Cognitive load and performance of health care professionals in donning and doffing PPE before and after a simulation-based educational intervention and its implications during the COVID-19 pandemic for biosafety

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Introduction: The Personal Protective Equipment (PPE) is essential to avoid the COVID-19 spread to health care workers. Its use can be difficult, posing a high risk of contamination, mainly during doffing, then with the risk of becoming infected.

Methods: We conducted a prospective before-and-after design that used clinical simulation as a research methodology in a clinical simulation center of Colombia. A simulation-based educational intervention with two cases related to COVID-19 was proposed in the emergency room and the intensive care unit. We conducted a workshop for donning and doffing of personal protective equipment (PPE) and a debriefing after the first case.

Results: In the pre-test, 100% of participants failed donning and doffing PPE, 98.4% were contaminated, only one person did not contaminate out of. The mean cognitive load was high (7.43±0.9 points). In the post-test, 100% were successful in donning the PPE and 94.8% in doffing; only 9.8% were contaminated. The mean of the cognitive load was low (4.1±1.4 points), and the performance was high (7.9±1.1). Of the total, 73.8% of participants reported overload in the doffing. The most difficulties were in gown/overall, and N95 mask removal.

Discussion: The PPE donning and doffing is critical and may be changed significantly by active training. In responding to the current COVID-19 pandemic in 2020, activities of training in donning and doffing PPE would provide a means of training personnel, reducing the cognitive load and maybe the risk of contamination and infection of health care workers.

Keywords: SARS-CoV-2/COVID-19, knowledge, donning, doffing, PPE, Colombia, Latin America.

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INTRODUCTION

Emergent infectious diseases are a challenge to any health system [1]. The current pandemic of the Coronavirus Diseases 2019 (COVID-19), caused by the Severe Acute Respiratory Syndrome coronavirus 2 (SARS-CoV-2), is the best recent example of this challenge[2, 3]. Originated in Wuhan, Hubei, China, in December 2019, this emerging infectious disease became a World Health Organization (WHO)-declared pandemic [4, 5]. Till May 13, 2020, this new infection has a worldwide distribution, with more than 4.34 million people infected and more than 296 thousand people dead [6, 7]. Many affected countries have had significant impairment among the healthcare workers. That has been the case of Italy, where up to March 15, 2020, reported COVID-19 in more than 22,000 people, with near 10% of them being health care workers [8]. That increased the health care crisis, the hospital collapse, and impose a high-stress load on the rest of health professionals [9]. In this setting, the Personal Protective Equipment (PPE) is essential to avoid the COVID-19 spread to health care workers [10]. However, its use can be difficult since it has multiple steps. Improper use of PPE poses a high risk of contamination, mainly during doffing [11]. Even more, complex procedures generate intrinsic and extrinsic cognitive load, which can increase the possibility of failure, and in this case, becoming infected [12]. The cognitive load theory assumes that working memory is limited, so complex tasks and experiences overflowing it. The cognitive load is divided into three types: intrinsic, extraneous, and germane. The intrinsic load refers to the difficulty of the task itself. Extrinsic load is defined as the working memory that deals with solving situations that are not directly related to the task, and germane load is the intentional effort of working memory to do the task and trespassing the information from short term memory to long term memory [13, 14]. The recommendations of the Italian experience with COVID-19 emphasize the difficulty of managing this new disease, the need to maintain non-technical skills and to make use of checklists, cognitive aids, adequate PPE, and assisted donning and doffing [15]. For all these reasons, the present study aimed to assess the cognitive load and the performance of health care professionals in donning and doffing PPE before and after a simulation-based educational intervention.

METHODS

We conducted a prospective before-and-after design, that used clinical simulation as a research methodology, between February and March 2020, in a clinical simulation certified center of the Coffee-Triangle region, Colombia. A simulation-based educational intervention with two cases related to COVID-19 was proposed in the Emergency Room (ER) and the Intensive Care Unit. (ICU). We conducted A workshop for donning and doffing of personal protective equipment (PPE) and a debriefing after the first case.

Scenarios
Scenario 1: A middle-aged man who returned from China five days before, develops cough, fever, and mental impairment. The intrinsic load was donning and doffing PPE; the extraneous load was her wife and the nurse’s anxiety in the Emergency Room.
Scenario 2. A middle-aged man who returned from Italy, was in respiratory failure and septic shock and he needed orotracheal intubation and shock treatment. The intrinsic load was donning and doffing PPE; the extraneous load was in the ICU nurse’s mental model of critical ill management.

The scenarios were piloted, retested, and approved by the academic committee of the simulation center. The first scenario concluded if more than 80% of the team was contaminated, the second scenario with mechanical ventilation start.

The sample was constituted by physicians, nurses, and respiratory therapists from the emergency room and intensive care unit of third-level institutions of Armenia, Quindio, Colombia; recruitment was by open call.

Instruments
The 9-point Paas scale was applied to determine the cognitive load (1: very, very low - 9: very, very high) [16] Instruction in the concept of cognitive
load, and diligence of the scale was included within the workshop design. The U.S. Centers for Disease Control and Prevention, Atlanta (CDC) donning and doffing checklist was placed on the scale sheets where the participant place the step that seems most complex to them. The checklist was be used for the placement and removal of the WHO personal protection equipment - CDC. It was be applied before and after the intervention. Each reviewer made a general evaluation of performance with a scale like that of Paas of 9 items (1: Very, very bad - 9: very, very good) considering the use of equipment and maintenance of protection during simulated cases. The evaluators were instructed in the techniques of the appropriate use of personal protection equipment and completion of the checklist.

With the two scales, it was represented a graph in terms of efficiency in four quadrants: Efficient (high performance - Low cognitive load), Effective (high performance - high cognitive load), Inefficient (low performance - high cognitive load) and Dunning-Kruger effect (low performance and low cognitive load).

A Likert-type survey of 14 questions and five items (1: Totally disagree, 5, Totally agree) was sent in Google Forms® related to the perception of cognitive load during the simulated cases. Statistical analysis was performed in SPSS 26, IBM®, the qualitative variables were summarized with proportions, and the quantitative variables with measures of central tendency and dispersion; statistical significance was considered only for \( p < 0.05 \).

**Ethics**

The participation was voluntary. Health professionals were invited and informed about the characteristics and scope of the study. All the participants signed an informed consent form. This work did not represent any type of economic incentive for the participants or researchers. A committee of ethics in research approved the study.

**RESULTS**

A total of 61 healthcare workers participated in this study. Of them, 59% were women. The median age was 32 years old (interquartile range, IQR=26-43). Of them, 49.2% were physicians, 18% respiratory therapists, and 16.4% nurses. The median time of clinical experience among them was 8 years (IQR=2-17). Most participants were ICU (52.5%), and ER (26.2%) staff.

Of all participants, the 57.4% knew the PPE, and the 32.8% had previously used it.

In the pre-test, all the participants failed donning and doffing PPE; moreover, all were contaminated, except one that did not touch the infected patient and took distance from the simulated scenario. The mean cognitive load was high (7.43±0.9 points), and the performance very low (2.5±0.8).

In the post-test, 100% of participants were successful in donning the PPE and 94.8% in doffing; only 9.8% were contaminated. The mean of the cognitive load was low (4.1±1.4 points), and the performance was high (7.9±1.1). Of the total, 73.8% of participants reported an overload in the doffing. The most difficulties were in gown/overall, and N95 mask removal (Figures 1-2).

![Figure 1 - Donning difficulties (%).](image)
No statistically significant difference was found in cognitive load or performance by gender, age, profession, or work area. The relationship between performance–cognitive load in the pre-test, showed most participants in the inefficient quadrant; in the post-test, most participants were in the effective and efficient quadrants ($p<0.05$) (Figures 3-4).

The Likert scale showed reliability with Cronbach’s alpha of 8.0. In the group of questions related to intrinsic load, there was a moderate-strong agreement on the overhead that a COVID-19 case management offers (40%-34.5% respectively), this includes donning and doffing. A moderate-strong agreement was also found in extrinsic loading that stress and the noise generated by the equipment increases the difficulty (38.2% and 38.2%, respectively). There was a strong agreement that stress and anxiety are factors that increase the difficulty of caring for the critically ill patient with COVID-19 and that doing assisted donning and doffing with the help of a verifier decreases the difficulty of the task, as well as individual and collective stress (54.5%) (Table 1).
Caring for critically ill patients is complex, due to the severity of the pathologies, the use of biotechnology and the emotional activation, which is related to increased cognitive load. One of the most critical issues with the pandemic caused by a biosafety threat agent, as is the SARS-CoV-2, is the appropriate use of PPE by health care workers during attending suspected or confirmed cases [17]. When working with infectious diseases with high risk of contagion, such as Ebola and COVID-19, the simple act of donning (putting on) and doffing (removing) PPE becomes a lifesaving task. The proper donning and doffing of PPE is crucial to prevent the spread of infections among healthcare workers.

### Table 1 - Perception of donning and doffing difficulties.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Pretest %</th>
<th>Post-test %</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand hygiene</td>
<td>36.1</td>
<td>6.6</td>
<td>0.0002</td>
</tr>
<tr>
<td>Putting on internal gloves</td>
<td>32.8</td>
<td>11.5</td>
<td>0.0089</td>
</tr>
<tr>
<td>Dressing with gown or overalls</td>
<td>60.7</td>
<td>36.1</td>
<td>0.0112</td>
</tr>
<tr>
<td>Putting on N95 respirator and hat</td>
<td>47.5</td>
<td>27.9</td>
<td>0.0399</td>
</tr>
<tr>
<td>Placement of glasses and/or face shield</td>
<td>44.3</td>
<td>9.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Putting on external gloves</td>
<td>29.5</td>
<td>8.2</td>
<td>0.0055</td>
</tr>
<tr>
<td>Doffing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breaks and splashes check</td>
<td>39.3</td>
<td>6.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hand hygiene #1 and removal of external gloves</td>
<td>39.3</td>
<td>9.8</td>
<td>0.0004</td>
</tr>
<tr>
<td>Hand hygiene #2</td>
<td>26.2</td>
<td>3.3</td>
<td>0.0009</td>
</tr>
<tr>
<td>Removal of face shield/glasses</td>
<td>34.4</td>
<td>21.3</td>
<td>0.1575</td>
</tr>
<tr>
<td>Removal of gown/overalls</td>
<td>67.2</td>
<td>70.5</td>
<td>0.8450</td>
</tr>
<tr>
<td>Hand hygiene #3 and removal of N95 respirator</td>
<td>47.5</td>
<td>36.1</td>
<td>0.2708</td>
</tr>
<tr>
<td>Removal of internal gloves and hand hygiene #4</td>
<td>37.7</td>
<td>11.5</td>
<td>0.0016</td>
</tr>
</tbody>
</table>

In bold, p, significant differences between pretest and post-test.

### DISCUSSION

Caring for critically ill patients is complex, due to the severity of the pathologies, the use of biotechnology and the emotional activation, which is related to increased cognitive load. One of the most critical issues with the pandemic caused by a biosafety threat agent, as is the SARS-CoV-2, is the appropriate use of PPE by health care workers during attending suspected or confirmed cases [17]. When working with infectious diseases with high risk of contagion, such as Ebola and COVID-19, the simple act of donning (putting on) and doffing (removing) PPE becomes a lifesaving task. The proper donning and doffing of PPE is crucial to prevent the spread of infections among healthcare workers.
procedure not only for the medical staff but also for the thousands of people who depend on them [18]. However, with a higher level of protection, the level of complexity in donning and doffing is also higher [10], that can be associated with rise of the cognitive load.

During the current COVID-19 pandemic, the cognitive load seems critical for multiple clinical settings, such as the emergency room, surgical areas, or ICU, among others [19]. There, numerous biosafety breaches during donning and doffing may occur. The correct use of PPE is necessary to decrease the number of infected healthcare workers caring for patients with COVID-19 [20]. For these reasons, training on procedures and techniques, the surveillance, and retraining can help to control it, decrease cognitive load [12], and fear perception, increase the feeling of safety and performance in multidisciplinary teams [21, 22].

In Colombia, where we performed this study, the appropriate use of PPE is critical as more than 7,006 cases of COVID-19 have been confirmed till May 1, 2020, and 459 (6.5%) corresponded to healthcare workers, and 7 of them have died, included critical care and ER personnel [23].

Our study is the first to measure the impact of cognitive load on the performance of donning and doffing PPE in clinical simulation whit ER and ICU staff, who are the first line of care for critically ill patients with COVID-19, therefore, the most exposed and vulnerable to contagion. This study suggests that donning and doffing PPE is critical and may be changed significantly by active training with clinical simulation in terms of performance and decreased cognitive load.

In response to the current COVID-19 pandemic in 2020, activities of training, on-site, or even virtual, in donning and doffing PPE, would provide a means of training personnel, and in the case of virtual tools minimizing the amount of time and PPE used in training and ensuring social distancing. Then, also, the use of training videos to be tested to ensure completeness, accuracy, and clarity of actions have been proposed, however, training in a high-fidelity clinical simulation scenario, with the imposition of intrinsic and extrinsic cognitive load, is closer to real clinical practice, which cannot be achieved just by watching a video, in non-stress conditions [18].

Finally, it should always be remembered that there is a very high risk of contamination during doffing the PPE. Therefore another individual should watch the health care worker while donning and doffing the PPE and alert the person to any possibility of contamination [19].

**CONCLUSIONS**

Despite the knowledge of PPE, healthcare professionals do not carry out fully adequate donning and doffing. Donning and doffing of PPE generate high cognitive load, teams training in high fidelity clinical simulation minimizes the load and increases performance. We recommended assisted donning and doffing, strictly following the checklists.

**Funding**

None.

**Conflict of Interest**

None of the authors report conflict of interests.

**REFERENCES**


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