Original article

# Does age still matter? An age-group comparison of self-efficacy, initial interest and performance when learning bystander resuscitation in secondary schools

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**Background:** CPR training is recommended for secondary school students in many countries to improve bystander resuscitation and survival rates after cardiac arrest. The recommended age for implementing first aid interventions varies between studies.

**Methods:** This study aims to examine psychological (self-efficacy, interest; primary endpoint) and physical (compression depth, rate and chest recoil) outcomes (secondary endpoint) in different age groups after a CPR intervention. A sample of 552 secondary school students from five different schools in North Rhine-Westphalia, Germany, was assigned to face-to-face CPR lessons held by student teachers. Participants were separated into two age groups (11-13 and 14-17 years), according to recommendations and previous evidence about appropriate training age. Time- and between-group-effects were analyzed using t-tests between baseline and the final testing point.

**Results:** A total of 365 questionnaires and 189 manikin recordings formed the complete dataset. No differences were found between age groups for self-efficacy, outcome expectancies and interest ($p > 0.05$). In both groups, self-efficacy and positive outcome expectancies improved, but negative expectancies as well as the students' interest did not. After the intervention, only the older students achieved a higher accuracy (80% vs. 60%; $p < 0.05$) and mean depth (62.6 vs. 53.9 mm; $p < 0.05$) in chest compressions but exceeding the 50-60 mm guideline. For rate and chest recoil, no significant differences were found ($p > 0.05$).

**Conclusion:** Regardless of age, all students benefit from this intervention regarding an improvement in self-efficacy and chest compressions. Negative consequences and inadequate compression rates are relatively stable within this age range and should be clearly addressed in lessons.

Besides first aid courses, the introduction and implementation of basic life support (BLS) educational approaches in secondary schools has been highly recommended in the past few years (Böttiger et al., 2017; Cave et al., 2011). These public health initiatives aim to achieve a substantial contribution to the improvement of general bystander cardiopulmonary resuscitation (CPR) rates and reduce the anxiety and inhibitions of teenagers to begin CPR (Böttiger et al., 2017).

However, the implementation process is challenging for schools (Dumcke et al., 2019; Schroeder et al., 2017) because of the concerns of teachers and the system's capacity to be innovative (Fullan, 1994). In addition, in Germany different teaching approaches are suggested (e.g. compression-only CPR, CPR and rescue breaths or multi-stage models with variation in complexity) according to geographical region or other local guidance, and in some parts of the country it is even unclear whether there is a legal requirement for schools to teach CPR. However, a number of US states and European nations are enforcing compulsory CPR training now and recognize the importance of it as a public health initiative (Brown et al., 2017; Semeraro et al., 2016). Every year, around 57 out of 100,000 individuals are treated by emergency medical services for cardiac arrests in the U.S. (Benjamin et al., 2018) and 56 per 100,000 in Europe (Gräsner et al., 2020). If bystander first aid (chest compressions) is provided in the first 3-5 minutes, the chance of survival is two to four times higher than without resuscitation efforts (Perkins et al., 2015).

Teaching CPR to schoolchildren has been highly researched (such as by Plant & Taylor, 2013), including aspects such as CPR quality and its correlations with BMI, age and gender (Abelairas-Gómez et al., 2014; Bohn et al., 2012; Fleischhackl et al., 2009; Jones et al., 2007). Studies have also considered the influence of professional and non-professional instructors (i.e. teachers, peers; Beck et al., 2015; Cuijpers et al., 2016; Lukas et al., 2016) and online vs. face-to-face-teaching ('blended-learning', e.g. Yeung et al., 2017). However, the most suitable age to start CPR exercises is still assumptive and varies within studies according to content (Abelairas-Gómez et al., 2014; Bohn et al., 2012). For example, basic interventions during cardiac arrest are suggested to be integrated early (10-12 years) according to de Buck et al. (2015). Furthermore, from an educational and psychological research perspective, self-reported beliefs have been assessed mainly without using tested scale-based instruments, e.g. as "self-image" (Bohn et al., 2012), "self-efficacy" (Lukas et al., 2016) or "self-confidence" (Meissner et al., 2012; Wingen et al., 2018).

Our project focuses on implementing CPR education in German schools. It evaluates the use of "health education" units in school subjects such as biology or physical education which are taught by regular educational staff like teachers or teacher students in practice (rather than specialist first aid trainers). In pedagogical terms the project considers context-based (e.g. role play, team exercises) and scientific-reasoning principles (e.g. physiology and pathology regarding circulatory system, heart conduction, diseases, etc.).

Generally, the project analyzes effects of the learning environments on learning achievements and self-perceptions. Our objective in this study was to validate evidence about performance outcomes in age groups within this educational setting and contribute new findings about specific self-efficacy, outcome expectancies and interest to contribute to the body of knowledge on confidence levels at different ages.

This study presents a pooled-sample interim analysis of a multi-year project because data for planned assignments was not fully available, predominantly due to the COVID-19 pandemic restrictions since February 2020. Intervention outcomes were analyzed for all participants regardless of different allocated course formats. The entire available data of German secondary school students was assigned to either a "younger" (11-13 years) or "older" (14-17 years) age group according to previous studies (Abelairas-Gómez et al., 2014; Jones et al., 2007) to provide a view on global intervention effects. Between-group differences and time effects were investigated.

## Background

Relevant theories and empirical background information about the test instruments used in this intervention are based on self-efficacy theory, interest research, European resuscitation guidelines and evidence in education research involving the issue of first aid and Basic Life Support (BLS).

## Self-efficacy theory

The theory of self-efficacy (Bandura, 1977, 1997) describes self-efficacy beliefs and outcome expectancies as the most important of behavioral change indicators. Behavioral change is considered to be particularly crucial during first aid decisions of laypersons. Self-efficacy assessments provide information about a person's potential mindset to react to altruistic tasks. Specific or situational self-efficacy is a multidimensional task- and domain-specific construct (more than general self-efficacy) which prospectively describes the confidence of individuals to master new or difficult tasks (Jerusalem, 2016). It is characterized by the certainty to cope with task-specific impediments (Jerusalem, 2016), in particular, the anxiety to do harm, or to face ignorant or people that are panicking – impeding concerns often reported for first aid situations (e.g. Dobbie et al., 2018).

Outcome expectancies are influenced by self-efficacy and described as believed consequences of actions. They are driven by forethought (Bandura, 1977; Fasbender, 2018). Outcome expectations can be rated by valence, temporal proximity or area of consequences. This study focuses on self-evaluative and social areas of consequences since bystander situations are regulated by self-oriented thoughts and/or social interaction with other people. Positive and negative consequences were assessed each to assess the valence of the orientation.

The theory-based self-efficacy BLS scale is described in detail, validated and tested in a previous paper (Dumcke et al., 2021a). Briefly, self-efficacy and outcome expectations were improved by intervention toward a more confident and positive self-perception within the students; however, negative expectations (anxiety to harm or to do something wrong, to receive no support by others) were maintained to a remarkable extent.

## Interest

Interest is described as a motivational factor, and refers to the reengagement or predisposition to re-engage with particular objects, events or ideas (Hidi & Renninger, 2006). Interest refers to a person/environment-interaction, which facilitates or reduces interest. Krapp (2007) distinguishes between individual and situational interest. Since individual interest is established over a period of time ('hold-facet'), situational interest can be triggered by methods, environments or content ('catch facet', i.e. interestedness). The content-specificity differentiates it from 'curiosity' (Krapp et al., 1992). To motivate students to learn CPR and related health issues, triggered interest is important and can be considered by choosing active, unconventional material or new media. Situational interest regarding CPR has been previously described in general and for gender-related differences in (Dumcke et al., 2021b).

## Resuscitation guidelines and performance evidence

The parameters for CPR efficacy assessed in this study rely on the 2015 resuscitation guidelines published by the European Resuscitation Council (Perkins et al., 2015), based on the International Liaison Committee on Resuscitation (ILCOR) consensus: Compressions should be at least 50 mm deep (and not exceed 60 mm), at a rate of 100-120 min$^{-}$, with full pressure release and minimized interruptions. The combination of compressions and rescue breaths (30:2) is recommended by the European Resuscitation Council (ERC; Greif et al., 2015) but not considered by this study for these reasons:

(1) This project focus on practical suitability and low implementation barriers for schools. German schools usually do not have the resources, staff and time to maintain hygiene

and disinfection procedures in connection with rescue breaths (besides legal restrictions). The study setting was adopted to these circumstances to provide results based on school contexts.

(2) Ventilations are more difficult to learn and not recommended for students aged up to 14 years (see the principle "check – call – compress"; GRC, 2012; Step 2) and/or if class time is limited (i.e. 90 min.; also: Greif et al., 2015).

There are a variety of age-related recommendations. For example, Bohn et al. (2012) compared students starting learning CPR at the age of 10 and 13. They found that although both groups demonstrated an average depth of < 50 mm after 3 years, students who started CPR training at the younger age achieved deeper compression (and more accurate ventilation volumes), whereas older students showed better compression rates and knowledge skills. Other studies (Abelairas-Gómez et al., 2014; Jones et al., 2007) report that students should be at least 13 years old when they learn CPR, as they can manage to do compressions with a performance comparable to adults. However, younger students may instead learn more operational handling skills like "calling for help", "checking responsiveness" and information about causes for cardiac arrest. Furthermore, Fleischhackl et al. (2009) found that age was an indifferent predictor for performance outcome, as the only correlation was with BMI instead of age - putting the age-question into perspective.

## Hypotheses

Our research questions with respect to the assessed variables self-efficacy and outcome expectations, interestedness and CPR quality parameters were a) "Do age groups achieve similar learning effects?" and b) "Do we detect significant 'age gaps' between groups before and after the intervention?"

Based on considerations of the authors' working group, the following hypotheses were stated, also taking prior evidence into account.

H1 Within both age groups, students improve self-efficacy, outcome expectancies (lower values for negative statements, higher values for positive statements) and initial interest in all dimensions over time ($t_0$ vs. $t_1$).

H2 Both age groups of students have a similar perception regarding self-efficacy and outcome expectancy, except that interest declines with age.

H3 Both groups show a better guideline-compliant performance at the final test compared to baseline for all measured parameters (means and accuracy).

H4 The older group scores significantly higher in practical CPR performance for mean outcomes (depth, rate) and accuracy (% correct compression depth, rate and release).

We assume self-efficacy and outcome expectations to improve with interventional measures, as it was shown before for related constructs as self-image or self-confidence (Bohn et al., 2012; Meissner et al., 2012; Wingen et al., 2018), whereas we have no reference for age differences. For interestedness we assume a decline with higher age, according to a general decline of interest in natural sciences (e.g.: Potvin & Hasni, 2014). For hypotheses 3 and 4, prior investigations already showed CPR trainings are effective for practical performance (Lukas et al., 2016), with age dependent outcomes known for interventions including differently aged students (e.g. Jones et al., 2007).

## Methods

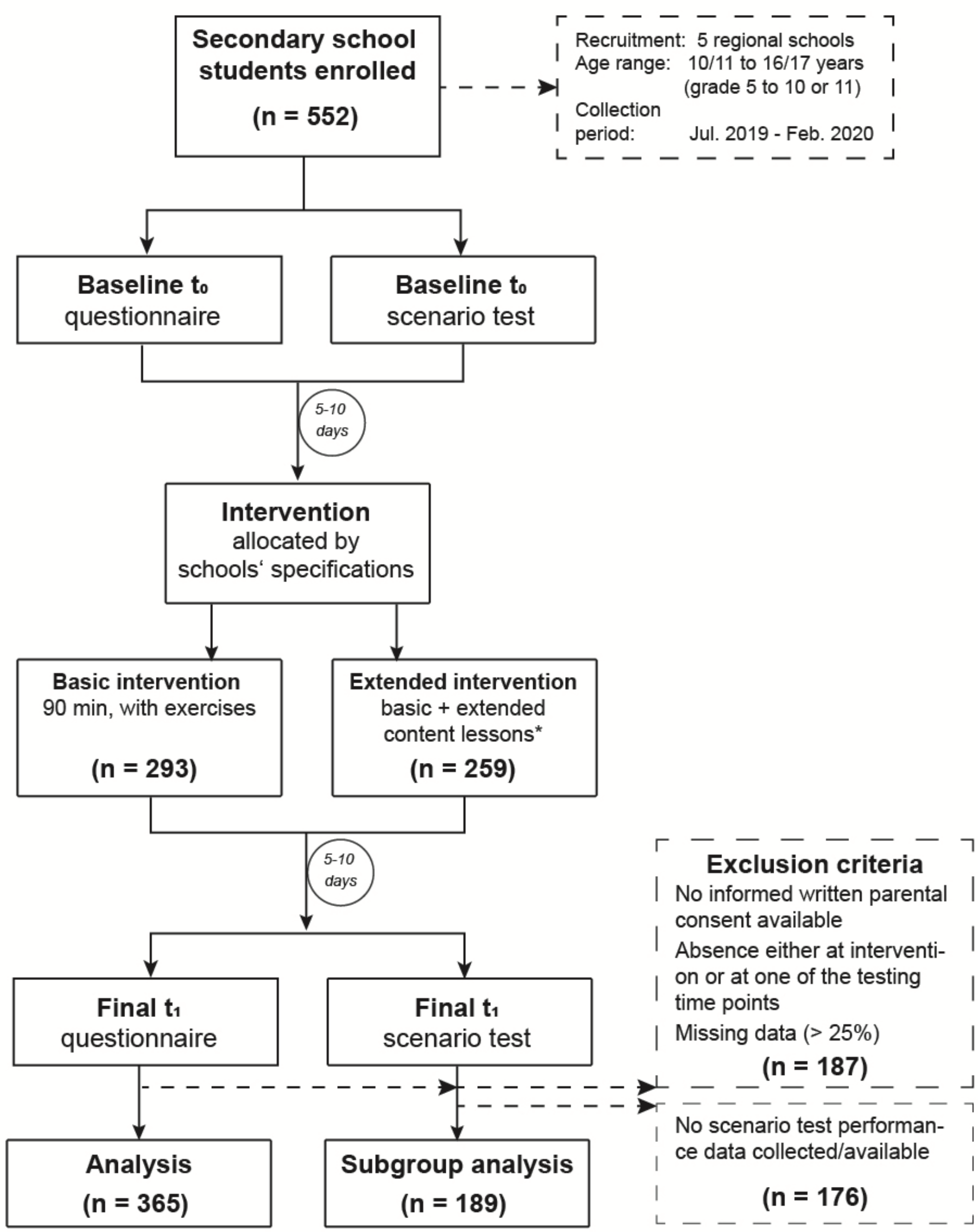
### Study description

Our intervention was conducted using a non-randomized, non-blinded, cross-sectional mixed-methods-design (following the TREND checklist) with baseline ($t_0$) and final ($t_1$) data collection (Figure 1). We assessed a) the students' self-perceptions using a written questionnaire and b) practical CPR performance skills in a scenario-based test. Participants were recruited from secondary schools in cities in North Rhine-Westphalia, Germany, between 5th (10/11 years) and 11th grade (16/17 years) and were included in interventions after receiving informed parental consent (also see: test instruments). Beforehand, regional schools were contacted by the investigators and selected by self-nomination.

**Intervention and teaching objectives**

According to the schools' capacity and willingness, students were assigned to either group a) short basic training unit or group b) basic training unit with extended content teaching. Table 1 shows detailed information about lesson plans and objectives. The didactic program was developed by the working group based on a basic

**Figure 1: Study Design and Flow-Diagram. * For example see Wegner et al. (2020).**



training outlined in the GRC curriculum, step 2 (GRC, 2012) and was adopted with modular units (B, Table 1). The aim was to investigate a modular design which gives schools and teachers a possibility for flexible arrangements of content and learning objectives in given structures (e.g. subjects like biology, etc.) and schedules while using scientific and problem-oriented principles (see the design-based research principle, The DBR Collective, 2003).

To compare the results including *all* participants, the lesson plans *of both groups* used two standardized units (90 minutes in duration) of face-to-face instruction following the basic algorithm "Check – Call – Compress" (compressions-only). During this basic part, for every participant two thirds of the program took group-based hands-on activities on manikins whereas one third took instructional and conversational parts (i.e. reflecting content and tasks of the lesson) at the beginning and at the end of the units. In the extended introductory and follow-up lessons (see Table 1) all lessons were designed action-oriented and followed the scientific path of knowledge. In all interventions, CPR feedback to the students' practice was provided by the instructors to the same extent, as outlined in Table 1.

For the conduction of the interventions, the lessons were supported and delivered by student teachers (biology) as educational staff, who worked on project modules or their thesis at Bielefeld University. This study design was selected to guarantee practicability and reliability of progress as a means to motivate school administrations to participate and relieve them from additional research effort. The student teachers were prepared prior to the intervention with standardized concepts for both formats and materials for the intervention, as they were described in lesson plans and didactic comments. Lessons were supervised by the authors.

**Endpoints**

According to the objective of this interim study we separated the students into two groups: 11-13 years (younger students) and 14-18 (older students) years old, based on the following:

(1) CPR performance is correlated to age or physical condition, with minimum achievements comparable to adults from 13- to 14-year old students (Abelairas-Gómez et al., 2014; Jones et al., 2007).
(2) Medical boards suggest starting to learn at a younger age (Böttiger et al., 2017).

However, we prioritized the evidence findings and decided to set the cut-off after 13 years of age.

To cover potential variance, this analysis is conducted independently from the interventional assessment for the pooled data sample (including all students). Primary endpoints were the mean differences between the age groups (at $t_0$, $t_1$). As secondary outcome, mean differences over time separated for age groups were analyzed to assess equality of interventional effects as set out in the hypotheses.

**Test instrument**

A closed rating and multiple-choice, standardized questionnaire was designed for this project's intervention. General information (age, marks in biology and physical education, prior first aid activities and prior experience with cardiac arrest/CPR) were assessed. Individual perceptions (33 items about subject-specific interest, self-efficacy, outcome expectancies) were adopted from established sources, as reported below. Students with an informed written consent signed by their parents were allowed to participate.

**Table 1: Description of the intervention and didactic information.**

| **Format** | **A) Basic Training**<br>*Standard short intervention* | **B) Extended Teaching**<br>*Advanced intervention combining basic training embedded in further units* |
|---|---|---|
| **Method** | • Set time for practice<br>• Instructional talk and working in groups | • Set time for practice<br>• Working in groups, problem-oriented, scientific approach |
| **Duration and lesson plan**<br><br>**(1 unit = 45 minutes)** | | **4 to 6 introductory units[a]**<br>• Assessment of preconceptions<br>• The circulatory system: How it works<br>• Modelling: Blood flow during CPR including heart conduction and ventricular fibrillation mechanisms |
| | **2 units basic training**<br>• Importance of BLS<br>• Instruction: How to do CPR (visualization, demonstration)<br>• Exercise in groups<br>• Reflection: problems, questions, concerns, common misconceptions | **2 units basic training**<br>• Importance of BLS<br>• Instruction: How to do CPR (visualization, demonstration)<br>• Exercise in groups<br>• Reflection: problems, questions, concerns, common misconceptions |
| | | **2 to 4 follow-up units[a]**<br>• How to apply an AED<br>• Recognition of agonal breathing<br>• Role plays: Working as a CPR team / Challenging "group effects" and reacting to surrounding people<br>• False friends: Differentiating heart attack and failure from cardiac arrest and how to help |
| **Learning objective(s)** | Students …<br>• know the importance of time during cardiac arrest<br>• can perform effective chest compressions | Students …<br>• know the importance of time during cardiac arrest<br>• can perform effective chest compressions<br>**Additional (advanced) objectives**<br>• can explain the circulatory function with respect to oxygen supply<br>• understand the correlation of heart rhythm and perfusion / oxygen supply<br>• can use an AED<br>• can communicate and organize their work as a team<br>• are competent in in role-playing the situation |
| **Feedback** | Posture, frequency, depth and interruptions are corrected when observed. | Posture, frequency, depth and interruptions are corrected when observed. |
| **Teacher** | Instructed student teachers | Instructed student teachers |
| **Standard-ization** | Yes (fix lesson plans) | Yes (fix lesson plans), but modular use of the extended lessons' issues |

Annotations: [a] the division of the units is flexible according to the timetable

The assessment was anonymized by using a combined code (six characters and numbers) derived from personal students' information. Items were randomly arranged for every scale at baseline and for the final test using randomizer.org.

According to the self-efficacy theory (SET) (Bandura, 1977, 1997), SET-BLS scales were developed to assess situational self-efficacy (SE) and outcome expectancies (OE) when approaching and deciding to help cardiac arrest patients. Each scale is subdivided into two dimensions. Self-efficacy was derived and modified from a sports-based tool by Fuchs and Schwarzer (1994). Self-developed items on outcome expectancies describe value-based (positive/ negative) consequences (Dumcke et al., 2021a). The interest scale was adopted from Wegner (2009), shortened and specified for CPR and circulatory issues from a general interest in the natural sciences. Scales and item reliability are given in the supplementary material, Table S1. The questionnaire survey was provided in the classroom with predefined instruction sheets to minimize bias.

### Scenario-based practical performance test

The practical subgroup assessment recording chest compressions quality was conducted in groups of 4 people. Due to their grade, the tested classes were of the same age. During the test, students were separated so that they could not see each other in order to minimize potential bias caused by group effects and existing knowledge. Before the activity, each student was registered using the individual code from the questionnaire to correctly assign the datasets. After registration, a documented, standardized instruction with a scenario description (e.g. "Imagine you are at the local bus station, a person is lying on the floor […]") was given to the participants. The test lasted one minute, starting with the initial chest compression. Students were briefly interviewed afterwards about how they felt with the task and informed about further steps. The test was repeated within 5-10 days after the last interventional unit, depending on the local schools' scheduling conditions.

Measurements were recorded with the CPR manikin Little Anne™ QCPR (Laerdal Medical, Puchheim, Germany) via Bluetooth using the Laerdal Instructor App (v. 3.13.1). The following records were defined as primary endpoints according to (Perkins et al., 2015, pp. 88-90): compression depth (required: 50-60 mm), compression rate (required: 100-120 $min^{-1}$) and chest recoil (required: complete release).

### Statistics

Data was analyzed with the Statistical package for the Social Sciences v.26 (SPSS 26). Reports on participants' and demographic information were provided in absolute and relative proportions. For questionnaire scales, if applicable, Cronbach's alpha is presented (see supplementary material S1, Tables 1-3).

Main and subgroup analyses followed identical procedures: Comparisons between the baseline assessment ($t_0$) and final test ($t_1$) were calculated with paired t-test statistics, between age groups independent t-tests were calculated. Normal distribution was assumed (cf. central limit theorem with n(group/time) > 50) and proofed visually with Q-Q-diagrams and histograms. For between-group analysis, independent comparisons were interpreted with Welch estimators (independently from Levene statistics, Rasch et al., 2011). T-statistics are presented in supplementary results Tables S2 and S3. Multiple comparisons of dependent variables were Bonferroni-Holm corrected. P-values $\leq 0.05$ were considered statistically significant. Cohens d was used to display effect size (small: $d \geq 0.2$; medium: $d \geq 0.5$; great: $d \geq 0.8$; Cohen, 1992).

## Results

### Participants and demographics

Of the 552 enrolled secondary students, 187 datasets were dropped due to absence or unfulfilled requirements (parental consent). As a result, 365 complete datasets were analyzed (mean age = 13.67 years, SD = 1.46; 47.1% female) and separated into 189 (51.8%) participants that received basic training intervention (90 min.) and 176 (48.2%) that were assigned to the extended intervention group. In the subgroup analysis (manikin recordings), 189 out of the 365 datasets had measurement data available. Further baseline data is shown in Table 2.

### Comparisons of younger and older groups' beliefs

Self-efficacy significantly improved in both age groups after the intervention. When asked for psychological/mental concerns, students reported to be "somewhat efficacious" (younger: M = 3.13±1.21; older: M = 3.12±1.12) before and "rather efficacious" (younger: M = 3.60±1.15; older: M = 3.63±1.05) after the intervention, (PSY; Figure 2). This effect was small for both age groups ($p < 0.001$; d = 0.40 and $p < 0.001$, d = 0.47). To a minor extent, we found a similar increase in efficacy for social challenges (SOC; younger: $p < 0.001$; d=0.35; older: $p <0.001$; d = 0.26, see Figure 2A and Table S2.1 found in the supplementary material). Self-efficacy perception in both sub-dimensions did not significantly differ for either group at either time point ($t_0$: p = 0.930 and 0.828; $t_1$: p = 0.828 and 0.400; for younger and older groups, respectively; see supplementary material Table S2.2).

**Table 2: Sample characteristics; overall N = 365.**

| variable | category | age group | |
|---|---|---|---|
| | | 11-13 years[a] | 14-17 years[a] |
| **sample (n)** | **size** | **127** | **238** |
| **gender (%)** | **female** | 44.9 | 48.3 |
| | **male** | 55.1 | 51.7 |
| | **other** | 0.0 | 0.0 |
| **school type (%)** | **"Gymnasium"** | 68.5 | 52.9 |
| | **"Gesamtschule"** | 25.2 | 18.1 |
| | **"Realschule"** | 6.3 | 29.0 |
| **grade (%)** | **06** | 66.1 | - |
| | **07** | - | - |
| | **08** | 31.5 | 30.3 |
| | **09** | 2.4 | 51.3 |
| | **10 / 11** | - | 18.5 |
| **age, mean (SD)** | **All participants** (n = 365) | 12.01 (0.82) | 14.56 (0.81) |
| | **Subgroup: scenario-based test** (n = 189) | 11.98 (0.93) | 14.22 (0.46) |
| **prior first aid course participation** | **yes** | 18.9 | 22.3 |
| **CPR performed** | **yes** | 1.6 | 1.3 |

Annotations: [a] for an explanation of age group separation see: methods.

Positive outcome expectancies for BLS behavior were higher after the intervention in both age groups (younger: $p > 0.001$; $d = 0.37$; older: $p > 0.001$; $d = 0.35$), with no significant effect between the groups ($t_0$: $p = 0.890$; $t_1 = 0.622$). However, after the intervention, younger students showed the tendency to achieve higher positive outcome expectation values.

Statements about expected negative outcomes achieved values ranging between "slight disagreement" (2) and "slight agreement" (3) (see Figure 2B, supplementary material Table S2.1) and we found no difference over time in both groups (younger: $p = 0.915$; older: $p = 0.096$), or between the groups (see Figure 2B; supplementary material Table S2.2). However, older students tended to report non-significant, but lower values after intervention regarding negative outcome expectations ($M = 2.32 \pm 0.88$ vs. $M = 2.22 \pm 0.96$; $p = 0.320$) (see Figure 2B).

Initial interest in the human circulatory system and BLS education showed no significant changes over time (for all comparisons: $p = 1.00$). Between age groups also no significant differences referring to our hypothesis (Figure 2C, supplementary material Tables S2.1/S2.2) were found before and after intervention. It is noteworthy to mention that self-reported agreement for both, circulatory system- and CPR-related interest, decreased from baseline to final test, although it maintained a moderate level (Figure 2C). Despite the non-significant decrease within our unidirectional hypothesis, the mean negative decrease was significant in two-sided comparisons for CIRC in both age groups ($t_{11\text{-}13}(126) = 3.63$; $p < 0.001$; $t_{14\text{-}17}(237) = 3.00$; $p = 0.003$) and for CPR in the older group only ($t_{14\text{-}17}(237) = 2.89$; $p = 0.004$). In particular, interest for circulation was higher at baseline compared to the final test, with no significant between group differences ($t_0$: $p = 0.226$; $t_1$: $p = 0.056$). A similar finding was seen for CPR interest ($t_0$: $p = 0.823$; $t_1$: $p = 0.725$). Independent from age and testing time point, circulation was perceived as less interesting than BLS/CPR (see supplementary material Table S2.2).

### Comparisons of younger and older students' performance

#### *Average compression depth and rate*

Mean compression depth, as main predictor for cardiac arrest outcome, was significantly improved after the intervention (Figure 3A; younger: $p < 0.001$; $d = 1.51$; older: $p < 0.001$; $d = 1.65$). However, younger students had lower depth values and remained in the 50-60 mm range ($t_1$) when final values are compared whereas older students performed better but exceeded the upper depth limit of 60 mm. Older students' average compression depth significantly differed from younger students before ($p < 0.001$; $d = 0.82$) and after intervention ($p < 0.001$; $d = 0.73$; see supplementary material, Tables S3.1 and S3.2).

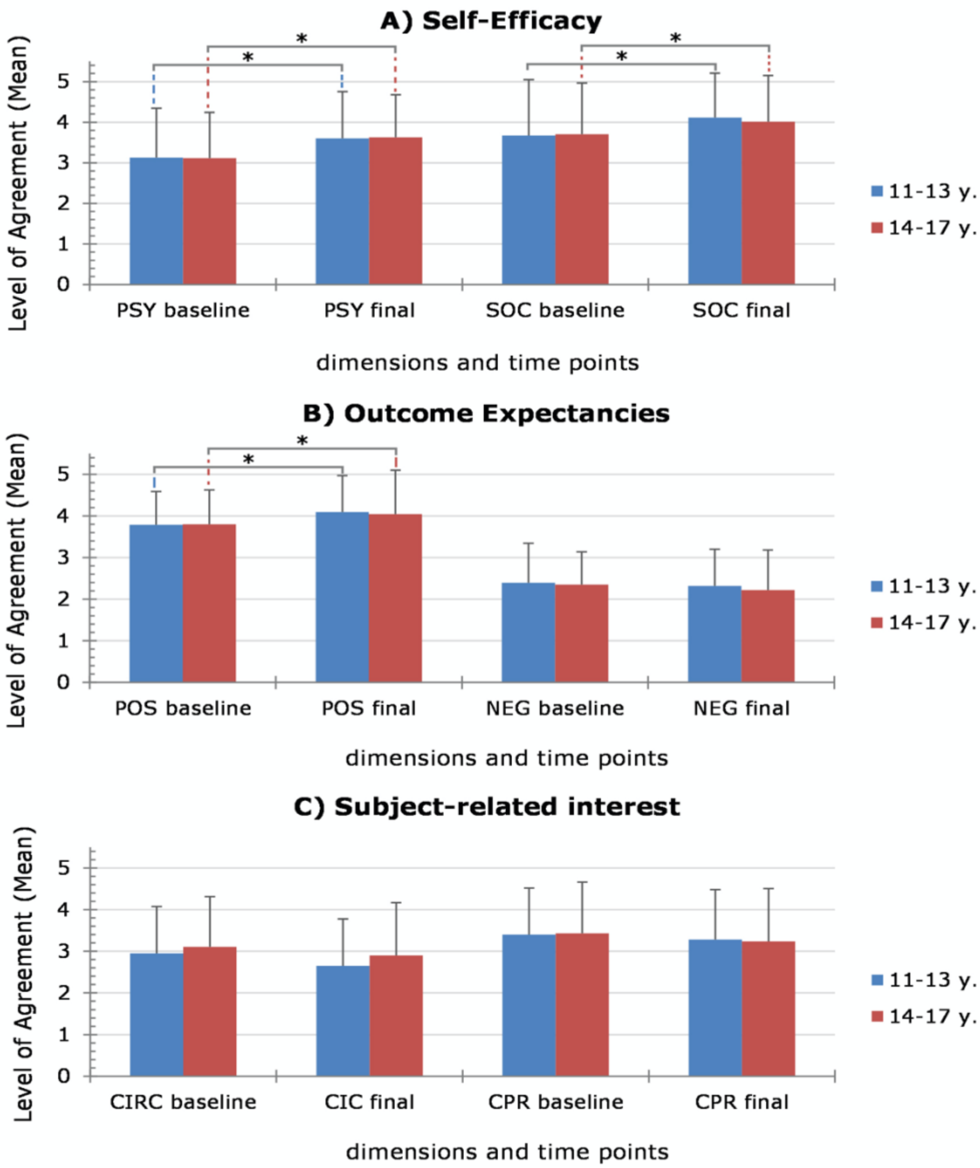
The average compression rate was not compliant to guideline requirements before, but afterwards it met guideline criteria. The increase was significant for both, the younger ($p < 0.001$, $d = 0.85$) and older student group ($p < 0.001$, $d = 0.68$). Between group achievements regarding the compression rates differed significantly before ($p = 0.002$; $d = 0.53$), but not after intervention ($p = 0.110$; Figure 3B).

#### *Qualitative outcome of compressions*

Performance quality is defined as the ratio of correct compressions to all compressions performed. Regarding the guideline-compliant compression depth, both age groups performed significantly better after the intervention (younger: $p < 0.001$; $d = 1.32$; older: $p < 0.001$, $d = 1.72$; Figure 3C), but older students achieved higher proportions of correct depth, before and after the intervention ($t_0$: $p < 0.001$, $d = 0.83$; $t_1$: $p < 0.001$, $d = 0.88$).

Correct compression rate was unacceptable for younger (11%) and older (20%) students and improved to 36% and 38%, respectively, after the intervention. This improvement was significant for both groups (younger: $p < 0.001$; $d = 0.98$; older: $p < 0.001$, $d = 0.77$). The younger group which performed less well than the older students at $t_0$ ($p = 0.037$; $d = 0.38$) managed to adjust their average rate to the values of the older students at $t_1$ (no sig. difference; $p = 0.545$; Figure 3D) – but the final performance (< 40%) remained

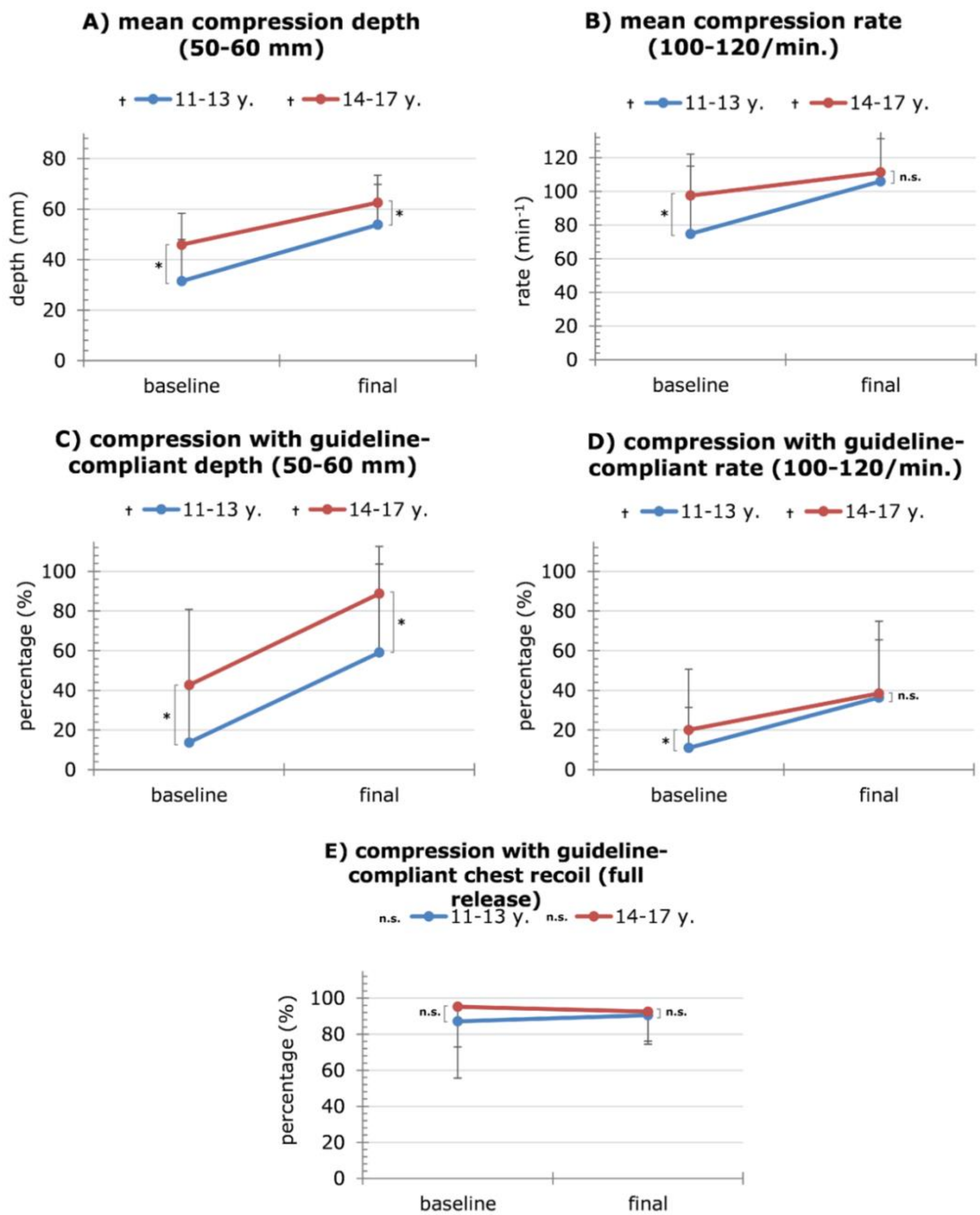
**Figure 2: Comparisons of self-efficacy, outcome expectancies and interest scales. Time and age group effects.** $n_{11\text{-}13} = 127$; $n_{14\text{-}17} = 238$. * indicates significant differences between baseline and final assessment. <u>All between group comparisons were non-significant</u>. One-sided p-values (corrected). Error bars were presented unidirectionally for better visibility. Scale abbreviations: see Table 1, detailed statistics are given in the supplementary material, Tables S2.




*Abbreviations:* PSY Self-efficacy, psychological facet; SOC: Self-efficacy, social facet; POS/NEG: positive/negative outcome expectancies; CIRC: circulation (subject); CPR: resuscitation (subject) inaccurate with reference to CPR rate recommendations.

All students succeeded in full release chest recoil, both before and after the intervention with 87% to 95% with no significant between-group differences. The younger students showed a tendency to be more accurate with a positive trend from $t_0$ to $t_1$ (see Figure 3E; see also supplementary material Tables S3.1/S3.2).

**Figure 3: Comparisons of the different performance achievements per age group.** $n_{11\text{-}13} = 64$; $n_{14\text{-}17} = 122$. † indicates significant differences for the grouped time effect, *indicates significant differences between age groups at the two time points. One-sided p-values (corrected). Error bars were presented unidirectionally for better visibility. Detailed statistics are given in supplementary tables S3.1 and S3.2.



## Discussion

This study adds new findings to understand potential age-related differences, relevant self-perceptions of confidence, and improvements in practical performance when teaching CPR to secondary school students.

As hypothesized (H1), self-efficacy and positive outcome expectancies improved after the intervention. Negative expectancies did not change and remained, as before, on a similar moderate level, whereas interest decreased (rejecting H1). These findings are in line with other studies, like CPR self-efficacy increases after three years of training described by Lukas et al. (2016) and reported improved self-confidence ratings within trained groups (Bohn et al., 2012; Wingen et al., 2018). Although we asked for intervention and *not* performance self-efficacy, limiting a direct comparison to the cited studies, it seems that a minimum of two units (90 min.) is feasible to achieve a significant, direct effect about how secondary students perceive their competency to intervene with first aid and CPR. However, causing fractures, having contact with fluids and potential infection risks or being criticized by others were commonly reported as barriers before and after our intervention, shown in our results in persisting moderate negative outcome expectations (see the item list in supplementary Table S1). It seems to be difficult to reduce negative expectations of potential rescuers when deciding to intervene in cardiac arrest situations. Previous studies in adults participating in first aid courses (Becker et al., 2019; Dobbie et al., 2018) and in Danish students (Kanstad et al., 2011) likewise revealed potential fears, such as doing something wrong, lacking competence, increasing the risk of infection and inappropriately touching a victim. These mental barriers are stable psychological characteristics that are firmly anchored in society and difficult to eliminate. School lessons should aim to put these obstacles into perspective and provide clear background medical information that is sufficient to let students figure out which relevant pathophysiological processes appear and justify intense measures – without hesitation. We suggest therefore, that it is important to facilitate self-efficacy and eradicate misconceptions. Since real-life experiences cannot be simulated in organized trainings, self-efficacious behavior is supported the best by verbal persuasion and emotional perceptions (Bandura, 1997).

We did not find significant differences in self-efficacy, outcome expectancies and interest scales between the age groups, as assumed for self-efficacy constructs (H2). This supports the prior recommendation that young students (even in primary school) are capable of being taught how to approach and evaluate a medical emergency (Buck et al., 2015). The decline in both domains of interest remains unclear, since we have no comparable evidence for interest. In this study, the decline of subject-related interest was not influenced by age (as it is known to do for natural sciences, cf. Potvin & Hasni, 2014), but was observed in general. Probably also because it is consistently stated that performing BLS is easy (Bohn et al., 2014; Böttiger & van Aken, 2015), statements like that regularly contradict the effort in catching and holding students' interest: Success seems to be achieved after a single training session and novelty effects lose their influence. However, repetition is crucial and early learners should be encouraged to grow and reinforce their knowledge.

We found significant improvements in performance, except for chest recoil. This positive effect was significant in young and old students. These findings encourage, along with the comparable good self-perceptions, an early beginning of BLS education. Social skills, soft skills, decision making, responsibility, and the familiarization with handling CPR can be promoted step-wise (Abelairas-Gómez et al., 2014; Buck et al., 2015). Although both groups performed acceptable compressions, our data otherwise highlighted the meaningfulness of follow-up trainings as well. The compliantly deep enough performed compressions, although the younger group had weaker compressions, confirmed that compressions can be improved by training and that older students have larger physical capabilities. This also enhances positive experiences in repeated learning settings. It is important to note that none of our groups managed to apply more than 40% of compressions in the correct frequency after the intervention. Educators should continuously organize to check for the correct tempo to ensure good frequency, either by training the rhythm explicitly before starting the algorithm or using instructed peer feedback. During the first experience, it can be difficult to simultaneously remember the correct posture, rate and depth (i.e. high cognitive load). Therefore, more time-on-task or a practice to mastery setting (which was not part of this study) may be successful in rhythm improvement. As older students compressed on average deeper than the upper limit, group-sensitive encouragement according to physical status might be considered, where instructors provide an upper limit instead of "push as hard as you can".

This study has serval limitations. First, only students in a single region were included, so findings are not generalizable for other regions. To compare ages, data from differently organized learning concepts were pooled. Second, even if all participants shared the standardized basic training, the further learning experiences of participants who experienced longer health/CPR-related teaching sequences may have influenced the survey results, and led to a minor bias. We also cannot eliminate minor recall bias due to little differences in the time interval between the end of the course and the data collection. Third, we were not able to assess other potential indicators such as BMI due to privacy regulations and did not analyze potential correlations in this paper. Finally, we assessed students during different time points throughout the school year, which may have led to biases in the students' performance (close vacations, exams; hot temperatures).

**Conclusion and Implications**

Teaching secondary school students in CPR by trained and instructed student teachers is feasible. Self-efficacy to provide BLS and the association to positive outcomes is likely to be similar for all students, regardless of age. Only the aspect of compression depth was significantly less effective in younger students. Social and soft skill simulation combined with compression-only formats is recommended to introduce this age group to the topic and improve performance throughout their school career. Further research should address ways to handle robust anxiety and misconceptions and investigate reasons for a decline in interest after training.

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## Conflict of Interests

None of the authors of the above manuscript has declared any conflict of interest.

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