in the classroom to optimize learning.[9] However, the guidance to select tasks is unique to the WLE, particularly in environments where fellows have agency in selecting tasks, and highlights the importance of future strategies to improve how trainees find the tasks they choose for learning. Furthermore, this finding raises the issue of how learners maximize learning when they are assigned clinical work by attendings or more senior learners: how do learners indicate when assigned patients, procedures, or imaging tasks are too challenging or too easy, and how much do attendings or more senior learners consider matching the complexity of the clinical work with the knowledge or skill level of the learner when assigning patients, procedures, or imaging tasks to learners?

The items in workplace-task factor emphasize the value of providing supportive resources in the WLE to manage IL. The workplace–teaching and feedback factor encompasses characteristics that enabled fellows to interact with supervisors or echo fellows for learning, as well as fellow-led strategies for learning, such as checking final reports. This factor further emphasizes the importance of strategies to facilitate near-peer and supervisor interactions in WLEs, such as dedicated time for interactions and feedback within the rotation organization. This finding aligns with learners reporting the desire to have more interaction with attendings as well as valuing what can be learned from near-peers.

The workplace factors perceived to impede learning in WLEs had some distinctions from how EL is conceptualized in classroom settings.[9] The workplace-environment factor was composed of workplace elements typically thought to impose EL, including distractions and interruptions. However, this factor also included items that are not present in classroom settings, such as interacting with other inpatient teams, performing other

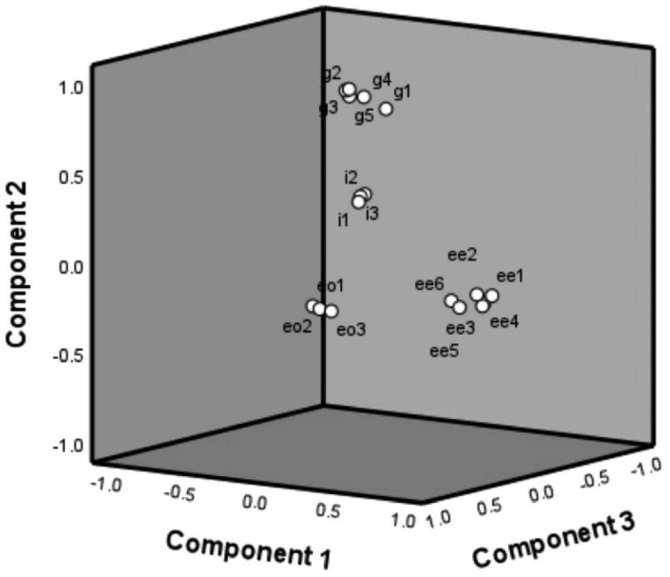

Figure 1 Exploratory factory analysis factor plot of the factors aligned with cognitive load theory subtypes in a study of a tool to measure workplace characteristics that cardiology fellows perceive affect learning, November 2020 and February 2021. Abbreviations: ee, workplace characteristics that affect extraneous environment (workplace-environment); eo, workplace characteristics that affect extraneous orientation (workplace-orientation); g, workplace characteristics that affect germane load (workplace–teaching and feedback); i, workplace characteristics that affect intrinsic load (workplace-task).

echocardiography-related procedures, and unfamiliarity with the workplace environment. Additionally, workplace-orientation items related to orientation to the reporting system, highlighting an opportunity for educators to enhance the orientation to software and equipment used to complete tasks in WLEs. These findings may prompt other specialty fields to reflect on sources of EL for their learners. Orientation is challenging because it is repetitive with each cycle of learners, but it clearly contributes to cognitive load and learning in WLEs.

Our findings also highlight that educators need to consider how the social and organizational components of a WLE could increase or impede learning. The presence of social and organizational components of WLEs in the W-CLT adds strength to the argument that the WLE is more than the shared physical or virtual space.[5] All 4 factors had items related to the social or organizational components of the WLE. In addition to items relating to physical space, workplace-environment and workplace-orientation also included organizational components (e.g., time pressures and orientation). Furthermore, there were no items relating to physical components in workplace-task or workplace–teaching and feedback. Workplace-task and workplace–teaching and feedback encompassed personal (e.g., writing questions and checking reports), social (e.g., reading with an attending), and organizational (e.g., teaching attending assigned) components. These findings highlight the importance of thinking beyond the physical environment, which, of course, should not be neglected.

From a theoretical perspective, our findings add 3 important insights into the emerging literature on how CLT may need to be modified for use in WLEs.[12,20] First, although EL has typically been conceptualized as a single entity, we identified 2 distinct workplace factors that mapped to EL (workplace-orientation and workplace-environment). Workplace-orientation encompassed orientation to the task and technology. Workplace-orientation may be a corollary to the "instruction to the activity" factor represented in a cognitive load scale for classroom environments.[18] However, the environment factor is not represented in classroom scales, emphasizing the need to adapt CLT principles for WLEs. Second, all factors were composed of workplace characteristics in addition to learner and supervisor characteristics, which adds to the ongoing conversation of how to define the "task" in a WLE. For example, is the "task" interpreting the echocardiogram, or is it interpreting the echocardiogram within the WLE? Our data support the latter definition because workplace characteristics mapped to all 3 cognitive load subtypes. Third, the workplace-task items highlight the nuances of supervision in managing IL in a WLE. In WLEs with direct supervision, the supervisor could help the learner manage IL by providing guidance around task complexity. However, in WLEs with less direct supervision, such as the echocardiography WLE, learners needed specific guidance to select tasks of appropriate complexity and direction regarding supportive resources to support task completion.

Any WLE where the trainee has agency in the tasks or part of tasks that they complete will find this study relevant. This situation applies in all health sciences training, including radiology, internal medicine, psychiatry, obstetrics, surgery, and anesthesia.[3,27,28] Our study and previous studies emphasize the importance of interactions with near-peers and supervisors to address GL to enhance development of schemata needed for future learning.[20,22] Accordingly, educators need to support the organizational and social components of WLEs to maximize interactions among learners, near-peers, and supervisors in all WLEs.

Our study leads to multiple lines of future inquiry within and beyond echocardiography WLEs. Within the echocardiography context, educators could apply the W-CLT to their own WLE to identify which workplace characteristics could be enhanced or mitigated to maximize learning and then design interventions for improvement. For example, if the W-CLT identifies that a WLE has highly prevalent interruptions that are impeding learning, then educators could design strategies to mitigate the impact of the interruptions on learning. In a radiology context, educators have accomplished this by assigning one trainee to respond to telephone calls and inpatient requests each day, allowing the other trainees to focus on image interpretation and learning.[29] The W-CLT could be readministered to determine whether it is sensitive to the improvements. If so, other specialties could create their own workplace cognitive load

inventory and use it to optimize cognitive load of workplace characteristics. As others adapt the W-CLT items to explore the workplace characteristics that are perceived to affect learning in their contexts, insights from seemingly unrelated workplaces, such as surgical contexts, may suggest how cognitive load and learning could be optimized in other WLEs. Our findings could also inform design of future task-oriented tools of learning or procedural skills in WLEs. We argue that future tools should consider inclusion of workplace characteristics beyond the supervisor and physical environment, including guidance for task selection, orientation to the task, and orientation to the environment.

There are 4 important limitations to acknowledge. First, we situated our study in an echocardiography WLE. Consequently, our findings may not generalize to all workplace contexts. Further study is required to explore the workplace characteristics that impose cognitive load and affect learning in contexts in which learners complete tasks of lower complexity, have less agency to select tasks, interact with technology to a lesser extent, or work in larger teams to complete tasks. Second, we surveyed about general experience with workplace characteristics rather than a posttask assessment. Accordingly, we could not correlate factors with overall mental effort ratings. Third, our response rate of 49% could potentially limit the generalizability of our findings. However, we believe our findings are representative because they align with the gender[25] and racial backgrounds[26] reported for cardiology fellows in the United States. Fourth, our survey items asked participants the extent to which a factor in the WLE impacted their perceived learning. Additional insights could be gleaned from identifying how often the factor was present in future studies.

In conclusion, we developed a tool with strong psychometric evidence to measure workplace characteristics that cardiology fellows perceive to affect their learning from a cognitive load perspective. The presence of social, organizational, and physical components in the tool highlights how workplace characteristics contribute to perceived cognitive load in WLEs. Educators could use the tool to evaluate strategies designed to optimize workplace characteristics to support learning from clinical tasks in the workplace.

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S. Blissett is assistant professor, Department of Medicine, Division of Cardiology, and a researcher, Centre for Education Research and Innovation, Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada.

S. Rodriguez is a cardiology fellow, Department of Medicine, Thomas Jefferson University, Philadelphia, Pennsylvania.

A. Qasim is associate professor, Division of Cardiology, and program director of the general cardiology fellowship, University of California San Francisco, San Francisco, California.

P. O'Sullivan is professor, Departments of Medicine and Surgery, and director of research and development in medical education, Center for Faculty Educators, University of California San Francisco, San Francisco, California.

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