Received: 9 September 2020 | Revised: 18 December 2020 | Accepted: 28 January 2021

DOI: 10.1002/acp.3803

RESEARCH ARTICLE

WILEY

# Features of the learner, task, and instructional environment that predict cognitive load types during patient handoffs: Implications for instruction

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## Summary

We used the cognitive load inventory for handoffs (CLIH) to identify predictors of cognitive load types during patient handoffs in order to identify opportunities to improve instruction. In 2019, out of a total of 1,807 residents and fellows within a 24-hospital health system, 693 (38.4%) completed the CLIH after a patient handoff. Multivariable regression yielded predictors for each cognitive load type. Intrinsic load associated with features of the learner (fatigue positively associated) and task (higher complexity clinical setting, number of patients, and handoff length positively associated). Extraneous load associated with learner (fatigue positively associated, and number of times trained in the verbal protocol negatively associated) and task design (number of sources of written information positively associated). Germane load associated with learner (level of training negatively associated, and fatigue positively associated) and instructional environment (interruptions negatively associated and formal feedback positively associated). Implications for instructional design are explored.

**KEYWORDS**

cognitive load theory, cognitive load types, instructional design, medical education, patient handoffs, patient safety

## 1 | INTRODUCTION

Patient handoffs occur when the responsibility for the care of a patient or panel of patients is transferred from one clinician or team to another. Patient handoffs occur frequently and are vulnerable to communication errors that can lead to patient harm (Horwitz et al., 2008). As a result, performing patient handoffs has been identified across the medical education continuum as an essential competency (Caverzagie et al., 2015; Lane-Fall et al., 2018; Lomis et al., 2017; Young et al., 2018). Despite the increased emphasis in both undergraduate and graduate medical education, patient handoffs remain a significant patient safety challenge, even in those studies reporting improvements (Starmer et al., 2014). Cognitive load theory (CLT) has helped unpack the complexity of handoffs (Young, Ten Cate, et al., 2016). Originally developed by Sweller (1988), CLT focuses on the implications of limited working memory (WM) for learning (Sweller & Van Merrienboer, 2013). While sensory and long-term memory have relatively infinite capacity, WM is highly constrained. In fact, WM can only actively process (i.e., organize, compare and contrast) two to four elements at any given moment (Baddeley, 2012; Cowan, 2001). When the cognitive load of a learning task such as a handoff exceeds the working memory capacity of the trainee, learning and performance suffers.

CLT envisions at least two, and possibly three, types of cognitive load (CL) (Young et al., 2014). *Intrinsic load* (IL) arises from the information processing demands associated with performing the task itself. Both task complexity and learner expertise determine the intrinsic load imposed by a handoff. More expert learners will experience less IL for any given task; similarly, higher task complexity will impose higher IL. *Extraneous load* (EL) occurs when learners use working memory resources to process information not essential to the task, most commonly originating from the design of the task (e.g., multiple sources of information forcing one to toggle between screens), external environment (e.g., noise or interruptions), or internal environment (e.g., excessive preoccupation with an unrelated matter) (Choi et al., 2014; Feldon, 2007; Young & Sewell, 2015). *Germane load* (GL) is imposed when learners use cognitive strategies (e.g., assess one's understanding, self-explanation) to refine existing schemata and enhance storage in long-term memory (Sweller et al., 1998). Recent work by Sweller and others has suggested that germane load may best be understood as a component of intrinsic load rather than a separate type of load (Leppink et al., 2014; Sweller et al., 2011, 2019). Yet, some empirical work, especially within medical education, has found evidence for germane load as a separate type (Sewell et al., 2016; Young, Irby, et al., 2016; Young et al., 2020). The relationship of germane and intrinsic loads and the arguments for two- versus three-factor models are active areas of theoretical and empirical research.

Prior theoretical research explored how characteristics of the learner, task, and instructional environment might modulate each cognitive load type during a patient handoff (Young, Ten Cate, et al., 2016). In this study, we examine these relationships empirically. We identify features of the learner, task and instructional environment that predict IL, EL, and GL to identify strategies to improve future handoff instructional design and protocol development.

## 2 | METHOD

### 2.1 | Study design

We performed a cross-sectional survey study to identify features of the learning and clinical environment that predict each CL type. We collected data for the current study contemporaneously with data for another study (Young et al., 2020). Both studies were planned a priori as separate efforts with different aims. The prior study focused on the instrument development process and developing evidence for validity for the Cognitive Load Inventory for Handoffs (CLIH) with respect to content, response process, and internal structure (Young et al., 2020). This study focused on associations of learner, task, and environment features with each cognitive load type in order to identify implications for handoff instruction and protocol development. We modeled this approach after a series of studies examining cognitive load during procedural learning (Sewell et al., 2016, 2017).

The Institutional Review Board for Northwell Health reviewed and deemed the study protocol exempt status as an educational research study with minimal risk.

### 2.2 | Procedures

As described elsewhere, we prospectively enrolled a sample of 1823 residents and fellows from a large, 24-hospital health system in New York that sponsors 122 distinct nationally accredited residency and fellowship programs (Young et al., 2020). Email addresses for all residents and fellows were obtained from the health system's Office of Academic Affairs. Between January and March, 2019, each trainee received an email invitation from three study authors (John Q. Young, Rebekah Sugarman, Karen Friedman) with a link to the electronic survey hosted by RED-Cap, an academic software program that supports research surveys (Harris et al., 2009). We asked participants to complete the survey after a handoff. Nonrespondents received weekly emails over 7 weeks in order to increase response rate (Dillman et al., 2008). Invitees could participate only once and could enter a drawing for one of four $250 gift cards (Stovel et al., 2018). Data collected included a measure of cognitive load types, demographic information, and features of the clinical and learning encounter, each of which is described below. Of the 1,823 trainees invited to participate, 16 had undeliverable email addresses, resulting in a pool of 1,807 potential participants. As previously reported, we received 693 responses (38.4%), representing all training programs in the health system.

### 2.3 | Measures

#### 2.3.1 | Cognitive load measures

We used the CLIH to estimate the IL, EL, and GL that each trainee experienced during the patient handoff (Young et al., 2020). A prior study collected evidence for validity for the scores generated by the CLIH. Factor analyses supported a three-factor rather than two-factor model. The three factors had high internal consistently and associated with the items for IL, EL, and GL, respectively. Model fit parameters were strong and the scores for IL, EL, and GL associated, as predicted, with level of training and clinical setting (Young et al., 2020).

The CLIH includes 16 items (11 point scale, strongly agree to strongly disagree): 5 for IL, 7 for EL, and 4 for GL. To calculate the IL, EL, and GL experienced by each individual, items within each cognitive load type were averaged together to generate a score. Table 1 depicts the items used to measure each type of CL.

#### 2.3.2 | Demographic characteristics

Demographic data included trainee gender; specialty; specialty and hospital in which the handoff occurred; reason for the handoff; and role in the handoff. We had no theoretical reason to expect these data to influence cognitive load and we did not include them in our analyses.

**TABLE 1** Items for the cognitive load inventory for handoffs[a,b]

| |
|---|
| Intrinsic load: Please rate your agreement with the following statements regarding the handoff you have completed: |
| 1. The patient problems were complex |
| 2. The handoff included significant clinical decision(s) that needed to be made |
| 3. The handoff included significant diagnostic and/or treatment uncertainty |
| 4. I had to consider multiple or complex interactions between diseases |
| 5. I had to consider multiple or complex interactions between treatments |
| 6. Extraneous load: Please rate your agreement with the following statements regarding the handoff. These statements are about the environment and your mindset during the handoff: |
| 7. The other clinician used jargon out of context |
| 8. I was distracted by the other clinician's attitude |
| 9. I was self-conscious due to who was present |
| 10. I was frequently interrupted (e.g., pages, phone calls, people, etc…) |
| 11. Noise made it difficult to concentrate |
| 12. During the handoff, important information was not easily available when I needed it |
| 13. I was thinking about things unrelated to the sign-out |
| 14. Germane load: Please rate your agreement with the following statements regarding your mental effort during the handoff you have completed: |
| 15. I had to work hard to connect my own medical knowledge to the patient problems |
| 16. I had to work hard to organize the patient information into a coherent clinical picture |
| 17. During the sign-out, I had to work hard to concentrate on how well I understood the information |
| 18. I had to take steps to clarify points of confusion |

[a]Participants were asked to rate their level of agreement with each item using a 0 ('strongly disagree') to 10 ('strongly agree') scale.
[b]Young et al. (2020).

### 2.3.3 | Predictor variables

While prior research has examined the impact of the learning and clinical environment on handoff accuracy (Young, Van Dijk, et al., 2016), previous explorations of the predictors of cognitive load types during a handoff have been theoretical (Young, Ten Cate, et al., 2016). Based on the findings from theoretical work and input from nine international experts in CLT (five) and handoffs (four), we developed questions to measure our predictor variables hypothesized to influence each type of CL. For IL, questions focused on factors related to the two main drivers as conceived by CLT: learner knowledge (e.g., level of training and fatigue—which effects learner cognition) and the task's complexity or number of information elements (e.g., clinical setting, length of handoff, number of patients, and number of clinicians).

For EL, questions related to either the learner (e.g., level of training, fatigue, number of times trained in the protocol), task design (whether the verbal and written communication were standardized, and the number of sources of written information), and the environment (e.g., interruptions and noise and their impact on concentration). Standardization of verbal and written handoff procedures is thought to reduce EL by allowing both the sender and receiver to know in what order and format each type of information is to be communicated (Young, Ten Cate, et al., 2016).

For GL, questions addressed the learner (e.g., level of training and fatigue) and the instructional environment (were receiver's able to take notes on the written component of the sign-out, did the learner receive formal feedback from a senior, fellow or faculty member, and to what extent did interruptions impact concentration). Per CLT, feedback should facilitate schema refinement and interruptions should impair concentration, a key mediator of GL.

The study authors iteratively reviewed and refined these questions and then incorporated them into the survey. Table 2 describes, for each CL type, the learner, task, and instructional environment variables that were identified as relevant and then, for each variable, the measure (i.e., survey question), data type, and the response options.

## 2.4 | Analysis

Analysis was conducted in RStudio (version 1.2.1335, build 1379). We calculated descriptive statistics using appropriate measures of central tendency and dispersion. Based on our knowledge of CLT, we used a consensus process among the authors to predict a priori whether each variable should have a positive or negative association with the relevant CL type. We then developed three multivariable linear regression models—one each with IL, EL, and GL as the outcome variable, respectively. The predictor variables identified as relevant by CLT were entered into the models. Following univariate analyses, only variables with a $p$-value of less than 0.1 were included in the multivariable regression analysis. Our data included three ordinal predictor variables, which were dichotomized. Level of training,

**TABLE 2** Measurement of handoff features predicted to be associated with cognitive load types

| Cognitive load construct | Variable | Data type | Survey question | Response options |
|---|---|---|---|---|
| Intrinsic load | | | | |
| Learner related | 1. Level of training[a] | Dichotomous (R1 vs. all other levels of training) | Indicate your year of training | PGY-1, PGY-2, PGY-3, PGY-4, PGY-5, PGY-6, PGY-7, PGY-8, or higher |
| | 2. Fatigue[a] | Dichotomous (fatigued vs. rested) | Rate your level of fatigue/rest | Very fatigued, somewhat fatigued, somewhat rested, very rested |
| Task related | 1. Clinical setting[a] | Dichotomous (ICU vs. all other settings) | Indicate the clinical setting in which the handoff occurred | Inpatient ICU, inpatient non-ICU, emergency department, ambulatory, peri-operative setting, other |
| | 2. Length of handover | Continuous | Roughly how long did the handoff take (in minutes) | Less than 5, 5–10, 11–20, 21–30, 31–40, 41–50, 51–60, 61–70, 71–80, More than 80 |
| | 3. Number of patients | Continuous | Estimate the number of patients that you signed-out or received | 1, 2, 3, …, 48, 49, 50, more than 50 |
| | 4. Number of clinicians | Continuous | How many clinicians (trainees, attendings, nurses, etc…) did you receive information from or send information to during the handoff | Text box to enter number |
| Extraneous load | | | | |
| Learner related | 1. Level of training | Dichotomous (R1 vs. all other levels of training) | Indicate your year of training | PGY-1, PGY-2, PGY-3, PGY-4, PGY-5, PGY-6, PGY-7, PGY-8, or higher |
| | 2. Fatigue | Dichotomous (fatigued vs. rested) | Rate your level of fatigue/rest | Very fatigued, somewhat fatigued, somewhat rested, very rested |
| | 3. Standardization of verbal communication | Dichotomous | Did the handoff follow a protocol (e.g., IPASS) for the presentation of verbal information? | Yes/No |
| Task design | 1. Standardization of verbal communication | Dichotomous | Did the handoff follow a protocol (e.g., IPASS) for the presentation of verbal information? | Yes/No |
| | 2. Protocol includes written component | Dichotomous | Did the handoff include a written handoff document? | Yes/No |
| | 3. Standardization of written communication | Dichotomous | Did the written document follow a standard template? | Yes/No |
| | 4. Number of sources for written information | Continuous | How many different sources of written information did you have to use? | 0, 1, …, 9, 10 |
| Environment[b] | 1. Number of times interrupted | Continuous | Roughly how many times were you interrupted during the handoff (e.g., page, person, etc…) | 0, 1, …, 9, 10, more than 10 |
| | 2. Impact of interruptions on concentration | Continuous | To what extent did the interruptions make to concentrate? | Extremely difficult, very difficult, somewhat difficult, not so difficult, not at all difficult |
| | 3. Impact of noise on concentration | Continuous | To what extent did noise make it difficult to concentrate | Extremely difficult, very difficult, somewhat difficult, not so difficult, not at all difficult |

**TABLE 2** (Continued)

| Cognitive load construct | Variable | Data type | Survey question | Response options |
|---|---|---|---|---|
| Germane load | | | | |
| Learner related | 1. Level of training | Dichotomous (R1 vs. all other levels of training) | Indicate your year of training | PGY-1, PGY-2, PGY-3, PGY-4, PGY-5, PGY-6, PGY-7, PGY-8, or higher |
| | 2. Fatigue | Dichotomous (fatigued vs. rested) | Rate your level of fatigue/rest | Very fatigued, somewhat fatigued, somewhat rested, very rested |
| Environment | 1. If receiver, were you able to take notes | Dichotomous | If you were a receiver, were you able to take notes? | Yes/No |
| | 2. Impact of interruptions on concentration | Continuous | To what extend did the interruptions make it difficult to concentrate | Extremely difficult, very difficult, somewhat difficult, not so difficult, not at all difficult |
| | 3. Formal feedback | Dichotomous | Did you receive formal feedback from a senior resident, fellow, or faculty[c] | Yes/No |

[a]Our data included three ordinal predictor variables, which were dichotomized. Level of training, which included options ranging from PGY-1 to PGY-8 or higher, was dichotomized into PGY-1 and all others because the authors believed that the difference in knowledge between PGY-1s and others was much greater than the difference between any subsequent level of training. Similarly, clinical setting was dichotomized into ICU versus all other settings because the difference in patient complexity between the ICU and other settings was thought to be far greater than any difference between the other settings. Fatigue was dichotomized because the option set included only four options making treatment as a continuous variable problematic.

[b]For extraneous load, the cognitive load inventory for handoffs asks about frequency of interruptions and impact of noise on concentration. Therefore, all of the items pertaining to the environment were not included in the analysis of extraneous load since the CLIH itself already incorporates.

[c]Our survey asked separate questions about whether the respondents received formal feedback from faculty and then from a senior resident or fellow. For our analysis, we combined these two items to make a single item for receiving formal feedback from any of the three.

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## 3 | RESULTS

The sample characteristics were described previously (Young et al., 2020). Most learners were either PGY-1, PGY-2, or PGY-3 level. Approximately 60% reported being either very or somewhat fatigued at the time of the handoff. Table 3 shows the descriptive statistics for the predictor variables and IL, EL and GL. Table 4 indicates the hypothesized relationship and the outcomes of the univariate and multivariable analyses.

### 3.1 | Intrinsic load

The handoffs occurred in a variety of clinical settings, including the ICU (about 13%) and non-ICU inpatient (67%). The average length of a handoff was nearly 18 min (*SD* = 15.3) and included 10 patients (*SD* = 10.6) and nearly 2.5 other clinicians (*SD* = 4.8) (Table 3). The multivariable linear regression model for IL indicated that ICU as a clinical setting was associated with significantly higher IL compared to other settings. In addition, as fatigue, number of patients, and length of the handoff increased so did IL. These findings were consistent with a priori predictions. However, contrary to our hypotheses, level of training did not influence IL (Table 4).

### 3.2 | Extraneous load

Respondents indicated that the handoff followed a standardized verbal communication protocol only 27% of the time and, in those situations, trainees reported on average about four prior trainings in that specific protocol. Sixty two percent of the handoffs had a written component with an average of 2.3 (*SD* = 1.03) different documents. Of those with a written component, 79% had a standardized template. Participants were interrupted on average 1.6 times (*SD* = 2.25), and about 56% of the learners reported negative impact of those interruptions on their concentration (Table 3). In the multivariable linear regression model, the number of prior trainings in the handoff protocol predicted lower EL while the number of written documents and fatigue predicted higher EL. These findings were as hypothesized. Several variables did not influence EL as hypothesized; namely, level of training and whether the verbal and written components of the handoff were standardized did not predict EL (Table 4).

**TABLE 3** Learner, task, and environmental features among trainees performing handoffs during the 2018–2019 academic year

| Characteristic | Measure |
|---|---|
| All models | |
| Number of trainees, no. | 693 |
| Year in training, no. (%) | |
| PGY-1 | 215 (31.02%) |
| PGY-2 | 180 (25.97%) |
| PGY-3 | 144 (20.78%) |
| PGY-4 residents | 59 (8.51%) |
| PGY-4 fellows | 20 (2.89%) |
| PGY-5 and higher | 74 (10.68%) |
| Missing | 1 (0.14%) |
| Fatigue, no (%) | |
| Very fatigued | 71 (10.25%) |
| Somewhat fatigued | 344 (49.64%) |
| Somewhat rested | 191 (27.56%) |
| Very rested | 77 (11.11%) |
| Missing | 10 (1.44%) |
| Intrinsic load model | |
| Intrinsic load, mean (*SD*) | 4.72 (2.06) |
| Length of the handoff (minutes), mean (*SD*) | 17.9 min (15.3) |
| Number of patients, mean (*SD*) | 10.25 (10.55) |
| Number of clinicians, mean (*SD*) | 2.46 (4.83) |
| Extraneous load model | |
| Extraneous load, mean (*SD*) | 2.55 (1.79) |
| Verbal protocol standardized, no. (%) | 187 (26.98%) |
| Number times trained in verbal protocol, mean (*SD*) | 3.94 (2.37) |
| Handoff includes written component, no. (%) | 429 (61.90%) |
| Written component standardized, no. (%) | 340 (79.25%) |
| Number of different written documents, mean (*SD*) | 2.31 (1.03) |
| Number of times interrupted, mean (*SD*) | 1.65 (2.25) |
| Extent to which interruptions made it difficult to concentrate[a], no. (%) | See GL model below |
| Impact of noise on concentration, no. (%) | |
| Not at all difficult | 187 (26.98%) |
| Not so difficult | 251 (36.22%) |
| Somewhat difficult | 175 (25.25%) |
| Very difficult | 49 (7.07%) |
| Extremely difficult | 22 (3.17%) |
| Missing | 9 (1.30%) |
| Germane load model | |
| Germane load, mean (*SD*) | 3.40 (2.25) |
| If receiver, ability to take notes, no. (%) | 111 (88.80%) |
| Extent to which interruptions made it difficult to concentrate[a], no. (%) | |
| Not at all difficult | 21 (4.90%) |
| Not so difficult | 154 (35.90%) |
| Somewhat difficult | 172 (40.09%) |
| Very difficult | 50 (11.66%) |
| Extremely difficult | 21 (4.90%) |
| Missing | 11 (2.56%) |
| Received formal feedback from a senior resident or fellow, no. (%) | 72 (10.39%) |
| Received formal feedback from a faculty member, no. (%) | 22 (3.17%) |
| Received formal feedback from a senior resident, fellow, or faculty member[b], no. (%) | 79 (11.40%) |

[a]This question was asked only of those who indicated they experienced interruptions (429).
[b]Our survey asked separate questions about whether the respondents received formal feedback from faculty and then from a senior resident or fellow. For our analysis, we combined these two items to make a single item for receiving formal feedback from any of the three.

### 3.3 | Germane load

About 14 percent of the time, the respondents reported receiving formal feedback from a senior resident, fellow or a faculty member. When a respondent was a receiver, they had the ability to take written notes almost all of the time (Table 3). A total of 56% of the respondents indicated that the interruptions made it somewhat, very, or extremely difficulty to concentrate. In the multivariable regression models, higher level of training predicted lower GL while interruptions, fatigue and formal feedback predicted higher GL (Table 4). These findings were all consistent with a priori predictions. Surprisingly, the ability to take notes during the handoff did not influence GL.

## 4 | DISCUSSION

In this study, we identified features of the learner, task, and instructional environments that predicted cognitive load types during patient handoffs. Higher IL was associated with fatigue, higher clinical complexity, more patients, and longer handoffs. Higher EL was associated with fatigue and number of sources of written information and lower EL with training in the verbal protocol being used. Higher GL was associated with fatigue and formal feedback and lower GL with more advanced stage of training and interruptions.

While the above findings were consistent with a priori predictions based on CLT, several findings were contrary to our predictions. CLT predicts that IL should decrease as the level of training increases. In our study, level of training was not associated with IL. There are several possible explanations. Interns may perform so many handoffs

**TABLE 4** Measurement of handoff features predicted to be associated with cognitive load types [Colour table can be viewed at wileyonlinelibrary.com]

| Cognitive load construct | Feature (directionality) | Predicted pattern of association | Univariate *p*-value | Coefficient (95% CI) | β coefficient | *p*-value |
|---|---|---|---|---|---|---|
| Intrinsic load model | | | | | | |
| Learner | Level of training (increasing; 0 = R1, 1 = all others) | ↓ | 0.496 | – | – | – |
| | Fatigue (increasing; 0 = rested, 1 = fatigued) | ↑ | 0.0002 | 0.46 (0.15, 0.77) | 0.11 | 0.004 |
| Task | Clinical setting (increasing complexity; 0 = all other, 1 = ICU) | ↑ | <0.0001 | 1.03 (0.57, 1.49) | 0.17 | <0.0001 |
| | Length of handover (increasing) | ↑ | <0.0001 | 0.18 (0.08, 0.28) | 0.15 | 0.0002 |
| | Number of patients (increasing) | ↑ | <0.0001 | 0.02 (0.0, 0.04) | 0.11 | 0.006 |
| | Number of clinicians (increasing) | ↑ | 0.03 | 0.02 (−0.01, 0.05) | 0.04 | 0.35 |
| Extraneous load | | | | | | |
| Learner | Level of training (increasing; 0 = R1, 1 = all others) | ↓ | 0.01 | 0.43 (−0.29, 1.15) | 0.10 | 0.25 |
| | Number of times trained in the protocol (increasing) | ↓ | 0.002 | −0.21 (−0.36, −0.06) | −0.25 | 0.006 |
| | Fatigue (increasing; 0 = rested; 1 = fatigued) | ↑ | <0.0001 | 0.94 (0.28, 1.6) | 0.24 | 0.006 |
| Task design[a] | Standardization of verbal communication (0 = No, 1 = Yes) | ↓ | 0.29 | – | – | – |
| | Protocol includes written component (0 = No, 1 = Yes) | ↓ | 0.58 | – | – | – |
| | Standardization of written communication (0 = No, 1 = Yes) | ↓ | 0.36 | – | – | – |
| | Number of sources for written information (increasing) | ↑ | 0.02 | 0.97 (0.18, 1.76) | 0.21 | 0.02 |
| Germane load | | | | | | |
| Learner | Level of training (increasing; 0 = R1, 1 = all others) | ↓ | <0.0001 | −0.88 (−1.36, −0.40) | −0.18 | 0.0003 |
| | Fatigue (increasing; 0 = rested, 1 = fatigued) | ↓ | <0.0001 | 0.55 (0.07, 1.04) | 0.11 | 0.03 |
| Instruction | If receiver, were you able to take notes (0 = No, 1 = Yes) | ↑ | 0.98 | – | – | – |
| | Number of interruptions | ↑ | 0.0007 | 0.003 (−0.11, 0.12) | 0.002 | 0.96 |
| | Impact of interruptions on concentration (worsening) | ↓ | <0.0001 | −0.45 (−0.71, −0.19) | −0.18 | 0.0007 |
| | Formal feedback (0 = No, 1 = Yes) | ↑ | 0.03 | 0.75 (0.05, 1.44) | 0.11 | 0.04 |

[a]For extraneous load, the cognitive load inventory for handoffs asks about frequency of interruptions and impact of noise on concentration. Because the extraneous load score incorporates these items, they were not included in this study of what learner, task, or environment features are associated with the EL score.

from the outset that they have acquired relative mastery by the midpoint of the first year, which is when the survey was administered. Alternatively, the finding may relate to how roles change with increased responsibilities associated with higher levels of training in medical education. The resulting increase in information elements as the trainee becomes more expert may account for the fact that IL was similar across years of training. If true, then in the setting of this study, the IL of the task seemed well matched to trainee experience. Also, while the evidence for the validity of the IL items is strong, it is possible that the construct of IL is not fully captured by the existing items on the CLIH and, as a result, the IL scores do not relate to level of training as they should and would with additional items added. Finally, it is important to consider that level of training may not the best measure of expertise, that is, knowledge about the clinical medicine and handoff process may vary more within a given level of training than between. For example, a study of simulated handoffs found that learner knowledge as measured by illness script maturity was a better predictor of IL than level of training (Young, Van Dijk, et al., 2016). While harder to measure, future studies might consider using illness script maturity or some other more specific measure of the relevant expertise.

Two additional findings were contrary to our expectations. First, the capacity to take notes did not increase GL for receivers. Note taking induces schema refinement and should increase GL. While all receivers had the capacity to take notes, it could be that most did not which would then explain the finding. In the authors' experience, whether receivers take notes is highly variable and depends on the modeled behavior (e.g., do seniors take notes?) and the architecture of the space (e.g., a learner may have the capacity to take notes but chooses not to if they are standing and not in a comfortable position). Second, while fatigue's association with higher IL and EL was expected and similar to what was found in a study of colonoscopy (Sewell et al., 2017), we did not expect fatigue to predict higher GL. In CLT, fatigue is understood to reduce working memory capacity and slow information retrieval and encoding (Sweller et al., 2019). In essence, the learner becomes 'less expert' and the same task then imposes higher IL. If the IL (and EL) of the task exceeds the working memory capacity of the fatigued learner, then you would expect GL to decrease as working memory resources are reallocated to manage the IL and EL. The positive association of fatigue with GL in our study may reflect that working memory capacity was not exceeded. This possibility is supported by the fact that mean IL was moderate and EL low. If so, then the same GL inducing strategies (e.g., compare and contrast, monitoring understanding) would require more effort in the 'slowed down' brain of the fatigued learner. Alternatively, this observed relationship between fatigue and GL may reflect the challenges of self-report. Finally, while the germane load items formed a factor separate from IL in prior research, it could be that this factor represents something other than germane load such as 'effort', as suggested by Leppink et al when their measure of cognitive load types during classroom learning yielded three factors (Leppink et al., 2013, 2014). If so, then increased fatigue would lead to increased effort on the same task and a higher score for this factor. Most importantly, it is clear that fatigue, even within an environment governed by duty hour restrictions, still needs to be actively managed to optimize learning.

Overall, these findings provide additional evidence supporting the validity of the CLIH. Prior research collected evidence supporting validity with respect to the CLIH's content, response process, and internal structure (Young et al., 2020). The results of this study provide evidence for validity with respect to how the scores associate with other variables. For the most part, the IL, EL, and GL scores varied as predicted with the learner, task, and instructional features. These findings lend added confidence that a measure such as the CLIH can measure cognitive load types during handoffs and can be used to deepen our understanding of the cognitive mechanisms of handoff errors and improve our instruction and protocols. Future validity research should explore how the CLIH scores associate with actual learning and clinical outcomes (e.g., information loss or distortion during the handoff, medical errors, patient morbidity, etc…).

These findings have important implications for handoff instruction. Faculty can titrate IL to the learner's expertise by modulating the number of cases in the handoff, the length of the handoff, and the clinical setting. Moreover, when this is not possible and the IL will exceed the learner's development stage, partial task completion and worked examples, both well-studied methods for managing IL, can be used (Young et al., 2014). In part-task approaches, the learner could perform only certain components of the handoff. In worked examples, the supervisor can take over the handoff (rather than permitting the learner to struggle unproductively) and then narrate how they are managing the complexity. To support these instructional elements, protocols could be developed that trigger the provision of more time for the handoff or more senior resident or attending support when the number of patients or complexity of patients exceeds a predetermined threshold (Young, Wachter, et al., 2016).

Prior research has argued that verbal protocols reduce EL by conserving working memory resources that otherwise would be consumed with anticipating when and in which order different types of information will be communicated (Young, Ten Cate, et al., 2016). It is noteworthy that standardization of the protocols did not influence EL when also including number of trainings in that protocol; familiarity with the protocol was more important than the mere existence of the protocol. Standardization is critical but additional gains can be achieved through training in the protocol. Similarly, EL increased when the trainee had to use more than one written document to obtain the essential clinical information. When working memory resources are expended on information search (e.g., looking back and forth between two or more documents), EL increases and less working memory is available for the core task. Decreasing the number of written sources is a key goal of standardizing the written process and can also be used to vary the EL for purposes of training.

Finally, the predictors of GL are instructive. Germane load relates to the use of working memory resources dedicated to cognitive activities that enhance schema refinement and automation during the performance of the task. Consistent with CLT, more experienced learners utilized less GL; as expertise increases, the need for schema refinement decreases. While the number of interruptions had no influence, interruptions that impacted concentration did reduce GL. This distinction is important; some interruptions are relatively benign while others are not. Meanwhile, the provision of feedback by a senior, fellow, or attending induced GL. While seniors and even attendings may participate in some handoffs, it is not common for trainees to be directly observed and provided structured feedback. In fact, only 14% of the learners in this study received feedback. Most curricula are likely heavy on practice and light on feedback. Given the large proportion of medical errors associated with handoffs, both UME and GME training programs should prioritize creating opportunities for structured observation and feedback.

## 5 | LIMITATIONS

The study has several limitations. The study was performed in a single health system. However, this single health system is diverse and participants in the study came from multiple specialties and hospitals. Participants included residents and fellows, so we do not know if students or faculty would respond in the same way. In addition, the CLIH only measures learners' perceptions of IL, EL, and GL as recalled after completion of the handoff. These perceptions are undoubtedly biased by recall. However, asking learners to complete the CLIH during actual handoffs was not thought to be feasible. Future research could compare the post hoc CLIH scores with in-the-moment physiologic methods, though, the physiologic methods to date cannot differentiate between cognitive load types. Finally, while the CLIH has three factors, it is important to acknowledge that given the current debate within the CLT research community, the third factor that we understand to be GL may in fact be something other than GL. Future research on the CLIH should collect additional evidence to better understand this third factor.

## 6 | CONCLUSION

In summary, this study identifies features of the learner, task, and instructional environment that modulate cognitive load types. These findings and the approach taken in this study in general can help inform future improvements to handoff curricula and protocols.

### CONFLICT OF INTEREST

The authors declare no conflicts of interest.

### DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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## SUPPORTING INFORMATION

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

**How to cite this article:** Young JQ, Thakker K, John M, et al. Features of the learner, task, and instructional environment that predict cognitive load types during patient handoffs: Implications for instruction. *Appl Cognit Psychol*. 2021;35: 775–784. https://doi.org/10.1002/acp.3803