Journal of Adolescent Health 63 (2018) 489–496

ELSEVIER

JOURNAL OF
ADOLESCENT
HEALTH

www.jahonline.org

Original article

Impact of a Neuroscience-Based Health Education Course on High School Students' Health Knowledge, Beliefs, and Behaviors

Leslie M. Babinski, Ph.D.[a,*], Desiree W. Murray, Ph.D.[b,1], Wilkie A. Wilson, Ph.D.[c], Cynthia M. Kuhn, Ph.D.[d], and Patrick S. Malone, Ph.D.[e]

[a] *Duke University, Center for Child and Family Policy, Sanford School of Public Policy, Durham, North Carolina*
[b] *University of North Carolina, Chapel Hill, North Carolina*
[c] *Duke University, Durham, North Carolina*
[d] *Duke University School of Medicine, Durham, North Carolina*
[e] *Duke University, Center for Child and Family Policy, Durham, North Carolina*

Article History: Received September 8, 2017; Accepted May 17, 2018
Keywords; Neuroscience; Health education; High school; Health behaviors

A B S T R A C T

Purpose: The purpose of this pilot study was to evaluate the potential of an innovative high school neuroscience-based health course for implementation feasibility and impact on student outcomes.
Methods: Thirteen teachers from two high schools participated in this quasi-experimental pilot study including 395 students (202 in the intervention classes and 193 in the comparison classes). Students completed pre/post online surveys assessing their knowledge, beliefs, and behaviors. Our analysis strategy for multi-item measures was to estimate the effects of the intervention on latent change scores in structural equation models.
Results: Students in the neuroscience health classes showed a significant increase in neuroscience knowledge as compared to students in the comparison group (difference estimate in proportion correct metric, adjusted for covariates = .04; 95% confidence interval [.01, .06]). However, none of the other primary outcomes showed a significant difference between conditions. Teachers in the intervention group were observed implementing the neuroscience and health components more often than the self-regulation and growth mindset components. Students in the neuroscience group were more likely to mention the importance of caring for their brain and its link to health behaviors.
Conclusions: Findings demonstrate that information about the link between health behaviors and brain functioning can be successfully integrated into a high school health education course, although effects on student health beliefs and behaviors were not observed. Additional development work should focus on clarifying the theoretical mechanisms of change, integrating the neuroscience content with self-regulation and growth mindset, and providing additional professional development for teachers.

IMPLICATIONS AND CONTRIBUTION

This pilot study demonstrated the feasibility of integrating information about the link between health behaviors and brain functioning into a high school course, although additional development work is needed to realize the potential of this approach with regard to student outcomes. Such work should consider additional professional development for teachers and stronger methods to help students apply knowledge to their health decision-making and behaviors. A thorough examination of recent developments in theoretical models for adolescent health decision-making processes may be helpful in strengthening the curriculum

Conflicts of interest: The authors have no conflicts of interest to disclose. During the implementation of this study,

* Address correspondence to: Leslie M. Babinski, Ph.D., Duke University, Center for Child and Family Policy, Sanford School of Public Policy, Durham, North Carolina.
E-mail addresses: leslie.babinski@duke.edu, lb107@duke.edu (L.M. Babinski).
[1] Dr. Murray was at Duke University, Durham, North Carolina.

1054-139X/© 2018 Society for Adolescent Health and Medicine. All rights reserved.
https://doi.org/10.1016/j.jadohealth.2018.05.016

Recent advances in developmental neuroscience hold potential for strengthening health education programs for youth. Studies have demonstrated the link between brain functioning and health behaviors such as sleep [1], exercise [2], healthy eating [3], and stress [4]. However, high school health education courses rarely focus on the link between health behaviors and the brain, and research in this area is limited. This is a missed opportunity since adolescence is a unique developmental period for both the promotion of healthy behaviors and prevention of risky behaviors [6,7]. Adolescents are beginning to exert control over their own health decisions, in both positive and negative ways. For example, the mean age at first use for many illegal drugs, alcohol, and cigarettes is during the teen years [8]. Adolescents are also adopting lifelong health-promoting behaviors such as regular physical activity and healthy eating [9].

Developmental neuroscience also provides a framework for thinking about how adolescents make decisions about their health behaviors. Steinberg argues that adolescent risk-taking depends on both logical reasoning and psychosocial capacities [10]. The adolescent brain is especially sensitive to social and emotional conditions related to processing information about rewards [10]. In addition, cognitive-control abilities continue to develop throughout adolescence including executive function abilities such as planning and self-regulation [10] and may be leveraged to support healthy decision-making.

While earlier models of risk-taking suggested that interventions should focus on getting adolescents to simply avoid all risks given their less well-developed prefrontal cortex (e.g., *Just Say No*), current developmental models also focus on adopting healthy behaviors. One such curriculum that integrates neuroscience and the promotion of positive health behaviors is the National Institute of Health curriculum called *The Brain: Understanding Neurobiology through the Study of Addiction* [5]. Researchers compared student outcomes for the five-lesson brain curriculum in two urban high schools, one that received the new curriculum and one that received the usual curriculum. An evaluation of the program found it to be a promising strategy for preventing substance use among adolescents, particularly for cigarette and marijuana use, although all differences between the groups were extinguished by the follow-up 6–8 months post intervention. The small sample and brief program suggest need for further research on this approach.

Capitalizing on recent research that links brain functioning and health behaviors and building on the extensive literature supporting social-cognitive approaches to behavior change, we developed a neuroscience-based health education class. This course is centered on an emerging new field of health neuroscience [11, p. 447] that aims to “characterize the bidirectional and dynamic brain-behavior and brain-physiology relationships that are the determinants, markers, and consequences of physical health states.” This approach is consistent with calls for applied research that examines the impact of developmental neuroscience in school-based prevention programs [12]. However, new programs also need careful evaluation to ensure that they can be implemented by school staff, and so that any limitations can be identified and addressed before large-scale dissemination.

The present study

Our study objectives were to assess the feasibility of integrating neuroscience into high school health education and to evaluate the promise of a neuroscience-based health course as compared to the standard health education course for a range of student outcomes using a quasi-experimental design. Primary outcomes focus on students’ awareness of the links between health behaviors and the brain, core neuroscience knowledge, growth mindset, self-monitoring and self-control, and self-efficacy for academic planning and academic focus. Secondary outcomes examined include beliefs about the impacts of positive health behaviors and

Table 1
Teacher and student demographics

			Comparison	Neuroscience	Total/average
Teachers n			7	6	13
	Gender n (%)				
		Male	6 (85.7)	4 (66.7)	10
		Female	1 (14.3)	2 (33.3)	3
	Race/Eth n (%)	Afr-Amer	1 (14.3)	0 (0)	1
		White	6 (85.7)	6 (100)	12
	Yrs exp in educ M (SD)		10.3 (4.9)	16.2 (7.9)	13 (6.9)
Students n			193	202	395
Student-reported variables					
	Gender n (%)				
		Male	109 (56.5)	92 (45.5)	201 (51)*
		Female	84 (43.5)	110 (54.5)	194 (49)
	Grade n (%)	Ninth graders	171 (89)	188 (93)	359 (91)
	Age in months M (SD)		175.5	175.2	175.4
	Race/ethnicity n (%)				
		Latino	27 (14)	35 (17)	62 (16)*
		Afr-Amer	33 (17)	55 (27)	88 (22)
		White	115 (60)	87 (43)	225 (57)
		Other	18 (9)	25 (12)	43 (11)
	Days of curr prior to pretest		2	2.7	2.3*
District-reported variables					
	Weighted GPA M (SD)		3.32	3.28	3.3
	Days absent M (SD)		2.57	2.78	2.7
	Students with disabilities n (%)		16 (8)	13 (6)	29 (7)
	Free or reduced lunch n (%)		47 (24)	54 (27)	101 (26)
	Limited Eng proficiency n (%)		6 (3)	12 (6)	18 (5)

* *t* test or chi square ($p < .05$).

self-reported changes in health behaviors including physical activity, healthy eating, sufficient sleep, stress management, and alcohol, marijuana and other drug use.

Methods

Participants and setting

Students from two high schools in a large school district were selected based upon recommendation by district leadership and principal interest. School A had about 2,379 students during the 2014–2015 school year with about 27% of students eligible for free or reduced price lunch. School B had an enrollment of 1,906 students during the 2014–2015 school year with about 24% of students eligible for free or reduced price lunch, compared to the state average of 53%. Academic achievement in the two schools was also similar as measured by the percentage of students who were proficient on the English II assessment (72.7% and 69.5%, compared to the district average of 70.6%). Thirteen teachers (6 intervention, 7 comparison) participated, representing all the teachers at the targeted schools who taught a section of the required ninth grade Healthful Living class.

All students in participating teachers' classrooms were invited to participate. In the intervention classrooms, 218 of the 285 students (76.5%) returned the parent consent form and agreed to participate while 208 of the 274 students (76%) in the comparison classrooms returned the parent consent form and agreed to participate. The final dataset includes 395 students, 202 in the intervention classes and 193 in the comparison classes (see Table 1).

Procedures

Prior to the start of the fall semester, one school was selected by the school administrators to implement the new Neuroscience-Based Health Education course in the fall while teachers at the other school implemented the usual Healthful Living course. The health course is offered on a semester schedule of 90 days of instruction, half physical education and half health. At the beginning and end of the semester, students completed an online survey assessing their knowledge, beliefs, and behaviors related to the curriculum as well as demographic information. A trained observer rated each teacher on implementation of core curriculum components.

Table 2
Neuroscience-based health education curriculum outline

Unit 1: Brain 101
Brain anatomy introduced all week via activities/games
• Lesson 1 – Brain growth, development & why it is important
• Lesson 2 – Great aspects of adolescent brain functioning
• Lesson 3 – Neurons, myelination, connectivity
• Lesson 4 – Limbic system (emotions), adolescent brain, and decision making
• Lesson 5 – Motivation and memory storage
• Lesson 6 – Behaviors that inhibit and strategies that enhance learning
Unit 2: Automatic processes
• Lesson 1 – Impact of alcohol & drugs on involuntary system functions
• Lesson 2 – Conscious/perception system functions
• Lesson 3 – Stress/ stress management
• Lesson 4 – Importance of sleep on brain function
Unit 3: Sensing & moving
• Lesson 1 – The brain & senses
• Lesson 2 – Responses to sensory input (the brain, senses, motor skills and movement)
Unit 4: Controlling voluntary behavior
• Lesson 1 – Survival & nutrition
Unit 5: Thinking, planning, prioritizing the cortex
• Lesson 1 – Decision making
• Lesson 2 – Conflict resolution & social behavior (aggression)
• Lesson 3 – Conflict resolution & social behavior (affiliation)
Unit 6: Relationships
• Lesson 1 – Neurobiology of social behavior
• Lesson 2 – Relationships (family, friends, romantic)
• Lesson 3 – Sex and the brain
• Lesson 4 – Healthy relationships
• Lesson 5 – Preventing unhealthy relationships
Unit 7: Responding and adapting: environment and your brain
• Lesson 1 – Physical risks in the environment
• Lesson 2 – The brain & drugs: part I
• Lesson 3 – The brain & drugs: part II
• Lesson 4 - Media influences
Unit 8: Healthy versus unhealthy behavior
• Lesson 1 – Addiction
• Lesson 2 – Depression & anxiety
• Lesson 3 – Chronic disorders in the brain
• Lesson 4 – Optimal overall brain health

Description of the intervention

The Neuroscience-Based Health Education curriculum includes information about the structure and function of the brain, the connection of neuroscience and health, and the relevance of this information to the students' everyday lives (see Tables 2 and 3). Throughout the course, students were encouraged to use a social cognitive framework [6] to promote self-regulation for healthy

Table 3
Classroom observations.

Content domain	Descriptor	Comparison observations[1] (n = 18 obs)	Neuroscience observations[1] (n = 20 obs)
Health behaviors	Information about a specific health behavior.	100%	100%
Connection of neuroscience to health behaviors	Information about how a brain function or structure impacts a specific health behavior OR Information about how a specific health behavior affects brain function or structure.	20%	89%
Neuroscience (without a connection to health)	Information about brain structure or function delivered in a scientifically accurate and understandable manner.	0%	77%
Self-regulation strategies	Information about self-regulation or self-monitoring strategies (such as the four P's) to encourage students to improve a specific health behavior.	0%	65%
Growth mindset	Information about embracing challenges, persisting in the face of setbacks, and seeing effort as the path to mastery.	0%	11%

decision-making that included four steps: Plan, Prioritize, Practice, and Praise, called the four P's, which was developed for this study. The curriculum focused on the brain's impact on health and the impact of health behaviors on the brain to apply the decision-making framework and growth mindset concepts to positively impact their health behaviors. The curriculum met the standards of the North Carolina Course of Study for Healthful Living.

Teachers attended a 3-day training about the structure and function of the brain and its connection to health as well as opportunities to practice several of the curricular modules. Curricular materials and video links were provided through an electronic course site. An instructional coach was available each week to support the teachers' implementation of the curriculum.

Measures

Classroom observations and teacher interviews. A classroom observation measure was developed to assess the delivery of the curriculum in both intervention and comparison classrooms. This measure assessed the extent to which the content was observed on a three-point scale from present, partially present, to absent on five core domains including: (1) health behaviors, (2) connection of neuroscience to health behaviors, (3) neuroscience content, (4) self-regulation strategies, and (5) growth mindset. A trained observer rated each teacher three times (except for one teacher who was observed twice) during the semester across a variety of lessons. Inter-rater reliability was calculated based on 12 observations (33%) (*Kappa* = .83 [$p < .001$], 95% confidence interval [CI] [.71, .96]).

Intervention teachers were interviewed at the end of the semester to provide formative feedback about the challenges and benefits of the curriculum to guide further development work. The students' open-ended survey responses and intervention teacher interview transcriptions were coded for common themes using QSR International's NVivo 11 Software for qualitative data analysis.

Neuroscience knowledge. Students' understanding of the core neuroscience content as it relates to health behaviors was assessed with a measure developed for this study. Areas of knowledge assessed include general and adolescent-specific brain structure and functioning, impact of health behaviors (i.e., exercise, nutrition, and sleep) and stress on the brain, role of the brain in motivation and practice, drug use in adolescence, and mental health problems and treatment.

Self-regulation. Self-regulation was assessed with a modified version of the *Self-Control and Self-Management Scale* [13] originally developed with college students. Psychometrics for the original measure indicated adequate internal consistency ($\alpha = .81$) and test-retest reliability ($r = .75$). In the present study, items were reworded to reduce the reading level for adolescents; thus, additional psychometric evaluation resulted in a measure that included 12 items with two subscales assessing components of self-regulation [14,15]: self-monitoring (SM; 8 items, internal consistency coefficient $\omega = .86$, 95% CI [.84, .89]) and self-reinforcing (SR; 4 items, $\omega = .80$, CI [.76, .84]).

Self-regulated learning behaviors. The self-efficacy for self-regulated learning scale of the high school version of the *Children's Multidimensional Self-Efficacy Scales* is an 11-item, seven-point scale that measures students' perceived capability to use a variety of self-regulated learning strategies such as "finish my homework assignments by deadlines" and "motivate yourself to do schoolwork." Previous work has demonstrated high internal consistency ($\alpha = .87$) [16]. However, in the present sample, two interpretable factors emerged from EFA that can be described as Academic Planning and Academic Focusing. The two-factor CFA showed predominantly acceptable measures of approximate fit, χ^2 (26, N = 380) = 81.51, $p < .001$, est. RMSEA = .074 (90% CI: .056, .093), CFI = .93, TLI = .90, SRMR = .048. Self-efficacy for Academic Planning (5 items) showed internal consistency $\omega = .84$, 95% CI [.80, .86]; for Academic Focusing (4 items), $\omega = .74$, CI [.69, .79].

Growth mindset. The *Theory of Brain Abilities* is a six-item measure adapted from Dweck [17] by modifying the word "intelligence" to "brain abilities" to broaden the assessment of incremental and entity theory. Students rated items on a six-point Likert scale with statements such as "No matter who you are, you can change your brain abilities a lot."

The original *Effort Beliefs Measure* is a 12-item scale assessing the extent to which students believe that their efforts (or practice) will lead to positive outcomes [18]. Students rated items such as "When something is hard, it just makes me want to work more on it, not less." Internal consistency ranged from .78 to .97 [18].

Examination of correlations among the Growth Mindset items in the current data indicated problems with the reverse-scored items—in most cases, they were essentially orthogonal to the positively-worded items. Given this, we used only the positively-phrased questions, three for Brain Abilities and four for Effort Beliefs. Confirmatory factor analysis (CFA) indicated good fit of this two-factor model in the current data, χ^2 (13, N = 380) = 16.31, p = .233. Coefficient ω for Effort Beliefs was .65, 95% CI [.56, .72]. ω is not defined for three-item scales (Brain Abilities).

Health beliefs, behaviors, and intentions. The measure was adapted from the *Center for Substance Abuse Prevention's Substance Use Prevention measure – Perception of Disapproval/Attitude and Perceived Risk and the CDC Youth Risk Behavior Survey*. We created specific items related to beliefs about health behaviors and substance use to align with our curriculum. Areas assessed include beliefs about how different health factors (physical activity, nutrition, sleep, stress, alcohol, marijuana, and drugs) impact the brain, school performance, sports performance, stress and health, with higher scores reflecting greater perceived impact. Due to sparse responding, only non-negatively valenced responses were used, consolidating the five-point response metrics to three. Categorical-data confirmatory factor analysis (CCFA) in the current supported these seven a priori health-belief factors, with acceptable measures of approximate fit, χ^2 (329, N = 380) = 420.00, p = .001, est. RMSEA = .026 (90% CI: .018, .034), CFI = .99, TLI = .99. Internal consistency was acceptable to good by coefficient ω from ordinal data: physical activity $\omega = .82$, 95% CI [.79, .85]; nutrition $\omega = .85$, CI [.83, .87]; sleep $\omega = .90$, CI [.88, .92]; stress $\omega = .90$, CI [.89, .92]; alcohol $\omega = .97$, CI [.96, .97]; marijuana $\omega = .98$, CI [.98, .98]; other drugs $\omega = .99$, CI [.99, .99].

Students were asked to indicate the actual frequency of health-related behaviors and experiences in a typical week, based on the *High School Youth Behavior Risk Survey* [19]. Students also responded to an open-ended question about the most important thing they learned in health class.

Analytic approach

We first examined the internal consistency of our scales using McDonald's coefficient ω. For continuous measures, we used the accelerated bootstrap to determine the CI around the estimate of ω. For ordinal measures (the belief scales, after truncation), we estimated ω from the polychoric correlation matrix. As the raw data were not used in this case, we report the normal-theory standard errors. Internal consistency was computed using the scale Structure function in the R package 'userfriendlyscience' v.0.7.0 0 [20]. In additional preprocessing, we also examined condition differences in all variables at baseline.

The general analysis strategy for multi-item measures was to estimate the effects of intervention on latent change scores in structural equation models. These change scores reflected differences in the means of the latent factors between pretest and posttest. We included all factors of multifactor scales (e.g., self-regulated learning behaviors) in single models; other outcomes were modeled separately due to sample-size limitations on model complexity. For single-indicator outcomes (e.g., neuroscience knowledge), we used simple difference scores as the outcome. The latent difference is defined by its relation to the post-test latent variable, which has its intercept fixed to zero and no disturbance (residual) variance. In this model, then, the latent post-test variable is the fully-determined sum of the pretest (fixed loading of 1) and the latent difference (fixed loading of 1).

Covariates partialed from both pretest and difference scores included gender, race, and ethnicity (coded as Hispanic or Latino, non-Hispanic African American, non-Hispanic white, multiracial, or other), free-or-reduced-price lunch status (binary), GPA at the end of the fall semester, grade in school (dichotomized as ninth or greater than ninth), absences (categorized as 0, 1–3, or 4–10), and days of curriculum delivered prior to the individual student's pretest (typically 2 or 3 days). Controlling for the number of days of the curriculum prior to the pretest was necessary because of the time needed at the beginning of the school year to obtain parental consent.

Results

Survey data preprocessing

We made an a priori decision to omit any survey data for which a student completed the entire battery in less than 10 minutes, with the assumption that such a short response time indicated noncompliance with the survey procedures. The mean completion time was 30.5 minutes, SD = 8.1 for pretest and M = 27.5 minutes, SD = 8.4 for post-test. Post-test survey data for 15 participants were omitted from all further analyses by this criterion. No pretest survey responses met the criterion.

We also tested for baseline differences in all outcome measures. After applying the Benjamini–Hochberg control for the false discovery rate, one variable showed a significant difference: students in the neuroscience health classes rated the impact of marijuana on health behaviors as weaker than did students in and the comparison group. Because effects on this variable were modeled as a latent difference relative to pretest, we made no further adjustments.

Implementation feasibility

Findings from the classroom observation measure showed that both groups included health content in every lesson (See Table 3). The neuroscience content connected to health domains was observed in 20% of the comparison classrooms and 89% of the intervention classrooms. The comparison classrooms did not include any neuroscience content (without health), self-regulation strategies, or growth mindset content. In the intervention group, neuroscience content was included in 77% of the observations, while self-regulation was observed in 65% of lessons. Growth mindset content was the least often observed domain, with just 11% of intervention classroom observations including this content.

Teacher interviews

An analysis of the teacher interview transcripts found that teachers were interested in a new way to teach health education. Teachers mentioned the value in discussing brain health with their students and how their brains are impacted by their health behaviors. Teachers expressed concern that some of the neuroscience content was too dense for their high school freshman, and, in some lessons, the connection to health was not clear. Several teachers mentioned that the neuroscience health course could be offered as an honors level elective rather than the required ninth grade healthful living class. Teachers also reported that it was a challenge for them to teach the neuroscience content and its link to health behaviors given their limited background in this area.

Student feedback

Of the 81% of students who answered the question about the most important thing they learned, students in the neuroscience group were more likely to mention the brain in their response (37% vs. 0%; see Table 4). For example, one student in the neuroscience group said that she learned "that our brains are a really important part of our bodies as teenagers." Another student responded, "It is important to take your teen years seriously because they are the time when your brain is developing." Other students specifically linked learning about the brain to health behaviors, such as sleep, stress, nutrition, and drugs. For example, one student wrote, "I learned about my brain and sleep. It has really helped me with staying awake during class and staying focused" while another learned "how drugs and alcohol affect your body and brain."

In the comparison group, the most frequently mentioned response was related to drugs such as I learned "to not do hard drugs," "no drugs and sex," and "to not do drugs because they will affect your future." Students in the comparison group were more likely to mention nutrition and healthy eating (15% vs. 2%) as compared to the neuroscience group.

Table 4
Open-ended student responses

	Comparison	Neuroscience
Most important thing you learned n	157	164
Information about the brain	0 (0%)	61 (37%)
Drugs or alcohol	56 (36%)	33 (20%)
Sleep	1 (1%)	18 (11%)
Stress	8 (5%)	17 (10%)
Nutrition and healthy eating	24 (15%)	4 (2%)
Sex or abstinence	7 (4%)	2 (1%)

Table 5
Primary outcomes

Variable/subscale	Effect of intervention[a] Effect estimate	95% CI	g	Effect of each curriculum: Standard curriculum[b] Change estimate	95% CI	Neuroscience curriculum[c] Change estimate	95% CI
Core knowledge	.04*	(.01, .06)	.38	.00	(−.03, .02)	.03*	(.02, .05)
Growth mindset							
Brain abilities	.05	(−.09, .19)	.05	.05	(−.16, 0.25)	.10	(−.1, .29)
Effort beliefs	.13	(−.01, .28)	.21	−.20*	(−.29, −.10)	−.06	(−.20, .08)
Self-regulated learning							
Self monitoring	−.11	(−.36, .14)	−.15	−.08	(−.22, .06)	−.19	(−.41, .02)
Self reinforcing	−.14	(−.42, .14)	−.13	−.07	(−.29, .15)	−.21	(−.50, .08)
Self-efficacy scale							
Acad. planning	−.05	(−.25, .14)	−.05	−.24*	(−.38, −.09)	−.29*	(−.51, −.07)
Academic focus	−.20	(−.4, .00)	−.18	−.15	(−.33, .03)	−.35*	(−.54, −.16)

Note. Models adjusted for grade in school, gender, disability status (binary), free-and-reduced-price lunch eligibility, self-reported grades from the previous semester, self-reported susceptibility to peer influence, and sensation seeking scale.
SCSM = Self Control and Self-Management Scale.
[a] n = 395.
[b] $n = 193$.
[c] $n = 202$.
[*] $p < .05$ after adjustment for multiple comparisons.

Intervention effects

Students in the neuroscience health classes showed a significant increase in core neuroscience knowledge as compared to students in the comparison group (difference estimate in proportion correct metric, adjusted for covariates = .04; 95% CI [.01, .06]). However, none of the other primary outcomes including Effort Beliefs and Brain Abilities, Self-regulated Learning, or Self-efficacy for Academic Planning or Academic Focus showed a significant difference between the groups (see Table 5).

Within condition effects

In addition to examining the impact of the neuroscience curriculum as compared to the standard curriculum, we also examined the pre/post changes within each group. We found significant differences from the beginning to the end of the semester within each condition for Effort Beliefs, Academic Planning, and Academic Focus. More specifically, the comparison group showed a significant decrease on Effort Beliefs from the beginning to the end of the semester (adjusted change estimate = −.20, 95% CI [−.29, −.10]) while students in the neuroscience group did not change (adjusted change estimate = −.06, 95% CI [−.20, .08]). On the Academic Planning scale, students in the comparison group reported a significant decrease in their ability to plan (adjusted change estimate = −.24, 95% CI [−.38, −.09]), as did students in the neuroscience group (adjusted change estimate = −.29, 95% CI [−.51, −.07]). On the Academic Focus subscale, students in the neuroscience group showed a significant decrease in their ability to focus from the beginning to the end of the semester (adjusted change estimate = −.35, 95% CI [−.54, −.16]) while students in the comparison group did not change significantly on this subscale (adjusted change estimate = −.15, 95% CI [−.33, .03]) by their report.

Secondary outcomes

There were no differences between the neuroscience group and the comparison group on any of the Health Belief or Health Behavior measures after controlling the False Discovery Rate to .05 using the Benjamini–Hochberg procedure (see Table 6). We also examined secondary outcomes within each group. We found an unexpected, significant difference from the beginning to the end of the semester for the neuroscience health group with a decrease in their belief that the use of marijuana was harmful (adjusted change estimate = −.51, 95% CI [−.78, −.24]). Students in the comparison group showed a significant increase in the number of days per week that they were physically active from the beginning to the end of the semester (adjusted change estimate = .22, 95% CI [.12, .32]) and in their belief in the importance of healthy eating (adjusted change estimate = .28, 95% CI [.09, .47]). Students in both the neuroscience and comparison groups showed a slight increase in the number of days they were stressed during the previous week from the beginning to the end of the semester (adjusted change estimate = .49, 95% CI [.19, .78] and adjusted change estimate = .48, 95% CI [.17, .79]).

Discussion

The goals of this pilot study were to examine the feasibility and promise of an innovative neuroscience-based health education course on a range of student outcomes. The curriculum was grounded in current developmental neuroscience and the health education literature, with an emphasis on the social-cognitive skills that promote healthy decision making such as growth mindset and self-regulation for behavior change. Evaluation of this new curriculum utilized a sample based primarily on convenience with a relatively low-risk albeit racially and ethnically diverse student sample.

The classroom observation data showed that teachers successfully implemented the neuroscience components, but reported this information as challenging for them. Teachers were less successful at integrating the self-regulation and growth mindset frameworks and reported a challenge in linking the neuroscience and health concepts. The low levels of implementation of these components may help explain the lack of significant student outcomes between the two groups.

Overall, students in the neuroscience group gained an appreciation of the links between health behaviors and the brain as evidenced by their responses about the most important thing they learned in health class and their improvement on the core

Table 6
Secondary outcomes

Variable/subscale	Effect of intervention[a]			Effect of individual curriculum			
	Effect estimate	95% CI	*g*	Standard curr.[b] Change estimate	95% CI	Neuroscience curr.[c] Change estimate	95% CI
Health beliefs							
Positive impacts:							
Physical activity	−0.15	(−0.38, 0.08)	−0.18	0.22*	(0.12, 0.32)	0.07	(−0.15, 0.29)
Healthy eating	−0.31*	(−0.55, −0.08)	−0.35	0.28*	(0.09, 0.47)	−0.03	(−0.24, 0.18)
Sufficient sleep	−0.33	(−0.68, 0.01)	−0.33	0.14	(−0.11, 0.39)	−0.19	(−0.44, 0.06)
Negative impacts:							
Stress	−0.43	(−0.76, −0.11)	−0.43	0.13	(−0.10, 0.35)	−0.31	(−0.57, −0.04)
Alcohol	−0.24	(−0.59, 0.12)	−0.23	0.01	(−0.23, 0.24)	−0.23	(−0.48, 0.02)
Marijuana	−0.45	(−0.80, −0.10)	−0.44	−0.07	(−0.27, 0.14)	−0.51*	(−0.78, −0.24)
Other drugs	−0.20	(−0.70, 0.30)	−0.19	−0.13	(−0.47, 0.22)	−0.33	(−0.74, 0.08)
Brain impact	−0.24	(−0.50, 0.03)	−0.33	0.11	(−0.06, 0.27)	−0.13	(−0.34, 0.08)
Health behaviors							
Personal health behaviors:							
Physical activity	−0.21	(−0.52, 0.10)	−0.17	0.29*	(0.07, 0.51)	0.08	(−0.13, 0.29)
Eating breakfast	−0.22	(−0.53, 0.09)	−0.18	0.18	(−0.06, 0.41)	−0.04	(−0.24, 0.16)
Hours of sleep	0.13	(−0.18, 0.44)	0.11	−0.22	(−0.42, −0.01)	−0.09	(−0.32, 0.15)
Stress frequency	0.01	(−0.42, 0.44)	0.00	0.48*	(0.17, 0.79)	0.49*	(0.19, 0.78)
Opinions about peers' Risky health behaviors							
Alcohol	−0.08	(−0.38, 0.22)	−0.10	−0.11	(−0.32, 0.11)	−0.19	(−0.40, 0.02)
Marijuana	−0.19	(−0.51, 0.13)	−0.23	0.01	(−0.12, 0.13)	−0.18	(−0.48, 0.11)
Other drugs	−0.07	(−0.27, 0.14)	−0.14	−0.01	(−0.12, 0.11)	−0.07	(−0.24, 0.09)

[a] n = 395.
[b] n = 193.
[c] n = 202.
* $p < .05$ after adjustment for multiple comparisons. Note. Models adjusted for grade in school, gender, disability status (binary), free-and-reduced-price lunch eligibility, self-reported grades from the previous semester, self-reported susceptibility to peer influence, and sensation seeking scale.

neuroscience knowledge questionnaire. This is an encouraging first step because it serves as proof of concept for a neuroscience-based health education course. Many students articulated the importance of sleep, healthy eating, and exercise in promoting optional brain functioning by the end of the course. As noted by Bandura [6], this informational component is the first step in an effective prevention program for developing healthy habits and preventing risky health behaviors.

However, we did not find significant differences between the neuroscience and comparison groups on growth mindset beliefs, self-management skills, or sense of self-efficacy as hypothesized by a social cognitive framework [6]. Instead, we found that students reported significant decreases in their effort beliefs (comparison group) as well as their academic planning (both groups) and academic focus (neuroscience group). In addition, students in both conditions reported increases in the number of days they were stressed by the end of the semester. One possible explanation is the developmental context of the transition to high school during which students' perceptions of their abilities shift based on the increased environmental demands of a high school setting. This certainly highlights the developmental relevance of interventions such as this for the transition to high school.

We also did not find significant effects of the intervention for the students' health beliefs or health behaviors. In fact, students in the comparison group reported improvements in their level of physical activity and understanding of the importance of health eating while students in the neuroscience group did not. It is possible that the standard health education course prioritized these health behaviors, similar to a study by Yoo and Lounsbery's study [21].

Additional curricular development work integrating theoretical mechanisms of health behavior change and the initiation of both positive and negative health behaviors is also warranted. Sheeran et al. suggest that existing health behavior change theories can be grouped into four categories, each of which may serve as the target of intervention: beliefs about health threats, beliefs about health behaviors, motivations that translate knowledge and beliefs into action, and automatic responses to stimuli [22]. For example, integrating a dual-process model that considers adolescents' emotional reactivity in addition to their analytic decision-making processes may strengthen the curricular approach [23].

Results of this study must be considered in the context of several limitations, including the small number of schools, lack of random assignment to condition, reliance on student self-report, and lack of follow up.

Acknowledgment

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A120659 to Duke University. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education. Special thanks to the teachers, students, administrators, curriculum developers and research assistants who contributed to this study.

References

[1] De bruin EJ, Van run C, Staaks J, Meijer AM. Effects of sleep manipulation on cognitive functioning of adolescents: A systematic review. Sleep Med Rev 2017;32:45–57.
[2] Ludyga S, Gerber M, Brand S, et al. Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: A meta-analysis. Psychophysiology 2016;53:1611–26.
[3] Cohen JF, Gorski MT, Gruber SA, et al. The effect of healthy dietary consumption on executive cognitive functioning in children and adolescents: a systematic review. Br J Nutr 2016;116:989–1000.

[4] Lupien SJ, Ouellet-Morin I, Herba CM, et al. From vulnerability to neurotoxcity: A developmental approach to the effects of stress on the brain and behaviors. In: Spengler D, Binder E, editors. Epigenetics & neuro-endocrinology; 2016. p. 3–32.
[5] Harris SK, Doyle S, Sherritt L, Van Hook S, Knight J. "This is your brain on drugs":Adolescent substance use prevention through neuroscience edu-cation. Addict Sci Clin Pract 2013;8(Suppl 1):A32. http://dx.doi.org/10.1186/1940-0640-8-S1-A32.
[6] Bandura A. Adolescent development from an agentic perspective. In: Pajares F, Urdan T, editors. Self-efficacy beliefs of adolescents. Adolescents and Education; 2006. p. 5.
[7] Suleiman AB, Dahl RE. Leveraging neuroscience to inform adolescent health: The need for an innovative transdisciplinary developmental science of adolescence. J Adolesc Health 2017;60:240–8.
[8] Lipari RN, Williams MR, Copello EAP, Pemberton MR. Risk and protective factors and estimates of substance use initiation: Results from the 2015 National Survey on Drug Use and Health. NSDUH data review 2016; Retrieved from http://www.samhsa.gov/data/.
[9] Sanchez A, Norman GJ, Sallis JF, Calfas KJ, Cella J, Patrick K. Patterns and correlates of physical activity and nutrition behaviors in adolescents. Am J Prev Med 2007;32:124–30.
[10] Steinberg L. Risk taking in adolescence. Curr Dir Psychol Sci 2007;16:55–9 http://dx.doi.org/10.1111/j.1467-8721.2007.00475.x.
[11] Erickson KI, Creswell JD, Verstynen TD, Gianaros PJ. Health neuroscience: Defining a new field. Curr Dir Psychol Sci 2014;23:446–53.
[12] Bradshaw CP, Goldweber A, Fishbein D, Greenberg MT. Infusing developmental neuroscience into school-based preventive interventions: implications and future directions. J Adolesc Health 2012;51(2 Suppl):S41–7.
[13] Mezo PG. The self-control and self-management scale (SCMS): Development of an adaptive self-regulatory coping skills instrument. J Psychopath Behav Assess 2009;31:83–93.
[14] Kanfer F, Schefft B. Guiding the process of therapeutic change. Champaign, IL: Research Press, 1988.
[15] Bandura A. Multidimensional scales of perceived self-efficacy. Stanford, CA: Stanford University, 1990.
[16] Zimmerman B, Bandura A, Martinez-Pons M. Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. Amer Educ Res J 1992;29:663 http://dx.doi.org/10.2307/1163261.
[17] Dweck CS. Self-theories: Their role in motivation, personality, and development. Psychology Press, 2000.
[18] Blackwell LS, Trzesniewski KH, Dweck CS. Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. Child Dev 2007;78:246–63. https://doi.org/10.1111/j.1467-8624.2007.00995.x.
[19] Centers for Disease Control and Prevention. 2013. Youth risk behavior surveillance – United States https://stacks.cdc.gov/view/cdc/234832013.
[20] Peters GJ, Verboon, P, Green J. *userfriendlyscience* v0.7.0. Downloaded December 10, 2017, from https://cran.rproject.org/web/packages/userfriendlyscience/index.htmland
[21] Yoo S, Lounsbery M. Recent high school graduates' conceptualization of health and physical education [Abstract]. Res Quar Exer Sport 2011;82:A–57 http://dx.doi.org/10.1080/02701367.2011.10599740.
[22] Sheeran P, Klein WMP, Rothman AJ. Health behavior change: Moving from observation to intervention. Annu Rev Psychol 2017;68:573–600.
[23] Gerrard M, Gibbons FX, Houlihan AE, Stock ML, Pomery EA. A dual-process approach to health risk decision making: The prototype willingness model. Dev Rev 2008;28:29–61.