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An evaluation of the effects of an innovative school-based cycling education program on safety and participation

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ABSTRACT

Cycling education programs for children could play a role in promoting both cycling participation and cycling safety, and they exist in many countries – often in school settings. Evaluations have generally shown improvements in skills and knowledge, but effects on less-researched outcomes such as safety-related behaviour, crashes or injuries, cycling participation, and cycling confidence, are unclear. The present research evaluated Safe Cycle, an innovative Australian school-based program that addresses hazard awareness and overconfidence in addition to more typical content (e.g. handling skills), in terms of a comprehensive range of outcomes. Students from Years 4 to 8 (n = 108) completed online surveys in class before, immediately after, and approximately 14 weeks after, the 8-week program was delivered. Significant increases in knowledge and confidence were observed, while results also suggested increases in cycling participation. The program appeared to address illusory invulnerability effectively, but there was no evidence that the program improved safety-relevant cycling behaviours or experience of crashes. The benefits of Safe Cycle might be enhanced by including elements to increase motivation to perform safety-relevant behaviours and durability of program effects.

1. Introduction

Overweight and obesity in childhood are associated with increased health risks in adulthood (Baker et al., 2007). Research has identified an inverse relationship between physical activity and overweight and obesity in children and adolescents (Mellin et al., 2002; Tremblay and Willms, 2003). Active travel to school is an important source of physical activity for children (Mackett et al., 2005). Cycling education programs for children could play a role in promoting cycling participation (Osborne, 1998) and they exist in many countries – mostly in school settings (see Richmond et al., 2013). Cycling education programs for children may reduce the frequency of bicycle-related injuries through increased knowledge and compliance with traffic regulations (Maring and van Schagen, 1990). In Australia, between 2008 and 2009 children aged between 10 and 14 years had the highest rate (per 100,000 population) of hospitalisation due to bicycling-related injury, children aged between 5 and 17 years who were seriously injured due to land transport accidents were most likely to be riding a pedal cycle (AIHW et al., 2012).

Evaluations of cycling education programs for children have mostly focussed on the effects on skills and knowledge taught within the program, and typically found improvements. For example, Ducheyne et al.'s (2014) Cluster Randomised Control Trial (CRCT) of a 180-minute playground-based cycling skills training program showed a significant effect significant improvement of ten of thirteen skills (e.g. straight-line riding, braking, shoulder checking) immediately after training, with the effect remaining at a 5-month follow-up for nine of these skills. Their earlier CRCT of a 135-minute version of this program showed a significant positive effect on eight of twelve basic cycling skills immediately after the training, but no follow-up was conducted (Ducheyne et al., 2013). Kearns and colleagues' CRCT (Kearns and Rothman, 1986; Trotter and Kearns, 1983) demonstrated positive effects of a longer program on observed cycling skills, including at follow-up. In contrast, in an earlier CRCT Macarthur et al. (1998) found no effect of a 90-minute playground-based cycling skills training program on observed straight line riding, coming to a complete stop, or shoulder-checking before turning, 3 months after the program. Van Schagen and Brookhuis (1994) reported greater improvement in skills amongst children who participated in a 70-minute playground-based skills training (with or without 60 min of theoretical lessons) compared to control school children, both immediately after training and at follow-up. Improvement in knowledge was dependant on the theoretical component. Improvements in knowledge of information covered by cycling safety programs - typically relating to bicycle safety checks,

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road rules, and safety-relevant behaviours - have been shown in several RCTs (Kearns and Rothman, 1986; McLaughlin and Glang, 2009; Trotter and Kearns, 1983), treatment/control studies (Kimmel and Nagel, 1990; Savill et al., 1996, who also observed improved skills) and before-after studies (without control comparisons) (Hooshmand et al., 2014; Lachapelle et al., 2013; Mandic et al., 2018). In their treatment/control study (Colwell and Culverwell, 2002[1]) observed no effect of training on knowledge.

The relatively fewer evaluations that have considered changes in attitudes or safety-relevant behaviours (more broadly than helmet-wearing) generally show no impact of cycling education programs. In their RCT Macarthur et al. (1998) found no effect of information provided during the playground-based skills training program on attitude and behaviour items (e.g. “Is it important for cyclists to signal before making a turn?”; “Do you always wear a helmet when you are riding a bicycle?”). Similarly, Colwell and Culverwell (2002) reported that children who reported having participated in the National Cycling Proficiency Scheme (which includes instruction on cycle rules and control skills) did not differ from those who did not in terms of “safer attitudes” (e.g. concentrating properly when riding), self-reported “safe cycling” behaviours (e.g. signalling turns), or “showing off” behaviour” (e.g. ride through traffic lights if safe). In contrast, education programs specifically targeting increased helmet-wearing have generally been found to be effective (for reviews see: Rivara et al., 1998; Royal et al., 2007).

Investigation of the effect of cycling education programs for children on crash and injury outcomes has also been rare, and results have been inconsistent. One case-control study (Carlin et al., 1998) reported that the likelihood of having participated in Bike Ed (a school-based cycling safety program that addresses traffic knowledge, riding skills, and basic bike mechanics) was not significantly different for children who were treated in emergency departments for injuries sustained in a cycling crash than for control child cyclists (recruited by random telephone survey). Importantly, a tendency for injured children being *more* likely to have participated in Bike Ed became significant when tested amongst boys and non-cycling families. Colwell and Culverwell (2002) reported that children who reported having participated in the National Cycling Proficiency Scheme did not differ from those who did not in terms of self-reported number of bicycle crashes resulting in hospital treatment. However, the retrospective design did not allow comparison only of crashes in the post-program period. One earlier study with a similar design also reported minimal effect of cycling education on self-reported crashes (Risk and Raymond, 1976; cited in Colwell and Culverwell, 2002), while a second reported a reduction in self-reported crashes (Darlington, 1976; cited in Colwell and Culverwell, 2002).

Until recently, surprisingly few studies have reported the effects of cycling education programs for children on cycling participation (Johnson et al., 2016), although it is important for interpreting changes in crash and injury numbers, as well as being an important outcome in its own right. The study with the strongest design, a CRCT, indicated no effect of four 45-minute skills training sessions on minutes spent riding to school in a given week – even when training was accompanied by homework activities intended to promote parental involvement (Ducheyne et al., 2014). Nonetheless, number of trips may have been a more sensitive measure of cycling participation. In their before/after study Mandic et al. (2018) reported no effect of skills training (either with or without an on-road component, in excess of 12 h) on frequency cycling, cycling as usual school mode, or preference for cycling to school. In contrast, Johnson et al. (2016) reported that Year 6 children who had previously been exposed to practical skills training (including an on-road component) had a greater likelihood and frequency of riding to school and were more likely to report cycling as their usual mode for at least 3 trip purposes (compared to those who had not). Johnson et al. (2016) observed no effect on cycling frequency more broadly.

There has been limited consideration of intermediate factors that might influence cycling participation. Mandic et al. (2018) found that compared to baseline children reported feeling more confident to ride in parks/playgrounds and on the road after playground-based skills training, while only children who also participated in the more advanced, on-road training felt more confident to ride to school. Similarly, Johnson et al. (2016) reported that Year 6 children who had previously been exposed to practical skills training including an on-road component reported feeling more confident riding on the road, compared to children who had not. A study in adults also suggest that skills training improves confidence to ride in traffic, as well as in performing taught skills (Telfer et al., 2006). Perceived safety of cycling has not been considered, although fear of injury risk is a key barrier to cycling (Dill and Voros, 2007; Winters et al., 2011).

Very few studies have assessed the effect of cycling education programs on more than a couple of measures. Colwell and Culverwell (2002) examined effects on knowledge, self-reported behaviour and self-reported crashes, but did not consider cycling participation or potentially associated factors. Moreover, their treatment/control study relied on retrospective reporting of exposure to the National Cycling Proficiency Scheme, introducing inaccuracy. Mandic et al. (2018) examined effects on knowledge, cycling participation, and confidence, while safety-relevant behaviours and crash outcomes were not considered. Their before/after study did not include a follow-up phase.

In a 2013 review Richmond et al. highlighted that cycling education for children has changed little in the past 30 years. In particular, it generally focusses on knowledge and skills relating to vehicle handling and manoeuvring in traffic. This may shed some light on the negative effects on safety observed by Carlin et al. (1998). “First generation” driver education, which also focussed on vehicle handling and manoeuvring, has been found to be of little benefit (see Ker et al., 2005 for Cochrane review), even increasing crash risk (Vernick et al., 1999) by causing overconfidence (Gregersen, 1996). Interestingly, Carlin et al. (1998) hypothesised that Bike Ed “may inadvertently lead susceptible children to undertake risky behaviour” (p.26) due to overconfidence, although risky behaviour and overconfidence were not assessed directly. State-of-the-art driver education addresses higher-level capacities such as hazard awareness and self-evaluation (see Hatakka et al., 2002).

Safe Cycle is a school-based cycling education program that is unlike similar programs that have previously been evaluated. Specifically, having been informed by state-of-the art driver education, it addresses hazard awareness and overconfidence (in addition to more typical cycling education program content such as handling skills and traffic manoeuvres). It is appropriate to evaluate this “new-generation” cycling education program in terms of outcomes relevant to both safety and participation. The effect of Safe Cycle on safety was primarily assessed in terms of self-reported risky behaviour, rather than observed skills (as in previous studies). Self-reported crashes and injuries were also measured. In addition to cycling participation the present study assessed several intermediate variables that have previously been considered only rarely or not at all (i.e. confidence, perceived safety, overconfidence). Knowledge of taught content was also assessed.

Previous literature allows of a directional hypothesis only in relation to knowledge and confidence because cycling education programs for children have found to be associated with improvements in these variables quite consistently. To date there has been no consistent and compelling evidence for a beneficial effect of these programs on participation, safety-relevant behaviour, or crashes. Moreover, because Safe Cycle directly addresses hazards perception and overconfidence, it may impact safety-relevant behaviour and crashes differently to more traditional programs.

[1] The measure was cast as attitude probably because items were phrased “In my opinion being a safe rider means….”. However, because the items detailed practices covered by the course it is more properly considered as assessing knowledge rather than evaluative beliefs about cycling or cycling safety.

2. Setting

Safe Cycle is a school-based cycling education program that was informed by state of the art driver education – with equal emphasis on skill and risk awareness. It involves theoretical as well as practical sessions. The program was developed by a teacher to build teachers' capacity to deliver cycling education with resources that are readily available in schools, and to align the Australian Curriculum. Generally, the program is delivered to students during a single class each week for eight weeks.

When the present evaluation was conducted in 2014 Safe Cycle had been rolled out in a small group of schools in Canberra, in the Australian Capital Territory [ACT] of Australia. "Canberra has one of the most extensive walking and cycling networks in Australia, comprising off-road shared paths, on-road cycle lanes and roads. All ACT footpaths, as well as shared paths, are able to be used by both pedestrians and cyclists." (ACT Government Health Directorate, 2012, p.29) Nonetheless, in a 2011 survey of 328 children in Years 5–8, only 20% reported that they normally ride to school (ACT Government Health Directorate, 2012).

3. Design

The evaluation was conducted using survey and naturalistic observation methodologies. The present paper focusses on the survey component of the study, while the naturalistic component is reported in detail elsewhere (Hatfield et al., 2017).

The study employed a Pre-program/Post-program/Follow-up design. Safe Cycle was delivered in the second school term at all participating schools. In order to promote response rate but minimise disruption at school, on-line surveys were conducted at the beginning of the first Safe Cycle session (Pre-program), and at the end of the last Safe Cycle session (Post-program). The Follow-up survey was conducted online in class approximately 14 weeks after the Post-program Survey. The timing of the follow-up survey was determined by the need to complete the study within a single school year (for practical reasons), combined with the inclusion of a waitlist control schools in the original design. Only data from treated schools was analysed because the control group was too small for reliable analysis and demonstrated a low response rate that raised concerns about selection bias.

Teachers responsible for delivering Safe Cycle were interviewed by telephone soon after program delivery at Treatment schools.

4. Methods

4.1. Sampling

The government department responsible for delivering Safe Cycle in schools in the Australian Capital Territory [ACT] approached 15 schools to both deliver the program and participate in the present evaluation. Seven schools decided to participate, of which four were allocated to the Treatment group. All schools were located within the relatively small region of the inner ACT. Across the treatment schools Safe Cycle was delivered to students in school Years 4 (one school), 5 (two schools), 6 (three schools), 7 and 8 (one school).

The presiding ethical committee required that both the student and their parents give consent for a student to participate in the evaluation. Early in the second school term an Information Statement and Consent Form was sent home with all students who would receive Safe Cycle (including at control schools). Only students who returned signed consent forms from their parents and chose to complete all three on-line surveys in class, contributed data for analysis. (Completing surveys was taken to demonstrate consent.)

At participating Treatment schools, teachers responsible for delivering Safe Cycle were invited to participate in a telephone interview about "the effects of the program on participation in cycling, and cycling safety outcomes, as well as how it is implemented". Teachers at each participating school consented to be interviewed.

4.2. Materials

Web-based questionnaires were developed and administered using Survey Monkey. The Pre-program survey assessed personal characteristics (age, gender, by whom taught to ride a bike), cycling participation and patterns, safe cycling knowledge, beliefs and behaviours, and experience of crashes and near-misses.

Respondents were asked whether they ride a bike. Only those who answered in the affirmative were asked further questions. Respondents indicated which of six non-exclusive reasons they had for riding their bike ("To get to/from school", "To get to friends' houses", "Fun", "Fitness", "Special cycling event (e.g. fun ride or fund-raising ride)", "competition (e.g. racing or stunt riding)") and specified any other reasons. Respondents indicated in which of six non-exclusive locations they ride their bike ("paths that are shared with pedestrians", "On-road bike lanes", "Roads without a bike lane", "Off-road trails (e.g. fire trails, mountain bike trails", "skate parks or dirt parks or BMX tracks", "Criterium circuit or velodrome") and specified any other locations. For questions about riding purpose and riding location a negative response was assumed if respondents reported not riding a bike.

Respondents were asked about how good they are at seven safety behaviours covered by Safe Cycle (see Table 3 in Results). Responses were made on a fully-labelled 3-point scale: "Not good at all" (0), "OK" (1), or "Very good" (2). The average score[2] was taken as a measure of Confidence performing safety behaviours. For analysis of individual items, confidence performing each activity was dichotomised as "Not good at all" and "OK or Very good".

Respondents were asked about how scared they would feel riding in each of four locations (see Table 4 in Results). Responses were made on a fully-labelled 3-point scale: "Not scared at all" (0), "A bit scared" (1), or "Really scared" (2). The average score[1] was taken as a measure of Fear when cycling. For analysis of individual items fear riding in each location was dichotomised as "Not scared at all" and "A bit or Really scared".

Participants were asked two questions to specifically assess "optimism bias" (see Weinstein and Klein, 1996), a type of overconfidence that is targeted directly by Safe Cycle. Respondents indicated how much time they spend riding, and how likely they are to have a bike crash, compared to their peers, both on a fully-labelled 3-point scale: "less", "about the same" or "more".

Next respondents were asked 14 questions to assess their knowledge of information relevant to cycling safety that is covered by Safe Cycle. For example, respondents were asked about ACT regulations relating to riding on footpaths, helmet-wearing, and bicycle-lighting. Other questions related to bicycle-maintenance, helmet fit, and braking techniques. All knowledge items had a multiple-choice response format. The "average percentage correct" was computed from completed knowledge items (including when the scale was partially completed).

Respondents who reported riding a bike on paths or roads in the last 2 weeks were asked on how many days, and for how many hours per day, they did so. Respondents who did not report riding on paths or roads during the last 2 weeks were automatically assigned "0 days". They also indicated their frequency of performing each of seven safety behaviours and seven risky behaviours (see Table 1 in Results) while doing so. Responses were made on a fully-labelled 3-point scale: "Never" (0), "Sometimes" (1), or "Always" (2). An average score was computed for frequency of performing Safety Behaviours and individual items were dichotomised as "Never or sometimes" and "Always". An average score was computed for frequency of performing Risky

[2] When the questions in a scale were partially completed the average score was computed across completed items.

Table 1
Percentage of respondents reporting "Always" conducting safety behaviours, and "Never" conducting risky behaviours, when riding "on roads or paths in the last 2 weeks" at each survey.

Safety behaviours	Pre-program Survey	Post-program Survey	Follow-up Survey
Performing a bike safety check	36.4%	43.6%	34.4%
Wearing a helmet	85.7%	88.3%	85.2%
Considering other people around you	78.9%	64.5%	73.3%
Doing a shoulder check when changing lanes	54.1%	48.6%	41.0%
Signalling when changing lanes	29.6%	30.3%	25.0%
Signalling when turning left	24.7%	25.0%	21.3%
Actively looking out for hazards	62.7%	48.7%	47.5%
Risky behaviours	**Pre-program Survey**	**Post-program Survey**	**Follow-up Survey**
Riding through red traffic lights	92.2%	91.0%	88.3%
Riding through a stop sign	77.6%	76.3%	75.4%
Wearing open shoes	66.7%	64.0%	67.2%
Riding across a pedestrian crossing (e.g. zebra crossing, traffic light crossing)	35.5%	38.5%	40.0%
Riding against the traffic on a one way street without a bike lane	79.7%	73.7%	71.7%
Listening to something with headphones	69.3%	67.1%	72.1%
Talking on a mobile phone (with or without hands free)	89.3%	83.6%	86.7%

Behaviours and individual items were dichotomised as "Never" and "Sometimes or Always".

Scales with three (rather than a higher number) of response options were used for Confidence, Fear, Safety-relevant behaviour, and Overconfidence items to facilitate responding for children. The use of three-point response scales with children is not uncommon (see Mellor and Moore, 2013) and some researchers have converted five-point scales to three-point scales for use with children (e.g. Wright and Asmundson, 2003).

Participants who reported that they had experienced a crash or near-miss while riding on paths or roads in the last six months were asked how many collisions and how many falls they had experienced. A near miss was defined as "an unexpected event that would have been a collision or a fall if you or another person didn't take sudden evasive action" following Poulos et al. (2015).

The Post-program Survey differed from the Pre-program Survey mainly in that there were no questions relating to crashes and near-misses, while the Follow-up Survey differed from the Pre-program Survey mainly in that the time frame for questions relating to crashes and near-misses was three months, to correspond to the period since completing Safe Cycle. Versions of the Post-program and Follow-up surveys included process questions assessed how participants found Safe Cycle. Follow-up respondents who reporting riding a bicycle were asked: "Do you think Safe Cycle has increased the amount you ride?" and "Do you think that Safe Cycle has made you a safer bike rider?" (both with response options: "Yes" or "No").

A structured interview protocol guided telephone interviews with teachers. Included were questions regarding the extent to which students engaged with Safe Cycle, as well as positive and negative aspects of the program.

4.3. Procedures

Each questionnaire was administered in class using Survey Monkey. Supervising teachers were asked to instruct students to complete the questionnaires on their own, and to assist students only with question comprehension. Completed questionnaires were checked against lists of consented students, and teachers asked to follow up with consented students for whom a questionnaire had not been completed (before the survey was closed). Teachers were interviewed by telephone at a time that was convenient for them. Interviews took about 15 min.

5. Analysis

All quantitative analysis was conducted using SPSS V22.

Inferential analysis was conducted to compare Pre-program Survey, with Post-program Survey measures, and with Follow-up Survey measures, separately. A Type 1 error rate of 0.05 was used for all inferential tests. In accordance with accepted practice, two-tailed p-values were halved when judging significance for tests with directional hypotheses (Cho and Abe, 2013).

McNemar's tests with a binomial distribution were used to compare the percentage of respondents who: reported riding a bike, riding a bike to school, riding on bike lanes, and riding on roads without a bike lane; being "OK or very good" at each safety behaviour; feeling "A bit scared" or "Really scared" riding in each location; being less likely than the average person their age to have a bike crash; "Always" performing each safety behaviour, and "Never" performing each risky behaviour.

Paired-samples t-tests were used to compare average reported number of days riding a bike on paths or roads in the last 2 weeks; average confidence performing safety behaviours; average fear when cycling; average percentage correct for knowledge relevant to cycling safety; and average frequency performing safety behaviour and risk behaviours.

Repeated-measures ANOVAs were used to compare the reported number of crashes and near-misses on paths or roads in the last six months at the Pre-program Survey with the estimated number of crashes and near-misses on paths or roads in the last six months at Follow-up Survey (doubled reported number in the three months since Pre-Program Survey. To account for exposure, the number of hours riding on paths or roads in the past 2 weeks (at each survey) was included as an offset variable. The analysis was also conducted without the offset.

Data from process questions were analysed descriptively.

Data from teacher interviews was analysed qualitatively by the lead author (JH). Themes relating to perceived engagement and outcome are reported here.

6. Results

6.1. Participation rate, completion rate, and sample profile

The percentage of students in the classes offered Safe Cycle who returned parental consent forms ranged between 39.7% and 73.9%, and averaged 59.9%, across the four participating schools. Feedback from teachers suggested that non-return of the consent form rarely reflected a decision not to participate, but rather resulted from students not conveying the form (in one direction or another), or parents forgetting to sign it.

The percentage of consented students who completed all three surveys ranged between 87.0% and 100% and averaged 94.8%. Among the six consented students at who did not complete all three surveys, two completed surveys subsequent to the one that they missed – suggesting that they did not discontinue as such, but rather missed school on the day of the survey and could not be followed up. At one school three students missed the Follow-up Survey and could not be followed up because it was too late in the term. Thus, attrition was not considered to be a substantial issue.

The sample was 60.2% female and had a mean age of 11.8 (s.d. = 1.0) at the Pre-program Survey. Bike ridership was initially high with only seven (6.5%) respondents reporting not riding a bike at the Pre-program Survey. Less than 1 in 10 riders reported any formal training, while 77.2% were taught by family members. Most riders reported riding a bike for fun (80.6%) or fitness (51.9%), with transport-related responses less frequently endorsed. Around 25% of riders reported riding to school, and to friends' houses.

6.2. Knowledge

As expected, the mean percentage of questions answered correctly increased significantly from the Pre-program Survey to the Post-program Survey ($t_{99} = 5.51$, $p_{1\text{-tailed}} < .001$) and to the Follow-up Survey ($t_{96} = 3.16$, $p_{1\text{-tailed}} = .001$) (see Fig. 1).

Around 70% of respondents felt that they had learned "a few things" from Safe Cycle while around 16% felt that they had learned "a lot".

6.3. Self-reported safety-relevant riding behaviour

Mean safety behaviour did not change significantly from the Pre-program Survey (mean = 1.4, s.d. = 0.4) to the Post-program Survey (mean = 1.4, s.d. = 0.4, $p_{2\text{-tailed}} = .987$), or to the Follow-up Survey (mean = 1.4, s.d. = 0.4, $p_{2\text{-tailed}} = .406$). Similarly, no significant change in mean risky behaviour was observed (Pre-program Survey: mean = 0.3, s.d. = 0.4; Post-program Survey: mean = 0.3, s.d. = 0.3, $p_{2\text{-tailed}} = .841$; Follow-up Survey: mean = 0.3, s.d. = 0.4, $p_{2\text{-tailed}} = .766$). Further, McNemar's tests showed no significant changes in the percentage of respondents who reported that they "Always" performed each safety behaviour, and "Never" performed each risky behaviour, and no consistent patterns were discernible (see Table 1). These categorisations were chosen because safety arguably requires that precautions be taken consistently, however the opposite categorisations (e.g. respondents who reported "Never" performing each safety behaviour versus the rest) did not change the pattern of results.

Table 2 presents the results of repeated-measures ANOVAs that compared the reported number of crashes and near-misses on paths or roads in the last six months at the Pre-program Survey with the *estimated* number of crashes and near-misses on paths or roads in the last six months at the Follow-up Survey, both with and without offset for

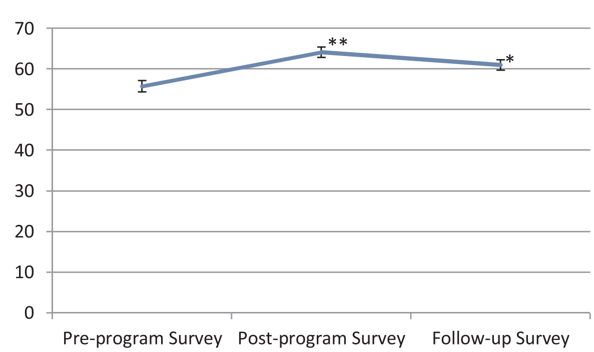

Fig. 1. Mean percentage of questions answered correctly at each survey (with S.E. bars), showing the results of statistical comparison with the Pre-program Survey (* significant with $p_{1\text{-tailed}} < .05$; ** significant with $p_{1\text{-tailed}} < .001$).
Note: Relevant questions were asked of the subsample of bike riders at each Survey

hours riding on paths or roads in the past 2 weeks (at each survey). No significant differences were observed. A marginal increase ($p_{2\text{-tailed}} = 0.089$) in near misses at the Follow-up survey was no longer marginal with exposure offset ($p_{2\text{-tailed}} = 0.356$).

6.4. Cycling participation

The 103 respondents who reported riding a bike at the Follow-up Survey were asked "Do you think Safe Cycle has increased the amount you ride?" Fifty-two reported that it did- representing 48.1% of the whole sample (n = 108).

The increase in percentage of respondents who reported riding a bike from the Pre-program Survey to the Post-program Survey (see Fig. 2) was not significant. However, the p-value was low ($p_{2\text{-tailed}} = .063$) and six of seven respondents who reported not riding at the Pre-program Survey reported riding. There was also no significant change from the Pre-program Survey to the Follow-up Survey ($p_{2\text{-tailed}} = .687$) and four of the seven initial non-riders reported riding.

Among questions relating to riding purpose, we focussed on riding to school because this is a focus of many policies and initiatives. Among questions relating to riding location we focussed on riding on bike lanes, and on roads without bike lanes, because these may reflect riding confidence. The percentage of participants who reported riding to school, on bike lanes, and on roads without bike lanes, each increased from Pre-program Survey to the Post-program Survey, and again to the Follow-up survey (see Fig. 2). No change was significant, but for the Follow-up Survey p-values were low ($p_{2\text{-tailed}} = .057$, $p_{2\text{-tailed}} = .077$, and $p_{2\text{-tailed}} = .077$, respectively; at Post-program Survey lowest $p_{2\text{-tailed}} = .146$).

The number of days ridden on paths or roads in the last two weeks for the Pre-program Survey (mean = 3.24, s.d. = 3.48) did not increase significantly to the Post-program Survey (mean = 3.62, s.d. = 3.78, $t_{105} = 1.15$, $p_{2\text{-tailed}} = .254$) at least in part due to substantial variability in the data. The difference from the Pre-program Survey (for this comparison mean = 3.25, s.d. = 3.47) to the Follow-up Survey (mean = 3.17, s.d. = 4.00) was also not significant (p = .829).

6.5. Confidence

As expected, confidence in performing taught safety behaviours increased significantly from the Pre-program Survey to the Post-program Survey ($t_{99} = 2.35$, $p_{1\text{-tailed}} = .010$), although not to the Follow-up Survey ($t_{97} = 0.32$, $p_{1\text{-tailed}} = .375$)(see Fig. 3). A significant increase (from Pre-program) was observed in the percentage of respondents who felt good at arm signalling when turning, and at using a roundabout, at the Post-program and the Follow-up surveys (see Table 3). No further significant increase was observed.

6.6. Perceived safety

The 103 respondents who reported riding a bike at The Follow-up Survey were asked "Do you think that *Safe Cycle* has made you a safer bike rider?"[3] Eighty-seven reported that it did, representing 80.6% of the entire sample (and 84.5% of those who reported riding).

Average Fear score did not change significantly from the Pre-program Survey (mean = 0.67, s.d. = 0.41) to the Post-program Survey (mean = 0.74, s.d. = 0.42, $t_{100} = 1.47$, $p_{2\text{-tailed}} = .146$), or from the Pre-program Survey (for this comparison mean = 0.66, s.d. = 0.40) to the Follow-up Survey (mean = 0.72, s.d. = 0.43, $t_{98} = 1.39$, $p_{2\text{-tailed}} = .168$).

A significantly larger percentage of respondents reported that they would feel scared riding on a road next to parked cars at the Post-program Survey compared to the Pre-program Survey ($p_{2\text{-tailed}} = .043$;

[3] This question was not asked at The Post-program Survey.

Table 2
Mean reported (Pre-program Survey) or estimated (Follow-up Survey)[a] number of crashes and near-misses on paths or roads in the last six months, showing the results of statistical comparison with and without offset for hours riding on paths or roads (in the past 2 weeks).

Variable	Pre-program Survey	Follow-up Survey	Without exposure offset			With exposure offset		
	Mean (s.d.)	Mean (s.d.)	F	df	$p_{2\text{-tailed}}$	F	df	$p_{2\text{-tailed}}$
Number of crashes in the last six months	1.91 (4.34)	1.96 (5.01)	0.01	1, 95	.921	0.02	1, 93	.921
Number of near-misses in the past six months	0.81 (2.77)	1.85 (6.53)	2.95	1, 95	.089	0.86	1, 93	.356

[a] For the Follow-up Survey estimated from reports about three months (i.e. doubled).

see Table 4). No further significant changes were observed.

6.7. Overconfidence

At the Pre-program Survey, 50% of respondents felt that they would be "less likely to have a crash than average (with only 2% reporting that they would be more likely), indicating biased judgement in the sample. This percentage was significantly lower at the Post-program Survey ($p_{2\text{-tailed}} < .001$), but not at the Follow-up Survey ($p_{2\text{-tailed}} = .222$)(see Fig. 4).

6.8. Students' and teachers' impressions of Safe Cycle

Around 6 in 10 Post-program respondents reported that they found *Safe Cycle* very engaging and fun, while the remainder reported finding it "a bit" engaging and fun. The aspects of the program that were most frequently endorsed as the "most useful" and "least useful" were components of the riding session involving learning how to: "look back over your shoulder when riding forward" (46% of respondents), "do hand signals" (46%), "do an emergency brake" (43.0%), and "how to control your speed" (39.3%). However, specific theoretical messages were not offered as options.

In their interviews, teachers uniformly described students as responding positively to the Safe Cycle program. Although many indicated that students preferred the practical sessions, teachers also stressed that students understood the value of the theoretical sessions, and generally found the content interesting and relevant. One teacher suggested capitalising on the link between the theoretical and practical components:

> "The practical stuff is where we hook them and the theoretical stuff is where we teach them."

Strengths of the program identified by teachers included: focus on developing risk awareness and self-awareness; increasing confidence; introducing children to the road environment. It was highlighted that these strengths extend beyond the cycling context.

Specific outcomes that teachers reported observing were: non-riders learning to ride; more children riding to school; children signalling turns more; children taking more care of their helmets; parents buying children helmets that meet the Australian Standard; and children using the language of risk management.

7. Discussion

The present study examined whether an innovative school-based cycling education program increased cycling safety and participation. The potential role for such a program was highlighted by the baseline findings that 93.5% of study participants reported riding a bicycle but only 20% reported riding to school. Cycling education programs might introduce non-riders to cycling and also increase level of cycling participation among riders. They may also play an important role in improving cycling safety, which is known to be an issue for this age group (see AIHW et al., 2012, p19, Fig. 4.3.1). In the present study 40.6% of respondents reported having experienced at least one crash or near-miss in the six months before participating in Safe Cycle.

As expected on the basis of previous literature that has shown an improvement in skills (Ducheyne et al., 2013, 2014; Kearns and Rothman, 1986; Savill et al., 1996; Trotter and Kearns, 1983; Van Schagen and Brookhuis, 1994) or knowledge of information (Hooshmand et al., 2014; Kearns and Rothman, 1986; Kimmel and Nagel, 1990; Lachapelle et al., 2013; Mandic et al., 2018; McLaughlin and Glang, 2009; Savill et al., 1996; Trotter and Kearns, 1983; Van Schagen and Brookhuis, 1994) taught during the program, respondents in the present study demonstrated improved knowledge of the safety-relevant information they were given during Safe Cycle. The significant increase in percentage of knowledge items answered correctly was maintained up to 14 weeks after the program. We are not aware of any other source of information available in parallel to Safe Cycle either locally or nationally, so, the observed improvement in knowledge most probably owes to the program. Moreover, 86% respondents reported that they had learnt at least a few new things from Safe Cycle.

Results provided no evidence of improvement in self-reported safety-relevant behaviour, even though behaviours considered related to course content. This finding obviates concerns about demand characteristics and is consistent with recognised difficulty in achieving behaviour change via education alone (Kelly and Barker, 2016). Further, it is consistent with earlier studies of the effects of cycling education programs for children on self-reported safety-relevant beliefs and behaviours (Colwell and Culverwell, 2002; Macarthur et al., 1998). The contrasting efficacy of education programs specifically targeting increased helmet-wearing (for reviews see: Rivara et al., 1998; Royal et al., 2007) may owe to the relative simplicity of the behavioural message and of the behaviour itself. Nonetheless, it is possible that self-reporting was not accurate, and that improvements occurred in safety-

Table 3
Percentage of bike riders "OK or Very good" at activities covered by *Safe Cycle* at each survey, showing the results of statistical comparison with the Pre-program Survey (* significant with $p_{1\text{-tailed}} < .05$).

Safety behaviour	Pre-program Survey	Post-program Survey	Follow-up Survey
Checking that your bike is safe to ride	91.9%	96.2%	96.1%
Putting your helmet on properly	100.0%	98.1%	96.1%
Looking back over your shoulder when you are riding forwards	92.0%	96.2%	92.1%
Using your arm to signal when you are turning	69.8%	88.6%*	83.3%*
Knowing when to give way to people when you are riding	90.0%	95.2%	93.1%
Doing a right turn in traffic when you are riding	78.8%	76.5%	79.2%
Using a roundabout when you are riding	65.6%	80.6%*	82.4%*

Table 4
Percentage of bike riders "A bit scared" or "Really scared" in various locations at each survey, showing the results of statistical comparison with the Pre-program Survey (* significant with $p_{2\text{-tailed}} < .05$).

Location	Pre-program Survey	Post-program Survey	Follow-up Survey
A path that is shared with pedestrians	17.2%	15.4%	19.4%
A busy road in a bike lane	71.4%	82.5%	74.8%%
A busy road without a bike lane	89.0%	89.3%	87.4%
A road next to parked cars	34.7%	45.6% *	46.6%

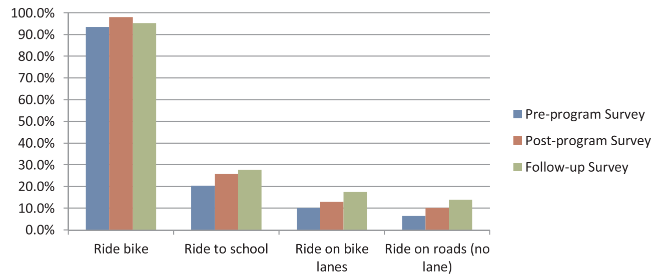

Fig. 2. Percentage of respondents who reported riding a bike, riding a bike to school, riding on bike lanes, and riding on roads without a bike lane, at each survey, showing the results of statistical comparison with the Pre-program Survey.
Note: Purpose and location questions were asked only of respondents who reported riding a bike, and "no" was inferred for respondents who reported not riding a bike.

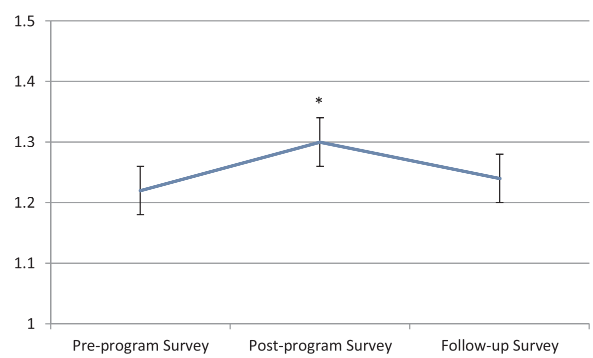

Fig. 3. Mean Confidence performing safety behaviours at each survey (with S.E. bars) showing the results of statistical comparison with the Pre-program Survey (* significant with $p_{1\text{-tailed}} < .05$).
Note: Relevant questions were asked of the subsample of bike riders at each survey.

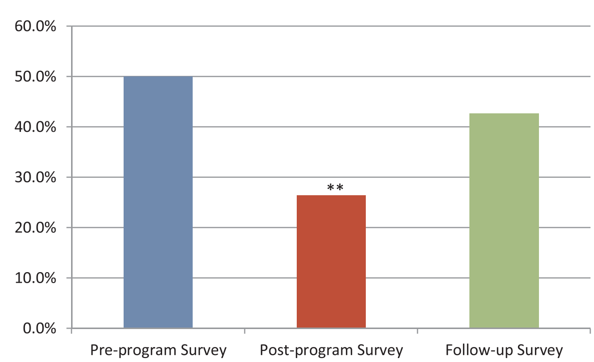

Fig. 4. Percentage of bike riders who reported that they were less likely than the average person their age to have a bike crash, at each survey, showing the results of statistical comparison with the Pre-program Survey (** significant with $p_{1\text{-tailed}} < .001$).

relevant behaviours that were not measured. In fact, teachers involved in delivering Safe Cycle reported that they had observed improvements in safety-relevant behaviours.

Given the lack of evidence for improvement in safety-relevant behaviour, it is unsurprising that the number of crashes or near misses experienced by respondents did not decrease significantly (with offset for cycling exposure). Importantly, a near-significant *increase* in near misses disappeared when cycling exposure was offset, suggesting that the association of cycling safety education with increased crash risk observed by Carlin et al. (1998) may have resulted in part from increased participation. However, the validity of the comparison between Pre-program with Follow-up crash/near-miss experience is undermined by relevant questions using a different time-frame. Specifically, crash/near-miss numbers experienced in the previous 3 months at the Follow-up Survey were doubled to provide an estimated number of crashes in six months (the time frame for the Pre-program Survey). These estimates are likely to exaggerate the number of participants with no crash experience, so the observed significant decrease in the number of participants who had experienced a crash must be treated with caution. Further, the exposure offset employed (reported number of days ridden in the past two weeks) is a very gross estimate of exposure during the time period for which crashes were reported.

Although no significant effect of Safe Cycle on cycling participation was observed in the present study, results are suggestive of a small positive effect which may have been significant with more sensitive measures, in a larger sample or, in a sample with lower initial ridership. Among seven (6.5%) respondents who reported not riding at the Pre-program Survey, six reported riding at the Post-program Survey, and the p-value associated with the change was low (.063). At the Follow-up Survey increases in the percentage of riders who reported riding to school, on bike lanes, and on roads without bike lanes, were each associated with p-values (.057, .077, and .077, respectively). Teachers involved in delivering Safe Cycle reported that they had taught non-riders to ride during the program, and that the number of students riding to school had increased as a direct result of Safe Cycle. Substantial variability in the number of days ridden on paths or roads in the last two weeks made statistical comparisons unreliable. Nonetheless, just under half of respondents at the Follow-up Survey reported that Safe Cycle had increased the amount they ride. Moreover, observed increases in self-efficacy (as reflected in confidence and knowledge) could be expected to result in increased cycling (Bandura, 1997).While the possibility of skills training increasing cycling participation is supported by some findings of Johnson et al. (2016), other studies have found of skills training sessions on cycling frequency (Johnson et al., 2016; Mandic et al., 2018), cycling as usual school mode (Mandic et al., 2018), preference for cycling to school (Mandic et al., 2018), or time riding to school (Ducheyne et al., 2014). Like these studies, Safe Cycle did not promote cycling participation directly. Cycling education may be a useful element in comprehensive programs incorporating sustained behaviour change activities together with supportive policy and environmental changes (Garrard et al., 2006).

The present study provided evidence that skill training builds confidence in performing taught safety behaviours. Participants in Safe Cycle are given information and practice to perform seven safety-relevant activities: checking that a bike is safe to ride, putting a helmet on properly, checking over the shoulder when riding forwards, arm-signalling when turning, giving way appropriately, turning right in traffic, using a roundabout correctly. Respondents reported feeling better at these activities (on average) immediately after Safe Cycle than they did before the program. This increase in confidence was no longer evident three months after the program, suggesting that respondents felt they had forgotten some of these skills with time and/or lack of practice. Significantly more respondents at both Post-program and Follow-up felt good at using a roundabout and arm signalling when turning. Interestingly, this did not translate into more respondents reporting always arm signalling when turning. Increased confidence performing particular skills (demonstrated in the present study and by Telfer et al., 2006) does not map exactly onto confidence riding in particular situations demonstrated in previous studies (Johnson et al., 2016; Mandic et al., 2018; Telfer et al., 2006) but is likely to contribute to it. Observed increases in confidence performing particular cycling safety behaviours may also have contributed to apparent increases in perceived safety of cycling.

Perhaps the most innovative aspect of Safe Cycle are elements addressing hazard awareness and overconfidence. Hazard awareness is increasingly recognised as an important component of training for young drivers (Hatakka et al., 2002; Wetton et al., 2011) and skills training alone may result in overconfidence (Carlin et al., 1998; Gregersen, 1996). Safe Cycle involves several components to promote awareness of the risks involved with cycling, and to teach participants to manage these risks. For example, participants tell stories about crashes or near-misses that they have had and discuss ways in which the incident could have been avoided. Participants are shown real-world images of scenes that they may encounter while riding (from the rider's perspective), highlight the hazards in the scenes, and discuss ways of managing their risk. Safe Cycle also includes a module addressing illusory invulnerability – a type of overconfidence reflected in the belief that one is less likely than average to experience negative events, which may contribute to risky behaviour (Dillard et al., 2006; Weinstein and Klein, 1996).

Results suggest that Safe Cycle was effective in increasing perceived safety, while avoiding overconfidence. Asked directly whether "Safe Cycle has made you a safer bike rider?" (at the Follow-up Survey), 81% of respondents felt that it did. Nonetheless, there tended to be an increase in the percentage of respondents who would feel at least a bit scared cycling in each of four locations - shared path, bike lane, road without bike lane, road with parked cars, although the increase was significant only for the latter. This is consistent with increased awareness of risk. The percentage of participants who thought they were less likely to have a crash at The Pre-program Survey (50%) was significantly reduced at The Post-program Survey. Because illusory invulnerability is an extremely robust phenomenon (Weinstein and Klein, 1995) messages may need to be reinforced to maintain the effect (which was not observed at the Follow-up Survey). By promoting hazard awareness and avoiding overconfidence Safe Cycle may be less likely to result in the increases in crashes and near-misses that have been observed with more traditional cycling education programs (Carlin et al., 1998).

This is the first study to assess the effect of a cycling education program on perceived safety and overconfidence, which are both useful for understanding effects on participation and safety. Future evaluations of cycling education programs for children could benefit from including a wider array of measures than were employed in the present study.

The high levels of reported bike ridership at the Pre-program Survey highlight that for the age group sampled there is limited value to teaching basic cycling skills. Most respondents had already learned basic bicycling skills (mostly from their parents), so that the "higher order" skills addressed by Safe Cycle were of much greater potential value. Several of the teachers involved in delivering Safe Cycle stressed this point.

The improvements in knowledge and confidence performing safety-relevant behaviour that were achieved by Safe Cycle are an important step toward behavioural change (Michie et al., 2011). However, for these improvements to translate into safer behaviour, and then to crashes and injury, it is important to address motivation. For example, self-reported frequency of hand-signalling a turn did not increase with self-reported confidence in performing this behaviour. Similarly, although at Follow-up more respondents knew that they must dismount when crossing a pedestrian crossing, no more reported actually doing (compared to baseline). The benefits of Safe Cycle might be enhanced by including elements to increase the perceived importance of particular safety-relevant behaviours (e.g. signalling turns), and to make safer practices habitual (Nilsen et al., 2008).

Durability of program effects is a key issue for any public health initiative, and it is a strength of the present evaluation that durability was assessed (albeit only over a period of three months). According to the review of Richmond et al. (2013) very few evaluations of cycling education programs for children reported the post-program follow-up period they employed. One study that included a 7-month follow-up reported that the improvement in manoeuvring that was observed immediately after the program was no longer evident after seven months. Similarly, several of the beneficial effects that were observed in the present study at the Post-program Survey (specifically participation, confidence, feeling scared near parked cars, and overconfidence) were no longer observed at the three-month follow-up. This highlights the need for refinements to Safe Cycle to enhance the durability of its benefits and converges with suggestions by teachers for broadening the impact of the program. Specifically, teachers suggested repetition of aspects of the program across time (school terms and years) as well as across the school curriculum (i.e. "a whole school approach").

8. Limitations and research challenges

The results of the present evaluation must be interpreted in the context of several unavoidable methodological limitations. Although survey data were collected at waitlist control schools these data could not be used in analysis. Assignment of schools to Treatment and Control conditions was based on practical considerations, raising the possibility of bias. Only three control schools participated, and participation and completion rates were lower at control schools, suggesting the introduction of further bias. Further, the Control sample was too small for reliable analyses with control for potential biases. These results highlight the difficulty of conducting controlled evaluations of school-based programs. Without a Control group changes from Pre-program in the Treatment group cannot be attributed to Safe Cycle with confidence. Nonetheless, increases in participation and perceived safety were directly attributed to Safe Cycle by both students and teachers (although demand characteristics might bias these reports). Further, the decay of the effects observed at Post-program by the three-month Follow-up suggests they may have been achieved at least in part by the program.

Self-report raises concerns about errors of recall or reporting. Nonetheless, knowledge cannot be faked, and self-report is the only way of assessing confidence and perceived safety. Students' reports of increased participation in bicycle riding converged with teachers' reports of increased student participation. Unfortunately, the naturalistic component of the present research (see Hatfield et al., 2017) suggests some error in self-reports of safe/risky cycling behaviour. Specifically, while around 45% of respondents reported "always" conducting an over-the-shoulder check and around 25% reported always hand-signalling (when turning left or changing lanes), no naturalistic study participant was observed to "always" conduct each of these behaviours. However, this may partly reflect the low sensitivity of the survey response scale; with respondents choosing "Always" to mean "Almost always".

9. Conclusions

The results of the present evaluation provide some evidence that a school-based cycle safety education program that incorporates hazard and self-awareness training (in addition to more typical content such as bike handling skills and traffic manoeuvres) may increase knowledge relevant to cycling safety, confidence performing safety-relevant behaviours, perceived safety, and participation, without increasing overconfidence and injury risk. Incorporating elements to increase motivation to perform safety-relevant behaviours, and improve the durability of cycling education program effects, may enhance the benefits that cycle safety education offers to school-aged children.

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