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Visual Fixation on the Thorax Predicts Bystander Breathing Detection in Simulated Out-of-Hospital Cardiac Arrest, but Video Debriefing With Eye Tracking Gaze Overlay Does Not Enhance Postallocation Success Rate

A Randomized Controlled Trial

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Introduction: Bystander cardiopulmonary resuscitation in out-of-hospital cardiac arrest is associated with higher survival rates. Even trained health care staff cannot assess breathing well enough to detect cardiac arrest. Recognition of cardiac arrest by lay rescuers might be overlooked in adult basic life support resuscitation guidelines, which explain what to do, but not how to do it. The 2015 Adult Advanced Life Support Resuscitation Guidelines recommend to "look for chest movement." We hypothesize (1) that instructing lay rescuers to look for chest movement allows detecting breathing (or lack thereof); (2) that showing a person their own recorded gaze overlay during a video debriefing intervention enhances breathing detection at postallocation; and (3) that the more time spent looking at a cardiac arrest victim's chest, the greater the probability of detecting breathing (or lack thereof).

Methods: Monocentric, blinded, prospective, 2-arm parallel randomized controlled trial with balanced randomization (1:1). The design entailed a preallocation simulation, an intervention (video debriefing with or without gaze overlay), and a postallocation simulation. A follow-up simulation took place after 6 months. The main outcome measured was success in detecting breathing. Participants were all prospective students of a bachelor's degree program in nursing.

Results: All participants performed better at postallocation (success rate at preallocation = 59%, postallocation = 79%, $\chi^2 = 7.22$, $P < 0.01$) regardless of viewing their own gaze overlay during video debriefing. We failed to obtain a sufficient number of participants for the follow-up simulation. Instructing lay rescuers to look for chest movement allows them to detect breathing (or lack thereof). Each second spent looking at the thorax increased the odds of successfully detecting breathing by 38%. Mean thorax gaze duration significantly increased by 5.95 seconds (95% confidence interval = 4.71–7.31) from preallocation (3.46 seconds, SD = 4.16) to postallocation (9.41 seconds, SD = 5.98). Laypersons' median diagnosis time was 15.5 seconds (range = 2–63 seconds), similar to another study (13 seconds, range = 5–40 seconds).

Conclusions: This is the second study in which the median time to decision exceeded the maximum 10 seconds recommended. International guidelines should consider increasing the time allowed for the "check breathing" step of bystander cardiopulmonary resuscitation procedures.

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Key Words: Out-of-hospital cardiac arrest, simulation, breathing detection, cardiopulmonary resuscitation, eye tracking, eye movements.

Bystander cardiopulmonary resuscitation (CPR) in out-of-hospital cardiac arrest is associated with higher survival rates and improved outcomes, such as diminished anoxic brain damage, nursing home admission, and risk of death at 1 year.[1–5] Increasingly, lay CPR has been suggested as an effective way to maintain blood flow to the brain until emergency medical personnel arrive, along with larger systemic changes aimed at strengthening rings of the chain of survival.[3] Trained health care providers are recommended to recognize cardiac arrest through a pulse check, whereas lay rescuers should rely on the victim's level of consciousness and respiratory effort,[6,7] although research has shown that even trained health care staff cannot assess breathing and pulse well enough to detect a cardiac arrest.[8–13] Recognition of cardiac arrest by lay rescuers might be overlooked in resuscitation guidelines,[13] which explain what to do, but not exactly how to do it.

Recurrent terms are "abnormal breathing," "no breathing," and "only gasping."

These terms assume that lay rescuers already know how to check for breathing, failing to provide guidance on how to do it in practice. One simple, immediate, understandable check recommended for health care staff (ie, not for lay rescuers) found in Section 3 of the 2015 European Resuscitation Council Guidelines for Resuscitation[8] (on adult advanced life support) is "look for chest movement," as part of the "look, listen and feel" routine:

- Look for chest movement
- Listen at the victim's mouth for breath sounds
- Feel for air on your cheek
- Look, listen, and feel for no more than 10 seconds to determine whether the victim is breathing normally.[8]

Looking for chest movement is a straightforward task, so we hypothesized the following:

Hypothesis #1: Instructing lay rescuers to look for chest movement should allow them to detect breathing (or lack thereof) and take appropriate action.

Because looking is a measurable behavior, we recorded participants' eye movements with an eye tracker in a pre-post simulation to test 2 more hypotheses:

Hypothesis #2: Showing a person's own recorded gaze overlay to them during video debriefing enhances breathing detection at postallocation.

Hypothesis #3: The more time spent looking at a cardiac arrest victim's chest, the higher the probability of detecting breathing (or lack thereof).

Although eye tracking has been used for many decades in disciplines, such as medicine, psychology, and engineering, and in applied settings, such as automotive and avionics design, advertising, and reading, its application in health care simulation is relatively recent.[14–16] The fundamental assumption underlying the measurement of eye movements is that there is a close relationship between where people look and what they pay attention to in a given moment. For instance, if a nurse fixates on a patient's ID band while the patient verbally states his name, we can imagine that the nurse is interested in double checking the patient's identity at that moment. More generally, eye movements are usually not random, because we tend to fixate on those parts of the external world that are informational, important, and relevant to performing tasks that we want to accomplish.[17]

In the present study, simulation is both an investigational method for research and the subject of research. For hypotheses 1 and 3, we used simulation as an investigational method to determine whether looking for chest movement enhances breathing detection. For hypothesis 2, simulation was the subject of research, in that we tested the alleged benefit of adding eye tracking to video debriefing. A few studies suggested the possibility of such an effect,[18–21] but solid results from a randomized controlled trial (RCT) were missing to date.

METHODS

This was a monocentric, blinded, prospective, 2-arm parallel RCT with balanced randomization (1:1) conducted in Switzerland. The trial was conducted to identify the superiority of a new intervention, namely, video debriefing with eye tracking gaze overlay, versus video debriefing without eye tracking gaze overlay. The design implied a preallocation simulation, an intervention (video debriefing), and a postallocation simulation. Finally, a follow-up simulation took place after 6 months (Fig. 1). No important changes to methods occurred after trial commencement.

Eligibility criteria included:

1. Enrollment as healthcare propaedeutic year (HPY) student. In French-speaking Switzerland, the University of Applied Sciences and Arts Western Switzerland (Haute Ecole Spécialisée de Suisse Occidentale) offers a bachelor in nursing degree. Achievement of the HPY is mandatory to enroll in the bachelor in nursing program. The HPY includes basic health care theory, as well as hands-on classes and internships in healthcare institutions.
2. Having obtained the "Basic Life Support–Automated External Defibrillation–Swiss Resuscitation Council (BLS-AED-SRC)" certification during the HPY.

Participants were recruited through internal e-mail lists. Volunteering participants received compensation of 30 Swiss Francs. The study protocol was submitted to Swissethics, who confirmed that the study did not fall inside the scope of the Federal Act on Research involving Human Beings.[22] We conducted the study respecting the Federal Act on Data Protection,[23] and all participants signed an informed consent form. The study took place in Switzerland, on the premises of Haute Ecole Arc's Delémont and Neuchâtel campuses.

We randomized HPY students in an RCT comparing 2 video-based methods of debriefing with the following procedure.

Preallocation

Eye Tracker Calibration

Each participant was equipped with a head-mounted eye tracker (Dikablis Professional, http://www.ergoneers.com). We calibrated the eye tracker while the participant was standing, looking at five 76×76-mm sheets of paper (numbered 1–5) laid flat and positioned 50 cm ahead on the floor in a 50×50-cm area.

Briefing

A certified BLS-AED-SRC trainer outlined the simulation exercise following a written script:

We aim at evaluating a video debriefing method. You will do an exercise, then we will do the video debriefing, after which you will repeat the exercise. The exercise is the following: you enter the secured room; an unconscious person is on the floor. You are requested to perform either a cardiopulmonary resuscitation or a recovery position.

Simulation

Each participant entered a room in which a SimMan3G active mannequin (patient/victim) laid supine on the ground and eyes half open. The breathing frequency was set to 8 breaths per minute. At the beginning of each test, breathing had been remotely turned either on or off by the technician according to a predefined randomization list. The participant's task was to determine whether the victim needed a reanimation protocol (for an unresponsive and unbreathing victim) or a secure lateral position (for an unresponsive but breathing

	Enrollment	Preallocation simulation	Allocation	Postallocation debriefing	Postallocation simulation	Follow-up simulation
STUDY PERIOD						
TIMEPOINT	$-t_2$	$-t_1$	**0**	t_1	t_2	t_3 (t_2 + 6 months)
ENROLLMENT:						
Eligibility screen	X					
Informed consent	X					
Eye tracker calibration		X			X	X
Allocation			X			
INTERVENTION:						
Debriefing with eye-tracking gaze overlay				X		
ASSESSMENTS:						
Anthropometric and demographic data	X					
Success/Failure		X			X	X
Thorax looking time		X			X	X

FIGURE 1. Schedule of enrollment, interventions, and assessments.

victim) and take appropriate action. The exercise was stopped by the experimenters as soon as the participant initiated the rescue action of their choice. The participant then entered the debriefing room and waited for the certified BLS-AED-SRC trainer to join them.

Allocation

An experimenter had previously generated a randomization list in MATLAB using a random block design (block size = 4–6). The list was hidden from the experimenters.

A locked Excel spreadsheet revealed group membership (ie, experimental or control) corresponding to the participants' IDs only after the preallocation simulation (input: participant ID; output: group membership; see Table, Supplemental Digital Content 1, http://links.lww.com/SIH/A749). Because of the nature of the intervention, blinding participants and experimenters was not possible. The person who later analyzed the data was unaware of participants' group membership.

Intervention

Debriefing

After each preallocation simulation, the technician obtained the participant's group membership (ie, experimental or control) from the locked Excel spreadsheet and then exported the video footage previously shot by the eye tracker scene camera during the preallocation simulation (Fig. 2). The video was exported either with gaze overlay (experimental group) or without gaze overlay (control group). The technician informed the certified BLS-AED-SRC trainer of (a) the group membership of the current participant and (b) whether

the mannequin had been set to breathing or no breathing for the current participant.

Next, the certified BLS-AED-SRC trainer entered the debriefing room where the participant was waiting. The debriefing took place following a predefined written script, taking into consideration (a) the group membership of the current participant, (b) whether the participant had made the right decision (success or failure) during the preallocation simulation, and (c) whether the participant had checked for thoracic lift for at least 10 seconds (Table 1). To maintain the highest level of debriefing standardization for all participants, the trainer did not ask any questions and allowed participants to ask questions only after the postallocation simulation.

Postallocation

After the debriefing (intervention), each participant performed another run with the following procedure:

Eye Tracker Calibration

Eye tracker calibration is the same as "Preallocation" (see hereinabove).

Briefing

A certified BLS-AED-SRC trainer outlined the simulation exercise following a written script:

You will now repeat the same exercise: you enter the secured room; an unconscious person is on the floor. You are requested to perform either a cardiopulmonary resuscitation or a recovery position.
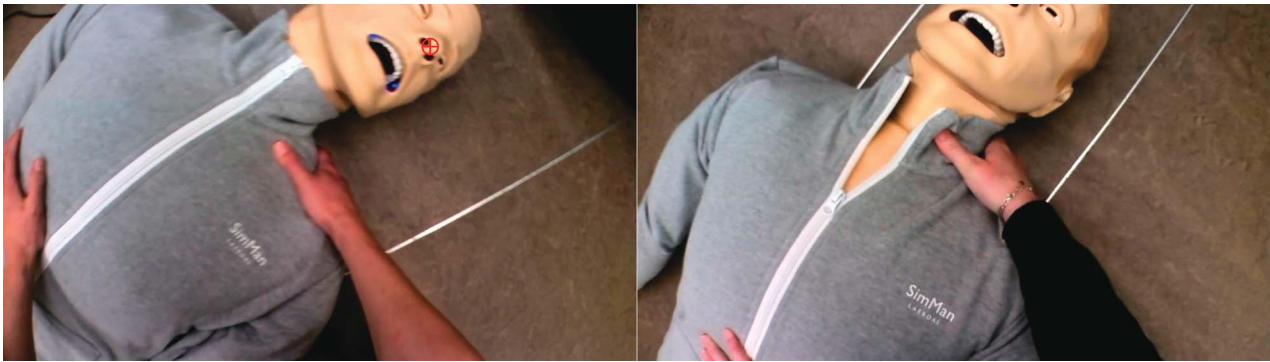
FIGURE 2. Intervention. Participants who received the intervention (experimental group) underwent video debriefing with gaze overlay (left image). The encircled red cross on the mannequin's nose represents the participant's gaze point at that moment. Participants who did not receive the intervention (control group) underwent video debriefing without gaze overlay (right image). For both groups, during the preallocation simulation, the scene camera of the head-mounted eye tracker was used to shoot the video footage shown during debriefing.

Simulation

The simulation is the same as "Preallocation" (see hereinabove).

Debriefing

The debriefing is the same as "Preallocation" (see hereinabove), except that this time, the trainer allowed participant questions and eventually replied to them.

Follow-up

Eye Tracker Calibration

The eye tracker calibration is the same as "Preallocation" (see hereinabove).

Briefing

The briefing is the same as "Preallocation" (see hereinabove).

Simulation

The simulation is the same as "Preallocation" (see hereinabove).

Debriefing

The debriefing is the same as "Postallocation" (see hereinabove).

Outcomes

The primary outcome was success or failure. A success was counted if the participant made the right decision, that is, the participant either placed a breathing mannequin in recovery position or initiated CPR on an unbreathing mannequin. The secondary outcome was the time in seconds spent looking at the mannequin's thorax. Both the primary and secondary outcomes were measured at preallocation, postallocation, and follow-up (Fig. 1). Because we failed to obtain a sufficient number of participants for the follow-up simulation, those data were not included in statistical analyses and are therefore presented for descriptive purposes only.

The independent variable was the type of video debriefing: either with eye tracking gaze overlay (experimental group) or without eye tracking gaze overlay (control group). No changes to outcomes occurred after trial commencement.

Sample Size

We computed the required sample size using G*Power 3.1[24] with the following input parameters: 1-tailed, moderate effect size ($d = 0.5$), $\alpha = 0.05$, $1 - \beta = 0.8$, allocation ratio = 1. Output parameters yielded a required total sample size of 102, that is, 51 participants for each group. Figure 3 illustrates participant flow diagram. We did not carry out any interim analyses.

Statistical Methods

We tested the change in success frequencies (ie, the ratio between number of success and number of participants) with a McNemar test.[25] We evaluated the associations between group (experimental vs control), time looking at thorax, and success rate through a logistic regression. The dependent variable was the success rate (binary variable, success = 1); the independent variables were group (intervention = 1) and time looking at thorax (in seconds) at preallocation and postallocation (in centralized values). We evaluated goodness of fit via receiving operator characteristic curve and area under the curve.

RESULTS

Recruitment and pre-post simulations took place between May 2019 and January 2020. Follow-up simulations took place in June 2020. Of 162 students enrolled, 125 agreed to participate in the study. Among the 125 participants, 28 could not complete or even begin the study because of technical problems with eye tracking, that is, impossibility of performing a calibration or even detecting the pupil. This represents a 22.4% data loss, in line with previous reports[18,26] albeit slightly lower. In the end, 97 participants received the intervention, and their data were analyzed for the primary outcome. Among these 97 participants, 65 declined to take part in the follow-up. Figure 3 shows the full participant flow diagram. Table 2 contains baseline demographics of participants. For all participants, this study was the first experience with simulation.

During preallocation, 57 of the 97 participants made the right decision (59% success rate). This success rate is not statistically different from 50% ($z = 1.62$, $P = 0.10$), meaning that the success rate at preallocation was not greater (or lesser) than chance. After debriefing, during postallocation, 77 of the 97 participants made the right decision (79% success rate). This was significantly greater than 50% ($z = 5.69$, $P < 0.001$).

TABLE 1. Intervention

| Experimental Group			
Outcome of Preallocation Simulation			
Success and		Failure and	
Looked at Thorax ≥ 10 s	Looked at Thorax < 10 s	Looked at Thorax ≥ 10 s	Looked at Thorax < 10 s
You made the right decision.	You made the right decision.	You made the wrong decision.	You made the wrong decision.
It was a matter of controlling the breathing to determine what to do.	It was a matter of controlling the breathing to determine what to do.	It was a matter of controlling the breathing to determine what to do.	It was a matter of controlling the breathing to determine what to do.
		If there is no evidence of breathing, CPR should be started; otherwise, the victim should be placed in RP.	If there is no evidence of breathing, CPR should be started; otherwise, the victim should be placed in RP.
Your gaze went to the thorax quickly and stayed there long enough.	However, you can improve. In fact, we can see that your gaze did not go to the thorax quickly enough and that it did not stay there long enough.	However, your gaze went to the thorax quickly and stayed there long enough.	Your gaze did not focus on the right place.
As a reminder, good breathing control requires checking the thoracic lift for at least 10 s.	As a reminder, good breathing control requires checking the thoracic lift for at least 10 s.	As a reminder, good breathing control requires checking the thoracic lift for at least 10 s.	As a reminder, good breathing control requires checking the thoracic lift for at least 10 s.
Control Group			
Outcome of Preallocation Simulation			
Success and		Failure and	
(Gaze overlay absent)		(Gaze overlay absent)	
You made the right decision.		You made the wrong decision.	
It was a matter of controlling the breathing to determine what to do.		It was a matter of controlling the breathing to determine what to do.	
		If there is no evidence of breathing, CPR should be started; otherwise, the victim should be placed in RP.	
As a reminder, good breathing control requires checking the thoracic lift for at least 10 s.		As a reminder, good breathing control requires checking the thoracic lift for at least 10 s.	

Information given to participants during video debriefing depending on group membership (experimental or control) and outcome of preallocation simulation.
RP, recovery position.

McNemar test showed that the increase in success rate from preallocation (59%) to postallocation (79%) was significant ($\chi^2 = 7.22$, $P < 0.01$; Table 3).

One experimenter unaware of participant group membership examined the first-person videos shot by the head-mounted eye tracker camera during simulations to determine
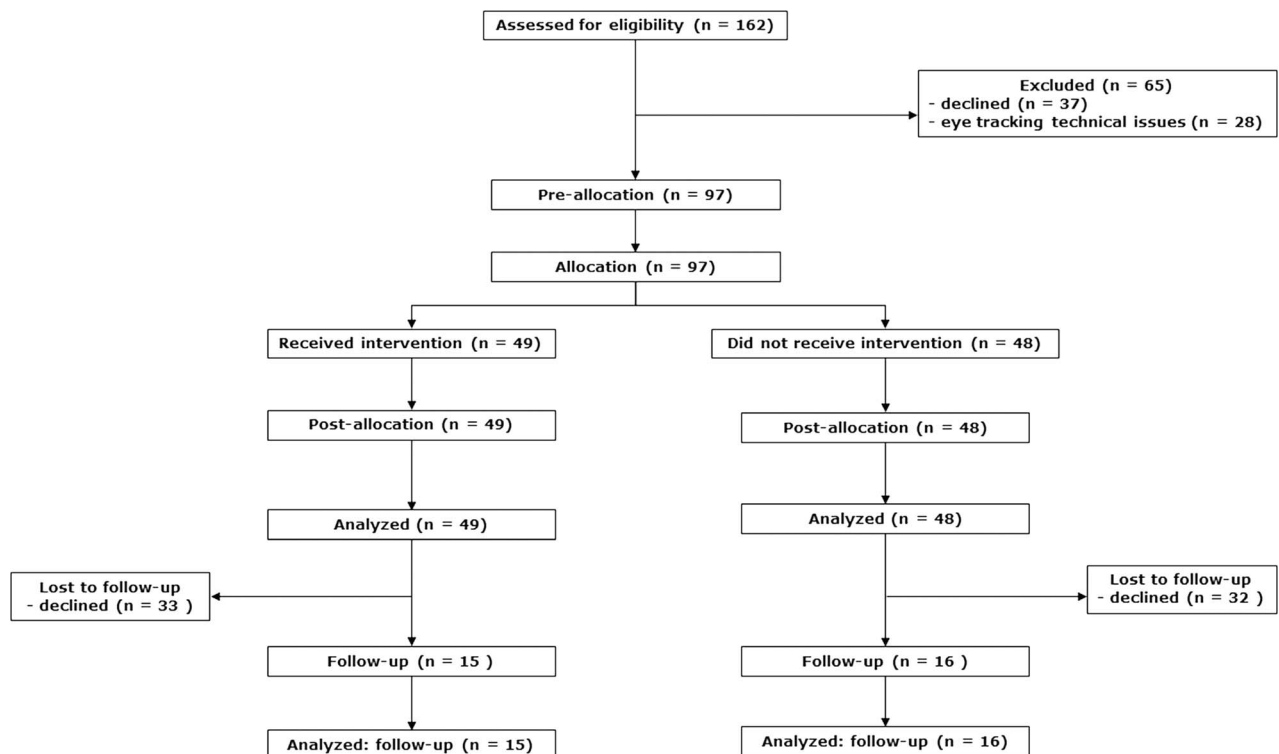
FIGURE 3. Participant flow diagram.

TABLE 2. Baseline Demographics of Participants

	n	Mean (SD)
Age, y	97	21 (4)
Sex	97	
Male	20	
Female	77	
Body mass, kg	97	64 (13)
Body height, m	97	1.68 (0.08)
Body mass index, kg/m^2	97	23 (4)
Wears corrective glasses or lenses?	97	
Yes	40	
No	57	
Completed first aid course for driver's license	96	
Yes	84	
No	12	

In Switzerland, a basic first aid course is part of the driver's license issuance procedure.

the time spent examining the thorax. Thorax inspection time was calculated by summing up the time during which the gaze reticle (Fig. 2) stayed between clavicles and umbilicus. Some participants occasionally stuck their cheeks to the dummy's upper chest for an oblique view of the thorax, a position that is too close to the target for correct gaze point estimation by the eye tracking system. In such cases, the time during which the participant stayed in this position was counted as chest examination time as well.

During preallocation, logistic regression did not show any association between thorax looking time and success rate (χ^2 vs constant model = 0.15, P = 0.69). After debriefing, logistic regression on postallocation data showed a significant association between the independent variables and success rate (χ^2 vs constant model = 16.5, P < 0.001). Area under the curve was 0.77, an acceptable discrimination performance.[27] There was no effect of group: the experimental group did not exhibit a significantly higher success rate at postallocation (P = 0.21) than the control group. There was an association between the time spent looking at the thorax and the success rate, in that the longer the time spent looking at the thorax, the greater the probability of making the right decision [odds ratio = 1.38, 95% confidence interval (CI) = 1.14–1.67]: each second spent looking at the thorax increased the odds of success by 38%.[28]

Consistently, mean thorax gaze duration significantly increased by 5.95 seconds (95% CI = 4.71–7.31) from preallocation (3.46 seconds, SD = 4.16) to postallocation (9.41 seconds, SD = 5.98; Fig. 4).

We did not carry out any ancillary analyses. Participants did not encounter any harm or unintended effects.

DISCUSSION

We randomized participants in an RCT to see whether adding eye tracking data to classic video debriefing has a positive effect on a learning outcome (breathing detection) in a pre-post design. Contrary to our expectations, we observed no effect, in that all participants performed better at postallocation regardless of having their own gaze overlays played back during video debriefing. In addition, instructing lay rescuers to look for chest movement allows them to detect breathing (or lack thereof) and take appropriate action. Gaze data showed that the longer the time spent looking at the thorax, the higher

the probability of making the right decision. Each second spent looking at the thorax increased the odds of successfully detecting breathing (or lack thereof) by 38%.

These results have implications both when considering simulation as a subject of research and when using simulation as an investigational method for research. For the former approach, the main finding of this RCT is that adding eye tracking to video debriefing does not improve learning outcomes. Trainers willing to add value to classic video debriefing, which is itself an already powerful tool, could avoid the burden of technical complexity presented by eye tracking.

For the latter approach, we showed that breathing detection can be taught and successfully learned through simulation. Researchers seeking causal relationships between human behavior and health outcomes should definitely integrate eye tracking into simulation when it comes to where and how people look when making decisions. Our study's procedure somehow suggests such a causal relationship, because participants instructed to look for chest movement effectively detected breathing at postallocation. However, looking at something does not necessarily mean that the information is being cognitively processed. Although gaze duration was associated with success in this study, other gaze metrics, such as pupil dilation, are more suited for directly measuring cognitive load when lighting conditions can be controlled.[29,30]

Our results confirm the findings of the only study that specifically targeted breathing detection.[13] When considering all trials, laypersons' median diagnosis time was 13 seconds (range = 5–40 seconds) in the study by Ruppert et al[13] and 15.5 seconds (range = 2–63 seconds) in our study. In the present study, median diagnosis time increased from 14.4 seconds (range = 2–54 seconds) at preallocation to 16.3 seconds (range = 5–63 seconds) at postallocation (see Table, Supplemental Digital Content 2, http://links.lww.com/SIH/A750). This likely occurred because of the instructions provided during debriefing (Table 1). However, the slight nonsignificant increase in diagnosis time came with a significant increase in breathing detection, from 59% correct (no different from chance) to 79% correct (significantly different from chance; see "Results" section). Thus, in both studies, the median time to decision exceeded the maximum of 10 seconds presently recommended for the breathing check. After debriefing, in which we instructed participants to look for at least 10 seconds, median time increased by 6.3 seconds above the recommended 10 seconds, with improved outcomes in terms of diagnostic accuracy. This reinforces the conclusion that international guidelines should consider increasing the time allowed for the "check breathing"[31] step in CPR guidelines.

TABLE 3. Success Rate

	Success	Failure	Success Rate
Preallocation	57	40	59%
Postallocation	77	20	79%
Follow-up	NA	NA	NA

N = 97. "Success" indicates that the participant made the right decision, that is, starting CPR for a nonbreathing victim or putting a breathing victim in recovery position. "Failure" indicates that the participant made the wrong decision, that is, starting CPR for a breathing victim or putting a nonbreathing victim in recovery position. NA indicates not available, because we failed obtaining a sufficient number of participants for the follow-up simulation.
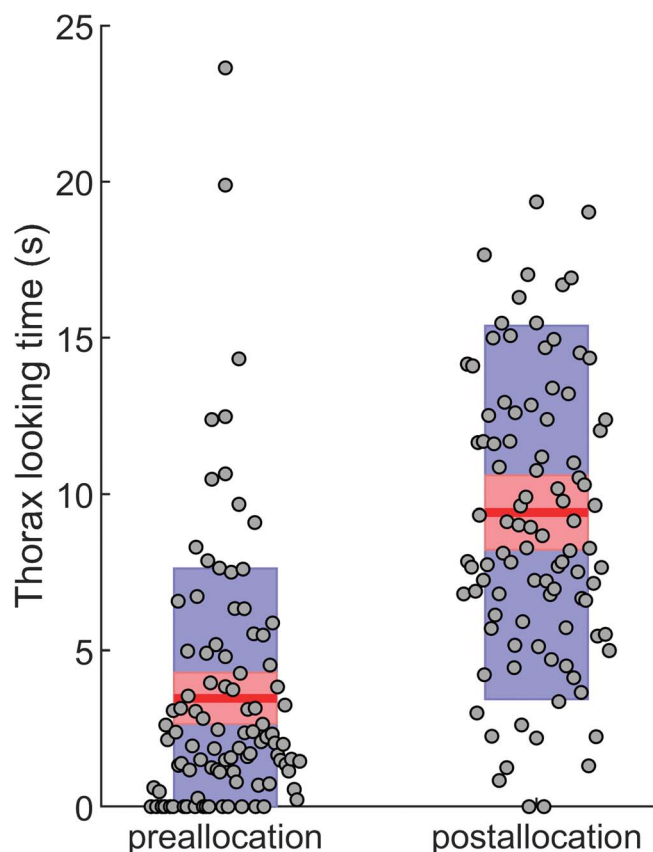
FIGURE 4. Thorax gaze duration during preallocation and postallocation. Each dot represents one participant. Red lines are medians with 95% CI (shaded red boxes). Blue boxes are 25th and 75th percentiles (n = 97).

The main limitation of this study is that we used a mannequin to simulate breathing. Ruppert et al[13] used both a mannequin and a trained test person who simulated either breathlessness or a regular breathing pattern (15 vs 8 breaths per minute in our study). Although breathlessness can easily be reproduced through simulation, the variety of irregular breathing patterns (eg, gasping, agonal breathing) occurring during cardiac arrest are more difficult to imitate and merit further studies. The Laerdal SimMan3G active mannequin used for this study cannot replicate such irregular breathing patterns. Moreover, we set the respiratory rate at 8 breaths per minute, because the physiological lower limit of 6 breaths per minute[32] would have made it too difficult to detect chest movement while looking for the recommended 10 seconds. We hypothesize that increasing the respiratory rate would increase the success rate, because more chest rises could be detected. This would reinforce the relationship between gaze behavior and breathing detection, but further studies are needed in this regard.

Finally, we failed to obtain a sufficient number of participants for the follow-up simulation (Fig. 3). Although all experiments were performed in compliance with COVID-19 prevention regulations, it is possible that participants who opted out preferred not to take risks and thus avoided the follow-up simulation, which took place after the COVID-19 outbreak in Switzerland. Previous studies found a significant deterioration of skill performance for the breathing check and more generally that the skills acquired through CPR classes decline appreciably over the subsequent 6 to 9 months.[33] Our results showed a 74% success rate at follow-up. This suggests good skill retention, but this result is purely descriptive and should not be interpreted because we lack sufficient power to perform statistical inferences on these data.

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