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Simulation and education

The design of instructional tools affects secondary school students' learning of Cardiopulmonary Resuscitation (CPR) in reciprocal peer learning: A randomized controlled trial☆

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ABSTRACT

Background: Research investigating design effects of instructional tools for learning Basic Life Support (BLS) is almost non-existent.
Aim: To demonstrate the design of instructional tools matter. The effect of spatial contiguity, a design principle stating that people learn more deeply when words and corresponding pictures are placed close (i.e., integrated) rather than far from each other on a page was investigated on task cards for learning Cardiopulmonary Resuscitation (CPR) during reciprocal peer learning.
Methods: A randomized controlled trial. A total of 111 students (mean age: 13 years) constituting six intact classes learned BLS through reciprocal learning with task cards. Task cards combine a picture of the skill with written instructions about how to perform it. In each class, students were randomly assigned to the experimental group or the control. In the control, written instructions were placed under the picture on the task cards. In the experimental group, written instructions were placed close to the corresponding part of the picture on the task cards reflecting application of the spatial contiguity principle.
Results: One-way analysis of variance found significantly better performances in the experimental group for ventilation volumes ($P = .03$, $\eta p^2 = .10$) and flow rates ($P = .02$, $\eta p^2 = .10$). For chest compression depth, compression frequency, compressions with correct hand placement, and duty cycles no significant differences were found.
Conclusion: This study shows that the design of instructional tools (i.e., task cards) affects student learning. Research-based design of learning tools can enhance BLS and CPR education.

1. Introduction

Although many innovative instructional tools have been introduced in BLS and CPR education (e.g., videos for self-instruction, online instructional videos), the design of these tools has not yet been the focus of research.[1–5] Very often, instructional strategies and tools are merely compared to determine which approach produces the highest learning or retention scores.[1,2,4] One could argue that this line of investigation fails to explore the potential of learning tools. Putting the focus on the instructional tool itself (e.g., instructional DVD) and identifying design features that affect learning could complement existing research and further enhance educational outcomes.

The cognitive theory in multimedia learning[6] offers a framework for designing multimedia instructional tools. Multimedia learning occurs when people build mental representations from words (e.g., spoken or printed text) and pictures (e.g., video, animations, photos, or illustrations). The foundational argument of this theory is that tools designed to account for human cognitive architecture will lead to higher learning than tools which are not.[6]

Underpinned by the cognitive theory in multimedia learning, researchers have produced design principles for instructional tools that explain how to organize words and pictures (i.e., multimedia) to foster learning outcomes.[7]

In general, multimedia design principles seek to reduce extraneous processing in favor of essential processing.[8] Extraneous processing is caused by extraneous load and does not contribute to learning the task. This type of load is created by too much extraneous information (i.e., too many words and pictures) or a poorly designed multimedia message. Essential processing on the other hand is the result of actively selecting and organizing relevant words and pictures in working memory, and integrating them with

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existing knowledge. Essential load therefore contributes immediately to learning.[7]

Design principles have now been retrieved in areas such as history,[9] mathematics,[10] and chemistry.[11] To date, research in the psychomotor domain remains scarce although it could be of prime importance for learning BLS and CPR. The case that a scientific development of instructional tools matters has previously been argued by Braslow et al., who in their study described the evaluation of a self-instructional video for learning CPR.[12]

According to spatial contiguity, a multimedia design principle, people learn more deeply when words are placed near rather than far from the corresponding part of the picture on the page.[7] Our group investigated the effect of spatial contiguity on university students' individual learning of BLS.[13] We applied this principle to task cards, which are instructional tools that combine a picture of the skill with written instruction about how to perform the skill. Results from that study demonstrated that spatial contiguity on task cards produced better scores on a transfer test.[13]

Since, researchers have emphasized the need to test design principles in ecologically valid environments such as secondary school classrooms.[13,14] The study presented herein aims at initiating multimedia research in BLS education in secondary schools. In Flanders (Belgium), the teaching of BLS is mandatory in secondary school curricula and therefore research enhancing instructional effectiveness is worth conducting. In this study, the effect of spatial contiguity on task cards was investigated in six intact year 2 classes from the first cycle. Secondary education in Belgium comprises three cycles of two years each. In all classes, students learned BLS by means of task cards in a reciprocal learning setting. During reciprocal learning, students work together in well-defined roles of doer and observer.[15] Reciprocal learning has previously been described as an effective instructional model for learning BLS.[16] While the doer is performing the task, the observer provides instructions and feedback based on the information on the task cards. Task cards in this study have previously been used for learning BLS in university settings.[13,16,17] It was hypothesized that task cards on which the spatial contiguity principle was applied would lead to better CPR performances than task cards on which this principle was not applied.

2. Materials and methods

A randomized controlled trial was conducted to investigate the effect of spatial contiguity on task cards for learning CPR. Six intact year 2 classes from the first cycle in general education with a total of 117 students (84 girls and 33 boys) were randomly selected from a secondary school in Belgium. The overrepresentation of girls in this sample represents the actual gender composition for classes in this school, and is not the result of prior exclusion criteria. This school was selected because no prior CPR and/or BLS courses had been offered to students. Informed consent was obtained from the students' parents, and the president of the school. The Institutional Review Board from the first author's university provided approval for conducting the study. Before intervention, students were asked to complete a questionnaire to determine whether they had received previous training in BLS or CPR. Students who indicated not to have received BLS or CPR training in the previous three years were eligible for participation.

All intervention classes were taught by an experienced BLS instructor who had been certified by the European Resuscitation Council (ERC) for over eight years. For reasons of intervention fidelity, this instructor received a 1.5 h training by a university expert in pedagogy to faithfully implement the reciprocal learning model with task cards. After this training, the instructor was asked to complete a written test and to teach a practice lesson according to the experimental protocol. Upon successful completion of both the written test and the practice class, the instructor was qualified to teach the intervention classes for the study. The BLS instructor was naïve to the purpose of the study.

2.1. Basic Life Support classes and task cards

All classes were taught in the gymnasium where students attended their regular physical education class. A standardized format was followed for all BLS classes. First, students received a 5 min introduction during which the importance of BLS education and the instructional model were explained. Then, students chose a partner they preferred to work with and received task cards according to their group. Research suggests that self-selection fosters the learning process during peer learning.[15,18,19] Before the learning phase, student pairs were randomly assigned by a supervising researcher to the control or the experimental group using an online randomizer tool (http://www.randomizer.org/form.htm). The teacher was blinded to group allocations. In both the control and the experimental group, the researcher distributed the task cards combining pictures of the BLS skill to be learned with written instruction about how to perform the skill. Task card design differed between the groups. For the control, the written text was placed under the picture, whereas the text for the experimental group was integrated in the picture (i.e., spatial contiguity principle). Student pairs from the control as well as the experimental group were learning BLS in the same gymnasium. Distance between pairs was about 3 m to ensure that students were unable to consult each others' task cards. Students in both groups were given 20 min to learn BLS with task cards as the only source of information. They worked together in a defined doer–helper relationship and were prompted by the instructor to switch roles every 5 min. The role of helper was defined as 'instructing the doer based on the information on the task cards, observing the doer's performance, comparing and contrasting the performance with the instructions on the task cards, and giving skill-related feedback.' The role of doer was defined as 'listening carefully to the instructions of the helper and taking into account the given feedback during subsequent trials.' Following this 20-min reciprocal peer learning episode, a 10-min peer assessment was conducted by the students using the same reciprocal peer learning model. While the doer performed BLS, the helper (i.e., assessor) observed and assessed the doer's BLS performance using a scoring sheet on which all BLS items were listed. The helper was asked to mark the performance of each item with 'correct' or 'not correct.' Correct was defined as 'according to the instructions on the task cards,' whereas not correct was defined as 'not according to the instructions on the task cards.' Doers were not allowed to check the task cards during the assessment. Learners switched roles at the 5 min mark after having assessed the quality of the BLS skill. Peer evaluation was embedded in the learning episode since it fosters BLS retention in reciprocal learning with task cards.[16] Every class ended with a 5 min repetition of the importance of BLS.

The content of the task cards was based on the 2005 guidelines for BLS by the ERC.[20] Eleven task cards were used for learning the following nine BLS items: (a) safe approach, (b) check responsiveness by shaking gently and shouting loudly, (c) shout for help, (d) open airway, (e) check for breathing, (f) call 112, (g) perform 30 chest compressions, (h) perform two ventilations, and (i) continue the 30-2 sequence until you become exhausted, professional rescuers take over, or the victim starts breathing normally. Instructions for performing chest compressions and ventilations were each provided on two task cards due to the complexity of these skills. All task cards had a dimension of 210 by 297 mm (8.3 by 11.7 inches) and were oriented in landscape.

Table 1
Comparison of Cardiopulmonary Resuscitation (CPR) variables three weeks after training with European Resuscitation Council 2005 guideline targets in the control and the experimental group.

	Guideline target	Control (n = 56)		Experimental (n = 55)		Mean difference	95% CI between groups	F value	P value	ηp^2
		M (SD)	95% CI	M (SD)	95% CI					
Ventilation volume (ml)	499–601	343 (350)	204–481	564 (381)	426–703	221	25–417	5.128	.03	.10
Ventilation flow rate (ml/s)	499–601	238 (255)	134–342	410 (293)	306–514	171	24–319	5.464	.02	.10
Compressions with correct hand placement (%)	N/A[a]	53 (31)	43–63	51 (21)	41–61	−2	−16 to 13	.047	.83	<.01
Compression depth (mm)	39–51	30 (7)	28–33	32 (6)	30–34	1	−2 to 5	.779	.39	.01
Compression rate (min^{-1})	100	118 (16)	111–125	121 (18)	114–128	3	−7 to 13	.332	.57	<.01
Duty cycle (%)	50	45 (7)	42–48	47 (7)	43–49	2	−2 to 5	.793	.38	.01

[a] Not applicable.

2.2. Assessment of CPR performance

Three weeks following intervention, BLS performance was assessed. It has been shown that BLS skill performance already significantly declined two weeks following initial learning in one study.[21] All assessments were individually completed on a Laerdal AED ResusciAnne Skillreporter manikin connected to a laptop running the Laerdal PC-Skill Reporting system version 2.21 (Laerdal Medical, Vilvoorde, Belgium). The following CPR variables were measured and served as quality indicators for CPR mastery: compression depth, compression rate, and ventilation volumes.[22] Two additional CPR variables were recorded as well, namely compressions performed with correct hand placement, and duty cycles (i.e., the ratio of compression duration to total cycle time). The 2005 ERC guidelines were used to assess the quality of the CPR performance in both groups.[20] BLS assessment was stopped after students performed three compression–ventilation cycles.

2.3. Statistical analysis

The trial was designed to determine whether implementing the principle of spatial contiguity on task cards would be superior to task cards where spatial contiguity was not applied. Statistical analysis was performed using SPSS, version 20.0 (SPSS Inc., Chicago, IL, USA). Cardiopulmonary Resuscitation variables between groups were analyzed using one-way analysis of variance and reported in terms of means and standard deviations with 95% confidence intervals (CI), mean group differences, and 95% CIs. Partial eta squared (ηp^2) was reported as an estimate of effect size. For sample size calculation, a significance level of .05 and a power of .95 was set. In order to detect a minimum difference of 5 mm in chest compression depth between groups, and given a previously reported standard deviation of 5 mm,[17] it was calculated that 27 participants would have to be included in each group. To anticipate drop out and since student pairs would be used as the unit of analysis, the researchers chose to recruit six classes, constituting 117 participants.

3. Results

A total of 117 students constituting six intact year 2 classes from the first cycle were recruited for this study. One student (male) received no intervention because he was absent during the scheduled study. In each class, students chose a preferred partner with whom to work and pairs were then randomized over an experimental group (n = 56 students) and a control group (n = 60 students). The experimental group consisted of 41 girls and 15 boys and the control group contained 43 girls and 17 boys. Mean age in both groups was 13 years (SD 0.8, range 12–14). Average class time in all lessons was 44 min (range 41–46). Three weeks following the intervention, four students (one girl from the experimental group, two girls and one boy from the control) were absent the day of assessment. Their CPR performance was not collected. The movement of the students through the study is presented in Fig. 1.

3.1. CPR group comparison

Group comparison results for the CPR variables with student pairs as the unit of analysis are presented in Table 1. Significant differences were found for ventilation volume and ventilation flow rate. Ventilation volumes in the experimental group (M = 564 ml, P = .03) were significantly higher than in the control (M = 343 ml). Ventilation flow rate was also higher in the experimental group (M = 410 ml/s, P = .02) compared to the control (M = 238 ml/s). Ventilation performance in the experimental group was also closely aligned to the ERC 2005 guidelines. No group differences were found for compressions with correct hand placement, P = .83, compression depth, P = .39, compression rate, P = .57, and duty cycle, P = .38.

Quality of CPR performance was assessed through comparison with the ERC 2005[21] recommendations (see Table 1). Results demonstrate close alignment with the guidelines in both groups for duty cycle (mean in both groups = 46%), but low values for chest compression depths (mean in both groups = 31 mm). Chest compression rates were higher in both groups compared to the recommendations (mean in both groups = 119 min^{-1}).

4. Discussion

The effect of the spatial contiguity design principle on task cards for acquiring CPR during reciprocal peer learning was investigated. This principle states that people learn more deeply when words and corresponding pictures are placed near (i.e., integrated) rather than far from one another on a page.[7] Students learning with task cards where the spatial contiguity principle was applied achieved significantly better ventilation performances compared to students working with task cards where this principle was not applied. Since providing rescue breathings is a technically demanding skill, we argue that when the technical information to provide ventilations (e.g., putting one's hand on the forehead, pinching the victim's nose) is presented close to the corresponding part of the picture, learners are guided to look at those parts of the picture that are crucial for learning. In doing so, more cognitive resources become available for actually learning the task (i.e., germane processing). Without spatial contiguity, cognitive effort is wasted by scanning around the task cards since the learner has no cues for connecting words with corresponding parts on the picture.[23]

Although statistically significant, the clinical relevance of higher ventilation volumes and flow rates should be interpreted taking into account gastric inflation. One could suggest that with lower tidal volumes, gastric inflation could be lower and consequently do less harm to the patient. Future research could address this issue.

Results from this study confirm previous research where it was found that applying the spatial contiguity principle on task cards

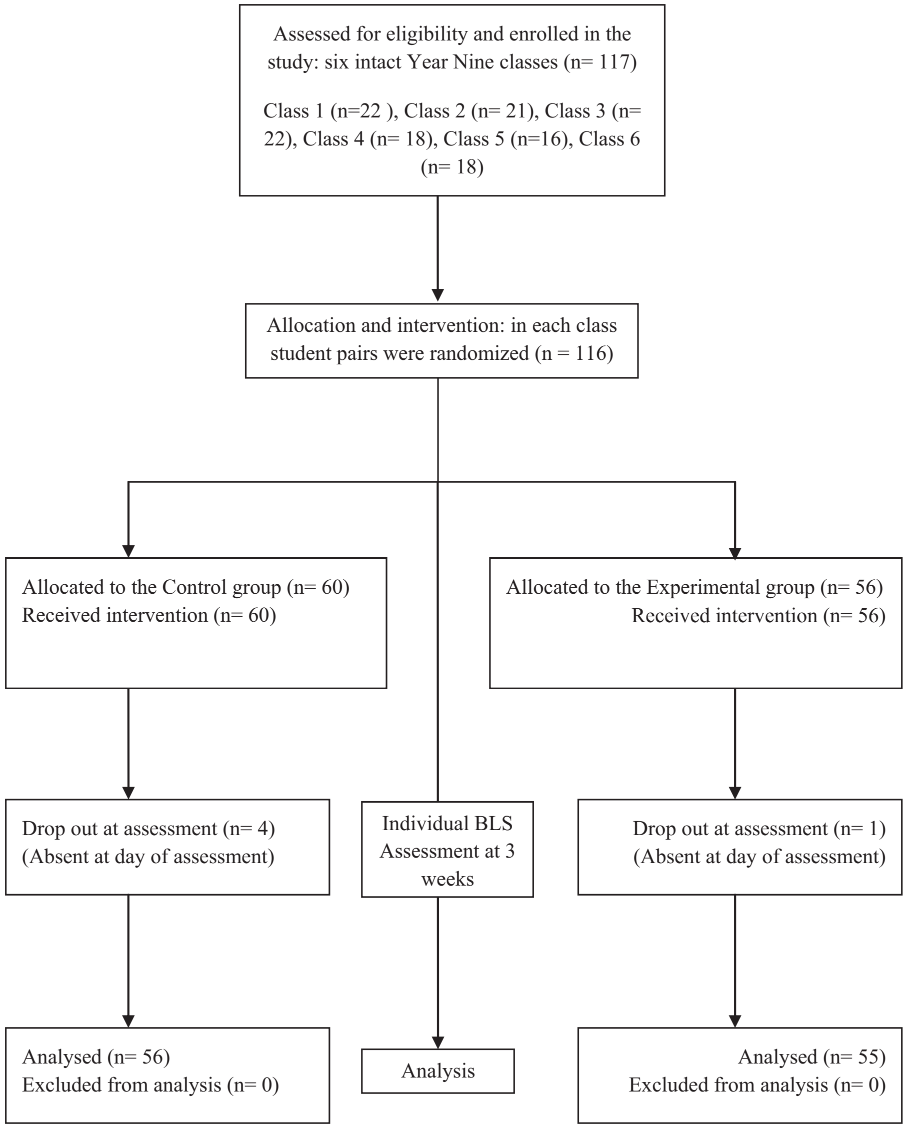

Fig. 1. Candidates flow through study.

for learning BLS individually leads to higher scores on a transfer test (Fig. 2).[13] Research in other domains has demonstrated evidence for the positive effect of spatial contiguity on learning. Sweller et al. found better transfer scores in geometry with students learning from a booklet with integrated text and symbols.[14] Moreno and Mayer demonstrated an effect size of .80 with students learning the process of lightning from a computer-based animation with on-screen, integrated text compared to students learning with on-screen text placed under the animation.[24] This study consequently demonstrates that a research-based design of instructional tools enhances BLS education. Since existing literature on multimedia tools for learning BLS and CPR generally lacks a design based on sound theory,[25,5,4,26] we argue that an important potential lies in reviewing existing multimedia tools and adapting them to the cognitive theory in multimedia learning framework. Future research could address the effect of spatial contiguity in instructional videos for learning BLS and CPR. Other design principles, such as the temporal contiguity principle, could further boost CPR and BLS learning from video. The temporal contiguity principle states that learners learn better when narration and corresponding animation are presented simultaneously rather than successively.[7,23,24]

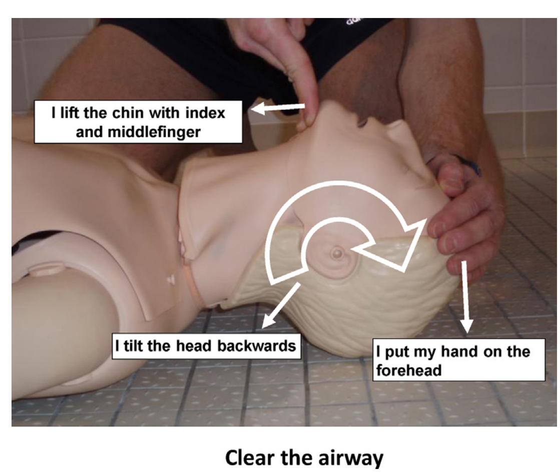

Fig. 2. Example of a task card with application of the spatial contiguity principle.

Objective assessment of CPR quality demonstrated that secondary school students achieved performances that closely align with the ERC 2005[20] guidelines after a reciprocal learning episode with task cards. Chest compression rates were higher than recommended, but satisfactory. Chest compression depths were too shallow. Limited strength because of students' younger age (13 year) could be a factor in explaining insufficient compression depth. In a study by Hill and colleagues, 10- to 11-year-old schoolchildren achieved similar compression depths ($M = 30$ mm) as in this study.[27] From the perspective of survival, chest compression depth is a crucial variable.[21,22] Achieving sufficient compression depths should therefore be addressed in future research. Recent work in this matter has demonstrated that training to deeper compression depths reduced shallow compressions after six months.[28]

Total class time for implementing reciprocal learning with task cards took about 44 min, which makes it suitable for secondary school teaching where class duration is 50 min. Evidence for high learning gains in a short amount of time can be found in work from Einspruch et al., in which it was demonstrated that lay persons can learn CPR through a 30-min self-instruction program.[1] Future research in secondary schools with reciprocal learning and instructional tools designed according to the cognitive theory in multimedia learning can be conducted to maximize BLS and CPR competence in this target group.

The pair-based analysis of CPR variables between groups is a potential limitation in this study. A mixed model approach could have been used since it would retain all of the information while accounting for any within-pair dependence. However, for reasons of simplicity and because research demonstrated that within-pair correlation in peer learning is negligible,[18,19] a pair-based analysis was presented.

5. Conclusion

Results from this study demonstrate that the design of instructional tools for learning BLS and CPR matter. In this study, designing task cards taking into account spatial contiguity, a design principle derived from research in cognitive psychology, has led to better ventilation performances. Therefore, a significant potential lies in reviewing existing multimedia tools and re-designing them taking into account multimedia learning research to maximize learning outcomes.

Conflict of interest statement

The authors have no conflict of interest to declare.

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