Effects of Brief Training on Use of Automated External Defibrillators by People Without Medical Expertise

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Objective: This study examined the effect of three types of brief training on the use of automatic external defibrillators (AEDs) by 43 lay users. **Background:** Because AEDs were recently approved for home use, brief training for nonprofessional users needs investigation. **Method:** During training, the exposure training group read an article about AEDs that provided no information on how to operate them; the low-training group inspected the AED and read the operating instructions in the paper-based manual but was not allowed to use the device; and the high-training group watched a training video and performed a mock resuscitation using the AED but no manikin. All participants returned 2 weeks later and performed a surprise simulated AED resuscitation on a manikin. **Results:** Most participants in each training group met criteria of minimally acceptable performance during the simulated manikin resuscitation, as measured by time to first shock, pad placement accuracy, and safety check performance. All participants who committed errors were able to successfully recover from them to complete the resuscitation. Compared with exposure training, the low and high training had a beneficial effect on time to first shock and errors. **Conclusion:** Untrained users were able to adequately use this AED, demonstrating walk-up-and-use usability, but additional brief training improved user performance. **Application:** This study demonstrated the importance of providing high-quality but brief training for home AED users. In conjunction with other findings, the current study helps demonstrate the need for well-designed training for consumer medical devices.

INTRODUCTION

Automatic external defibrillators (AEDs), which correct the heart rhythm during sudden cardiac arrest (SCA), have recently been approved for sale to the public. Given this approval and the increasing availability of AEDs in public places, the likelihood of the device being used by people with little or no training is increasing. Although AEDs have been made easy to use, it is unclear if training is necessary or effective.

The current study focused on training for AED use by laypersons with no medical expertise, as would occur for people using an AED in the home or in a public place such as an airport. Most home users will probably rely on the training materials that come with their AED. In the current study, college students received one of three levels of brief training – no training, paper-based training, or video training – and then, after a retention interval, performed a surprise emergency resuscitation.

Prior research has shown that untrained users can often use AEDs in an acceptable amount of time (Andre, Jorgenson, Froman, Snyder, & Poole, 2004; Eames, Larsen, & Galletly, 2003). However, some studies have shown that training and experience improves peoples' ability to use AEDs effectively (Gundry, Comess, DeRook, Jorgenson, & Bardy, 1999; Woollard et al., 2004). The generalizability of these findings is questionable because AEDs are not standardized, and many early studies used AEDs that were more cumbersome than current models and had different displays. Also, previous research was very liberal in defining acceptable electrode pad placement.

Current Study

No training is required for home use of AEDs.

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In the worst-case scenario, it is expected that home users may purchase an AED but do nothing to learn how to use it. In this study, the exposure-only training group represented this level of training. They read an article describing AEDs and their purpose.

Another possible home-use scenario is when consumers spend a few minutes looking over the AED and its instruction manual just after purchase, and then forget about it until they need to use it. The low-training group read the paper-based instruction manual provided with the device and gave a verbal summary of how to use the AED. They inspected and could handle the device but did not experience any audio or visual prompts and were not able to effectively use the device. The low training emphasized textual and verbal descriptions of the AED procedure.

In a third home-use scenario, consumers watch the included training video, go through the motions of using the device, and contact customer service if they have any questions. Our high-training group watched the AED training video and then performed a simulated resuscitation on an imaginary victim while experiencing the normal audio and visual prompts from the AED. The experimenter answered any questions participants had. The high training emphasized perceptual-motor modeling and performance of the AED procedure.

Participants in all three groups returned 12 to 16 days later, when they performed a simulated resuscitation on a manikin. The performance of the three groups was compared in terms of task completion times and errors.

We used a convenience sample of university students. These participants represent some of the lay users who will use AEDs in the home or in public places. Later research should assess whether our findings generalize to older adults. One reason to expect this generalization is a study by Mykityshyn, Fisk, and Rogers (2002), who found that older adults benefited from brief training in a medical procedure similar to the training in our study.

Hypotheses

We hypothesized that 90% or more of participants in each of the three training groups would meet criteria of minimally acceptable performance during the simulated resuscitation. This hypothesis is based on the Gundry et al. (1999) finding of only a slight difference when sixth graders' AED performance was compared with that of emergency medical technicians, even though these two groups represented extreme differences in training and experience.

We also hypothesized that the high-training group would outperform the low-training group. This hypothesis was based on the more active nature of the high training (i.e., participants actually performed a simulated resuscitation) and on the study by Mykityshyn et al. (2002), which found some advantages for video training (similar to our high training) over training with a paper manual (similar to our low training). The low-training group was hypothesized to outperform the exposure training group because the exposure group received no information about the AED procedure. Finally, the high-training group was hypothesized to perform better than the exposure-only group.

These two sets of hypotheses were advanced with respect to three performance variables: time to first shock, accuracy in placing the electrode pads, and performance of safety checks.

METHODS

Participants

Forty-four university students went through the training process, but 1 did not return for the second session. The remaining 43 participants ranged in age from 18 to 24 years ($M = 19.5$). The exposure-only group had 8 men and 6 women. The low-training group had 13 men and 2 women. The high-training group had 4 men and 10 women. Participants received class credit in return for participation.

Materials

AED. The AED used was a Philips Medical Systems Model M5085A Edition 2 HeartStart Trainer, which is a training device for the HeartStart HS1 Defibrillators (Philips Medical Systems, 2003). Each electrode pad had a diagram to specify the proper placement location.

Manikin and training mat. The Laerdal Little Anne Manikin was fully dressed. The manikin had HeartStart Internal Manikin Adapters, which allowed the trainer AED to read the simulated heart rhythm of the manikin and which were not visible to users. The training mat is a flat piece of plastic with an outline of a human on it. The adapters on the mat were visible, thereby directing the user to the ideal pad placement.

Training materials. Some participants read two

1-page articles, one on AEDs and one on insulin pumps. Each article included a picture of the device and described its purpose but gave no information on how to use it. The paper-based instruction manual illustrated both in written text and in schematic drawings the steps that were to be followed in order to use the AED. The 5-min training video showed a person going through the steps to use the AED while orally describing each step. The AED audio prompts could be heard clearly on the video.

Exclusion questionnaire. Prior to the experiment, participants completed a questionnaire about their prior experience with AEDs, their English reading ability, their vision and hearing proficiency, and whether they could kneel or sit on the floor for 5 min.

In-training quiz. Administered during the training, the quiz for the exposure-only group consisted of two questions regarding the articles. For the other groups, the questions pertained to the specific steps in using the AED. The low-training group quiz consisted of three questions. The high-training group quiz included these questions, plus five more on material unique to this group.

Posttraining and posttest questionnaires. These assessed participants' feelings about ease of use of the AED and the clarity of the instructional materials.

Design

The independent variable consisted of three between-subjects groups: exposure only, low training, and high training. Each participant was randomly assigned to a group, with the constraint that the groups had similar levels of cardiopulmonary resuscitation (CPR) experience.

Procedure

Participants were trained and tested individually. All participants completed an exclusion questionnaire when they signed up for the study. Only participants who had no prior AED use, were able to speak and read English, had acceptable vision and hearing proficiency, and could sit or kneel on the floor for 5 min were invited to participate. During the first session, participants completed a consent form, completed the exclusion questionnaire again, and then received training.

Exposure-only training. In about 15 min, participants read the articles on AEDs and insulin pumps and took the in-training quiz on each article.

Low training. Participants were instructed to look over the automated external defibrillation device and its instructions so that they would be able to use it in the case of an emergency. Participants were informed they would take a quiz on the material and were given the training electrode pads and the instruction manual. Participants had up to 10 min to familiarize themselves with the AED. During this period, participants read through and interpreted, out loud, the instruction manual.

The experimenter asked participants to look at the inputs, outputs, buttons, and figures on the AED itself and to mentally identify the function of each. The experimenter did not answer participant questions regarding the AED. Although the participants could manipulate the AED, the batteries were removed, so the device did not give audio or visual prompts. After familiarization, the participants gave the experimenter a verbal summary of how to use the AED but received no feedback on this summary. Participants then completed the in-training quiz. The low training took about 20 min.

High training. Participants were instructed to watch the training video, go through the instruction manual, and practice using the AED device using the training defibrillator and training pads. Participants then watched the training video while following along by manipulating the AED (with batteries removed). Participants then read through the instruction manual and explored the AED. Participants were asked by the experimenter to mentally identify the function of the inputs, outputs, and buttons. Following familiarization, participants completed the in-training quiz. The experimenter explained the answers to any quiz questions participants answered incorrectly. Then, participants performed a mock resuscitation using the AED (with auditory/visual prompts working) and the training mat. The experimenter then reviewed the participants' performance, pointing out errors and suggesting how to fix them. The high training took about 30 min.

At the end of the high- and low-training sessions, participants completed the posttraining questionnaire. Then, participants in all groups scheduled their second session. Participants were told that the second session would focus on the usability of medical devices; no mention was made of AEDs.

Test session. Upon arrival, participants were given a description of an emergency situation in which a brother (simulated by the manikin) had collapsed from SCA in the next room and an AED was available. Participants were asked to resuscitate the victim and told that speedy and accurate performance was important in order to save the victim's life. Then, participants entered the room, where the manikin was on the floor, in a position representative of an SCA victim, and the AED was nearby. The resuscitation was videotaped. Following the resuscitation, participants completed the posttest and demographic questionnaires.

RESULTS

Analysis Procedures

There were two types of hypotheses in this study. In the first type, more than 90% of participants in each of the training groups were expected to meet criteria of minimally acceptable performance during the resuscitation. Descriptive statistics were used to evaluate whether each group met these criteria for each dependent variable.

The second type of hypotheses held that performance would be better for low than exposure training, better for high than low training, and better for high than exposure training. Because these hypotheses were specific directional statements about differences between groups, statistical contrasts (one-tailed t tests) were used to evaluate the group differences (Hallahan & Rosenthal, 1996). For each dependent variable, three contrasts were tested. To control for inflation of Type I error attributable to testing multiple contrasts for each variable, the alpha level (α) was based on Simes's (1986) modified Bonferoni adjustment. Cohen's d was used to indicate effect size; d values of 0.3, 0.5, and 0.8 indicate small, medium, and large effects sizes, respectively (Cohen, 1988).

Because of space limitations, the data from the posttraining and posttest questionnaires will not be presented.

Prior Experience

No participants had any experience with AEDs. In the exposure-only group, 1 participant was certified in CPR at the time of the study, 3 had prior (but not current) experience with CPR, and 10 had no CPR experience. In the low-training group, 1, 6, and 8 participants were in these categories, respectively. In the high-training group, 2, 3, and 9 participants were in these categories, respectively. The slight imbalance in the number of low-training participants with prior experience occurred because 3 participants gave an inaccurate assessment of their CPR experience prior to training group assignment, and they later corrected this.

Time to First Shock

Time to first shock was the amount of time between when the participant first walked into the testing room and when the manikin received the first shock. Because of technical difficulties, the time to first shock was not recorded for 3 participants; these participants were not included in the time analysis. For 4 other participants, the AED temporarily malfunctioned and would not initially deliver a shock, even though the pads were placed correctly. For these participants, the time the AED was malfunctioning was subtracted from the overall time to first shock to determine what the time would have been without the error.

The minimum acceptable time to first shock was set at 150 s because brain death starts to occur 4 min after SCA (Chain of Survival, 2004), and we assumed that in a real emergency situation, 90 s would be used in recognizing that a victim needs resuscitation and in finding and retrieving the AED. In the exposure-only group, all but 1 participant (92.3%) performed the task in the acceptable time, and in the low- and high-training groups, all participants performed the task in the acceptable time. These data supported the hypothesis that 90% or more of participants would deliver the first shock within 150 s.

The second hypothesis was that the high-training group would deliver the first shock faster than the low-training and exposure training groups and that the low-training group would be faster than the exposure group. Figure 1 and Table 1 show the data relevant to this hypothesis. To provide some context for evaluating the time to first shock data, ideal performance time (77 s) was determined by having the experimenter, after practice, complete the defibrillation task three times.

The mean times for the low-training group (73 s) and the high-training group (86 s) were close to the ideal, whereas the exposure group (107 s) was considerably slower. Both the low-training group, $t(24) = 3.25$, $p = .002$, $\alpha = .017$, $d = 1.27$, and the high-training group, $t(25) = 1.92$, $p = .033$, $\alpha = .05$, $d = 0.73$, were faster than the exposure group, as hypothesized. However, contrary to expectations, the low-training group was faster than the high-training group, $t(25) = 2.34$, two-tailed $p = .027$, $\alpha = .033$, $d = 0.91$.

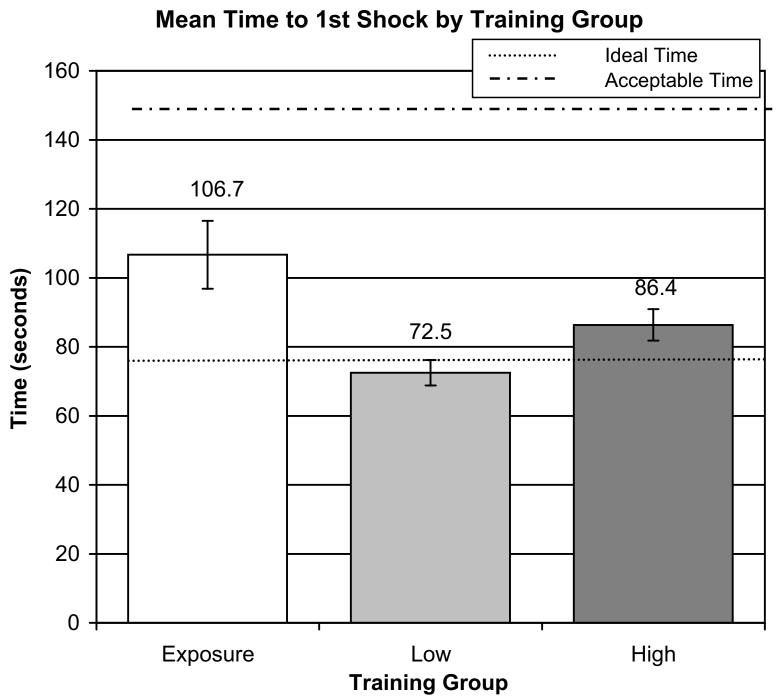

Figure 1. Mean time to first shock for each training group, compared with the acceptable time (short dashes) and the ideal time (long dashes).

Pad Placement

The boundaries of minimally acceptable placement of the right and left pads, shown in Figure 2, were defined according to the AED manufacturer's descriptions. If pads were placed outside these areas, the effectiveness of the shock would be diminished.

The ideal pad locations were defined as the locations matching the testing adaptor on the inside of the manikin's skin. Figure 3 shows the boundaries for the acceptable areas mostly by the straight horizontal and vertical lines (these boundaries are clearer in Figure 2), and the ideal areas are marked in white. An individual pad placement was defined as ideal if less than 10% of the pad fell outside the ideal area, acceptable if it was not ideal and 50% or less of the pad fell outside the acceptable area, and unacceptable if more than 50% of the pad fell outside the acceptable area or the pad was not placed directly on the manikin's skin.

Pad placement was assessed by placing a grid of 2-cm squares on the pads. The variables measuring pad placement accuracy were the percentage of a pad's squares located outside the ideal boundaries and outside the acceptable boundaries. (Regarding interrater reliability, two raters had a mean difference of 2% of total pad area.)

TABLE 1: Means (and *SE*s) for Performance Variables by Training Group

	Training		
	Exposure	Low	High
Time to first shock (s)	106.7 (9.9)	72.8 (3.4)	86.4 (4.6)
Outside ideal area (%)			
Right pad	13.8 (2.8)	19.5 (5.7)	11.0 (1.9)
Left pad	34.9 (5.5)	33.3 (3.7)	42.19 (4.8)
Errors (number)	1.43 (0.29)	0.67 (0.19)	0.31 (0.17)

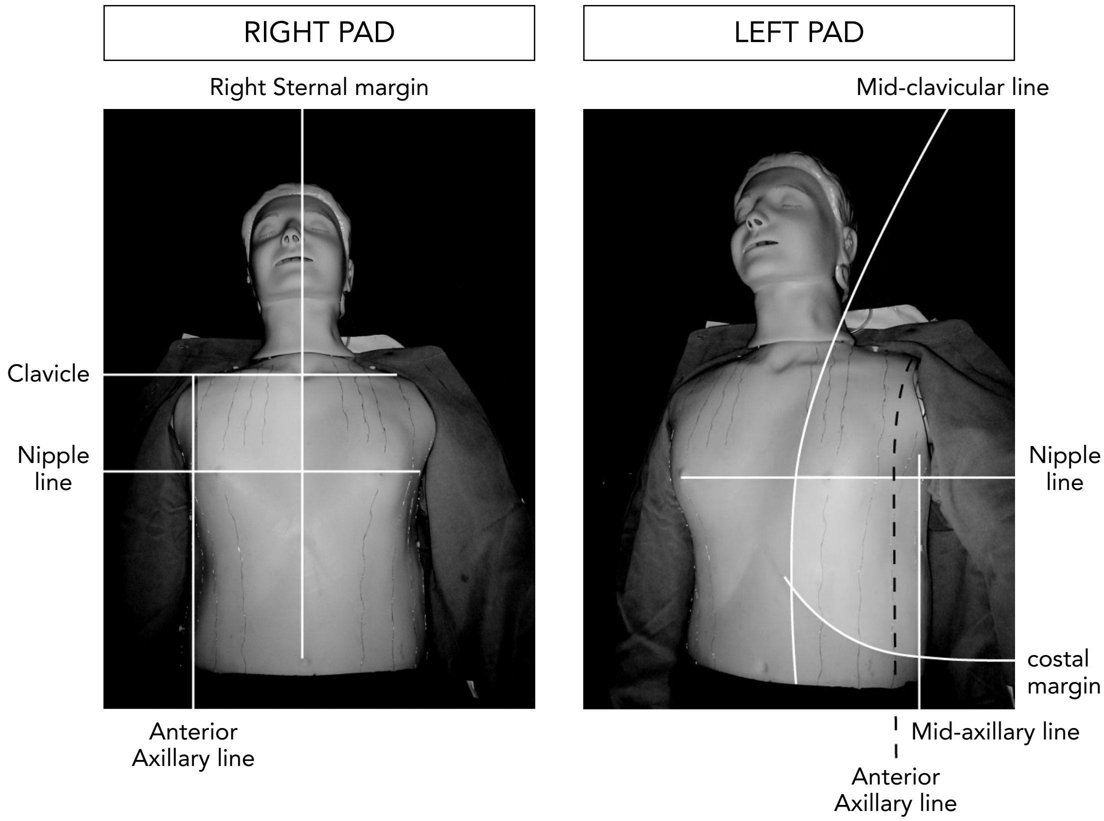

Figure 2. Areas of acceptable right and left electrode pad placement as defined by the manufacturer. Courtesy of Philips HeartStart.

Four participants originally placed the pads in incorrect locations, then corrected this. All ratings of pad placements were based on participants' final pad locations.

The only unacceptable pad placement was for a single participant in the low-training group (see the right pad in Figure 3). Therefore, the hypothesis that at least 90% of participants in each group would have acceptable pad placements was supported.

The hypotheses that more advanced training would lead to better pad placements was tested separately for the right and left pad because the accuracy in placing the two pads could differ. For the right pad, the high-training group had 11%, the low-training group 19%, and the exposure group 14% outside the ideal location. For the left pad, the high-training group had 42%, the low-training group 33%, and the exposure group 35% outside the ideal location (see Table 1). For both pads, there were no significant differences between any of these means (one-tailed $p > .08$ for each contrast). Thus, training had little effect on pad placement.

Additionally, we conducted an analysis of the location of each pad based on the pad center points. The location of the center of each pad was recorded using a 1-cm coordinate layout on another sheet of clear plastic that was placed over the curved surface of the manikin. (An alternative system showed very similar measurements.) The pad center points for individual participants are shown in Figure 4. The graph shows that almost all participants placed the left pad more toward the center of the chest than is ideal. On average, participants placed the left pad 4.3 cm closer to the center of the body than was ideal. This placement was significantly different from the ideal placement, $t(42) = 13.59$, $p < .001$.

Safety

The most important safety procedure, and the one measured in this study, was staying clear of the victim as the AED charges and delivers a shock.

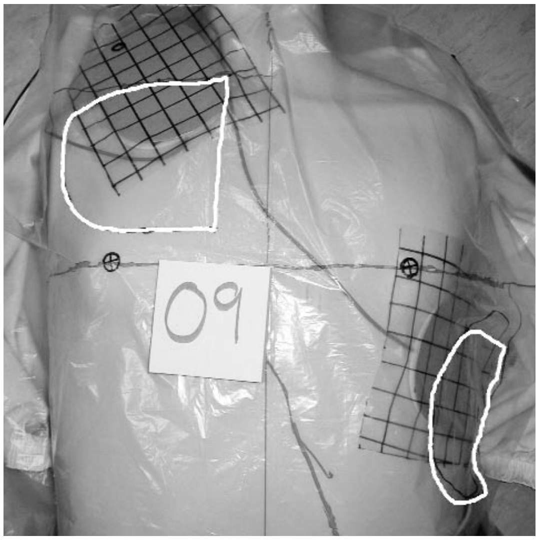

Figure 3. Areas of ideal right and left electrode pad placement are bounded by the white lines. Also shown are the actual pad placements of a participant who placed the right electrode pad outside the acceptable region, which is defined mostly in this figure by the straight horizontal and vertical lines and is shown more clearly in Figure 2.

This was given a rating of ideal if the participant did not touch the manikin or its clothing in any way, acceptable if the participant was touching the manikin in a way that did not cause danger (e.g., clothing-to-clothing contact), and unacceptable if the participant made skin-to-skin or skin-to-clothing contact. All of the participants in the study received a rating of either ideal or acceptable. Therefore, the hypothesis that 90% or more of participants in all groups would perform acceptably (or better) was supported.

Errors

Any behavior that deviated from the perfect completion of the task was counted as an error, even if the behavior allowed the participant to successfully resuscitate the victim. The experimenter counted errors during the experimental session and after reviewing the video recording.

The majority of the errors involved not staying clear of the victim (as discussed in the Safety section) or incorrect pad placement on the first attempt. Other errors were not removing the liner from the pads, trying to press the shock button too early, placing the pads outside the manikin's clothing, and placing the pad cartridge cover instead of the electrode pad. As shown in Table 1, the average number of errors for each participant decreased as training level increased, from 1.43 errors with exposure training, to 0.67 with low training, to 0.31 with high training.

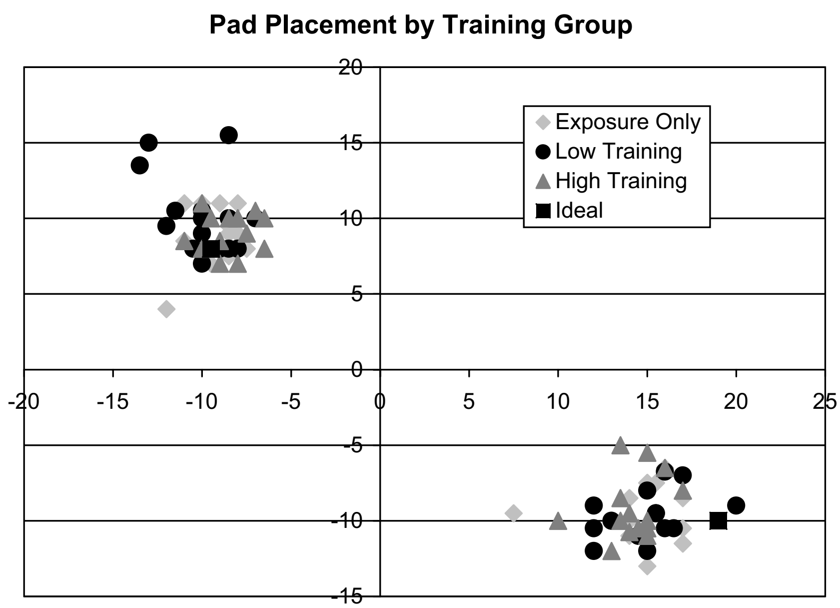

Figure 4. Center points for each pad as placed by individual participants, by training group; the squares represent the ideal pad locations. The *x* axis represents distances on the nipple line, and the *y* axis represents distances on the center section of the chest, or the sternal border. The units for both axes are centimeters.

Because hypotheses were not made regarding the number of errors, paired comparisons of group differences in number of errors were tested using two-tailed *t* tests. The number of errors with exposure training was greater than with low training. Although this difference did not reach significance, $t(27) = 2.23$, $p = .034$, $\alpha = .033$, it showed a large effect size, $d = 0.82$. The number of errors with exposure training was significantly greater than with high training, $t(25) = 3.24$, $p = .003$, $\alpha = .017$, and also showed a large effect size, $d = 1.26$. The difference in errors between the high- and low training-groups was not significant, $t(26) = 1.39$, $p = .077$, $\alpha = .05$, $d = 0.53$. Thus, training played a large role in reducing errors during AED use. It should be noted that although some participants made errors, all were able to recover from them and successfully deliver a shock.

Effects of Gender and Prior Experience

Given our goal of matching the training groups on prior CPR experience, these groups were not balanced in terms of gender ratio. However, there were no significant gender differences for any of the quantitative variables (time to first shock, percentage of pads outside the ideal area, and errors), nor did gender interact with training group for any of these variables. ANOVAs evaluating the effect of training group on these variables while statistically correcting for the gender imbalance showed a pattern of significant effects and effect sizes very similar to those described previously. (The only different findings revealed by these ANOVAs were that the exposure and high-training groups no longer differed significantly in time to first shock and that the exposure and low-training groups did differ significantly in errors.)

A possible explanation for the low-training group performing the first shock in less time than the high-training group is that the low-training group had slightly more CPR experience than did the high-training group. However, when the time data were collapsed across training groups, participants with no CPR training were as fast as or faster than those with active or prior CPR training, suggesting that CPR training was not a cause of better performance on the AED task.

DISCUSSION

Participants in each of our training groups were able to successfully deliver a shock in an acceptable amount of time. In fact, 41 of 43 participants met all the requirements for acceptable performance (i.e., locating the pads correctly, not touching the victim's skin, and delivering the shock within 150 s). Thus, the hypothesis that each of the three levels of training would allow most people to achieve minimally acceptable levels of performance was supported, and therefore this AED demonstrates "walk-up-and-use" usability.

Our quantitative analyses showed that as predicted, both the high- and low-training groups were significantly faster than the exposure group at delivering the first shock, and these group-average time reductions ranged from 20 to 34 s and showed medium to large effect sizes. Using the rule of thumb that each minute of delay in defibrillation leads to a 10% drop in survival rate (Varon & Marik, 2003), the maximum time reduction found here (34 s) translates to a 6% increase in survival rate. Thus, even relatively short training experiences of 20 to 30 min, as in the low- and high-training conditions, can decrease time to first shock by meaningful amounts.

Unexpectedly, the low-training group delivered the first shock in significantly less time than the high-training group did. One possible explanation for the low-training group exceeding the high-training group is that the low level of training – in particular the requirement that participants encode, recall, and describe the AED procedure in their own words – put more emphasis on understanding the meaning of the material and making elaborative connections between the information being learned and other relevant information.

At the early stages of learning a procedural skill such as AED use, behavior is under the control of explicit, declarative knowledge (Anderson, 1982). Research has demonstrated that declarative information processed in this elaborative, meaning-based manner will be learned more effectively than information processed in terms of less-meaningful, perceptual features (Craik & Lockhart, 1972; Hyde & Jenkins, 1969). In contrast to the low-training group, participants in the high-training group followed along in the video and did not have to describe the AED procedure. This may have emphasized more perceptual-based and less meaning-based processing. This post hoc explanation suggests the hypothesis that requiring participants to describe a procedure in their own words is an important facilitator of meaning-based processing and better learning.

An alternative explanation for the slower speed of the high-training group is that this group may have been taught a more detailed AED procedure with extra or more time-consuming steps as compared with the low-training group. An analysis of the high- and low-training materials showed a few steps that were present only in the high training (e.g., check for victim response and breathing). However, analysis of the videos of participants' AED use suggested that these extra steps accounted for very little of the speed difference between the high and low groups because only a few participants performed the extra steps, and these participants were evenly distributed across the three training groups.

However, there is another difference between the high and low training that may have contributed to the speed difference. Because only the high-training group heard the AED auditory prompts during training, perhaps this group expected the AED to guide them through the procedure and therefore used the AED prompts as a "crutch," waiting for the device to finish its instructions before completing the steps. Analysis of this question was not possible from the videos, but the question merits further investigation.

Training level affected the number of errors made during the resuscitation, with the exposure group making more errors than the low- and high-training groups. All of the errors made by participants in the current study were errors that could be, and were, corrected. This gives evidence that the device and its verbal prompts do a good job of allowing users to realize when they have made an error and to correct it. One notable error, made by 6 participants, was attempting to place one of the electrode pads without removing the liner from the pad.

Training level did not affect accuracy in placing the electrode pads. Regardless of training, participants were very accurate in placing the right pad and less accurate in placing the left pad. Other research found similar errors in placing the left pad by laypeople (Nurmi & Castrén, 2005) and by resuscitation experts (Nurmi, Rosenberg, & Castrén, 2004). Nurmi et al. (2004) also found that this error was reduced when the AED picture for the left pad placement location showed a side view (instead of the usual front view, which was used in the current study).

In conclusion, users receiving either of two kinds of brief training or mere exposure were able to successfully use an AED, but even the brief training improved users' ability to deliver a shock quickly and with less error. Taken together with the findings of Mykityshyn et al. (2002), the current findings help demonstrate the effectiveness of brief training for consumer medical devices. Both of these studies also demonstrate that the format and content of the brief training matters; therefore further research is needed to optimize the training effectiveness of these brief interventions.

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