

ARTICLE

Students Apply Research Methods to Consumer Decisions About Cognitive Enhancing Drinks

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The goal of this class project was to provide students with a hands-on research experience that allowed autonomy, but eliminated duplication of effort and could be completed within one semester. Our resources were limited to a small supply budget and an introductory psychology subject pool. Six students from a behavioral neuroscience class tested claims made by a drink company that their product improves cognitive function. The students each chose a cognitive task for their part of the project. The tasks included the Donders Reaction Time Task, the Stroop Task, the Raven's Progressive Matrices, a short-term memory span test, the Rey-Osterrieth Complex Figure Test and a simple measure of prefrontal EEG activity. Participants were randomly assigned to an experimental or control drink. The experimental group received the putative cognitive enhancing drink and the control group

received a placebo drink that was very similar in color and taste. The two drinks shared no active ingredients. Results suggest that the putative cognitive enhancing drink did not improve performance on any of the tasks and decreased performance on the short-term memory task. These findings are discussed in regard to implications for consumers as well as further research into supplements and their ability to improve cognitive performance. Each student presented his/her results at a university-wide research conference. This project provided a rich experience in which students had the opportunity to carry out a research project from conception to presentation.

Key words: research methods; cognitive-enhancement, teaching neuroscience, consumer decisions, behavioral neuroscience

This paper describes a project conducted by a small group of students enrolled in Behavioral Neuroscience at MSU Denver. In this project, six student researchers from a behavioral neuroscience class chose to collectively test the hypothesis that a recommended serving of NeuroSonic® would enhance cognitive performance. The project allowed the students to hone their research methods skills by investigating a topic that fit within the subject matter of the course — pharmacological enhancement of brain function. The goal of the project was to provide training in neuroscience research methods and hypothesis testing that would develop critical thinking skills and creativity, while minimizing redundant work to optimize output with limited resources. The project focused on developing teamwork, at the same time holding each student personally responsible for his or her portion of the project.

Students were interested in testing the validity of a claim on the bottle of a drink with a brain logo on the label. There is no shortage of people trying to cash in on the human desire to be smarter, including companies who market dietary supplements in pill and liquid form. One such company makes a drink called NeuroSonic®, which according to their website “supports mental focus and performance.” (<http://www.drinkneuro.com/the-drinks/sonic>). The potential cognitive enhancing effects of the drink seem to hinge on the ratio of caffeine to L-theanine, an amino acid commonly found in tea leaves. L-theanine and caffeine have been shown to be effective at increasing cognition on certain cognitive tasks (Kelly et al., 2008; Owen et al, 2008; Giesbrecht et al., 2010). Self-reported alertness and task switching accuracy have also been

shown to improve after consumption of an L-theanine and caffeine blend (Haskell et al., 2008).

In our literature review, we were unable to find any research testing NeuroSonic® directly. This led to the development of a research opportunity for the behavioral neuroscience class: Students were given the option of testing NeuroSonic's® effects on cognitive tasks in lieu of writing a short essay. With the assistance of instructors, students devised a battery of cognitive tasks with each student selecting and designing his or her own task. The students collected the data, determined and performed appropriate statistical analyses for each particular task, and presented their results at a university-wide undergraduate research conference.

MATERIALS AND METHODS

Participants

Test participants were recruited from either an Introductory Psychology subject pool or from the MSU Denver population via a verbal recruiting script. The Introductory Psychology students received course credit for participating. The participants were 35 (27 men and eight women) students or staff, with the mean age of 24 (range 18-45).

Procedure

Participants entered a room and were asked to complete an informed consent form. Then, participants were given a plastic cup containing either the experimental or control drink and asked to drink its contents. During a 20-minute

delay, participants filled out a drink preference questionnaire and a distractor task. The distractor task took 20 minutes to allow the drink to take effect. The distractor task was a scene-change task in which participants were shown a series of photographs and asked if they had seen them before (Smith et al., 2006; Chau et al, 2011). After the delay, participants were tested on a battery of six tasks. Three of the tasks lent themselves to group testing whereas the other three required that participants be tested individually. Participants were tested on group tasks, individual tasks or both. The appropriate statistics depended on the individual tasks. For example, some tasks involved simple comparisons using t-tests; whereas other tasks included additional variables which then had to be analyzed with ANOVAs. The statistical choices for each task were discussed individually with each student.

Figure 1 illustrates the order in which the participants proceeded through the tasks.

A single umbrella Institutional Research Board (IRB) proposal was submitted in order to streamline the process. Each student researcher was listed as a co-investigator, with the course instructor serving as the principal investigator.

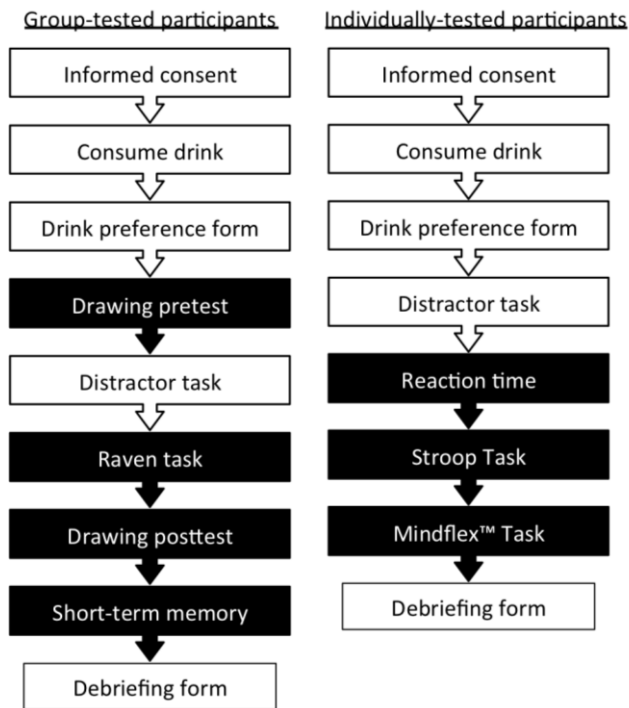


Figure 1. Participants were tested either in groups or individually depending on the specific task demands. All participants were randomly given a cup to drink from and asked to fill out a drink preference form. The group-tested individuals were given a drawing pretest (Rey-Osterich) prior to the distractor task. The distractor task was a scene change task used to take up 20 minutes of time between consuming the drinks and the onset of the actual cognitive tasks. The Raven task, Rey-Osterich Drawing task and Short-Term memory tasks were given in groups. The tasks given to the individually tested participants were the Reaction time, Stroop and MindFlex™ tasks. All participants were debriefed and thanked.

Tasks

Each student experimenter independently researched and developed his/her own task in order to determine how “cognition” could be operationally defined. With faculty guidance, a six-part cognitive assessment battery was devised to test participants’ cognitive abilities in a variety of different ways (Fig. 1). The tasks tested in groups were the cognitive reasoning task, the visuospatial task and the short-term memory task. The tasks in which participants were tested individually were the reaction-time task, the Stroop task and left prefrontal EEG (the Mindflex™ game).

Cognitive reasoning. Cognitive reasoning was assessed with a modified version of the Raven’s Progressive Matrices (Sternberg, 1977). The Raven’s Progressive Matrices consists of a series of progressively more difficult reasoning problems. Each problem is a matrix with a missing component (Sternberg, 1977). The task involves identifying an image belonging to a superordinate image or group of images (see examples in Fig. 2). The task used in this part of the study was similar to the original Raven task, but modified for group testing. Novel problems of varying difficulty were generated and presented using PowerPoint. Each slide presented a unique problem for which participants chose from four or five options and wrote their answers on a machine-readable data form (Scantron). The slides were timed to progress every 20 seconds. Participants were tested with one of two sets: A smaller set with 24 problems or a larger set with 40 problems.

Visuospatial Memory. Visuospatial memory was tested using the Rey-Osterrieth Complex Figure Test. This is a validated test that has been used to measure visual memory (Hamby et al., 1993). This task involves drawing three copies of a complex 2-dimensional geometric figure. Participants are first presented with the figure and asked to copy it onto a blank sheet of paper without being told that they would be asked to redraw it later. The drawings were removed upon completion and participants were immediately asked to draw the same image from memory. After a delay of 20 minutes they were asked to draw the figure a third time, again from memory. The final drawings were objectively graded on specific features outlined in Hamby et al. (1993). Identifiable features were used to assign a percent correct value.

Short-Term Memory. Short-term memory was tested using a memory-span task. Participants were shown a number of letters projected onto a screen with an LCD monitor and then asked to write the letters on a piece of paper. Stimulus sets were first presented with increasing difficulty and then decreasing difficulty for a total of 11 trials.

Reaction Time. Simple and choice reaction times (Gottsdanker and Shragg, 1985) were measured with stimuli presented on a university-owned laptop computer. Simple reaction time was measured by asking participants to respond to a stimulus “X” by pressing a key on the keyboard. In the choice reaction time task, participants responded to an “X” in a specified left or right box. Participants were asked to press a button corresponding to the stimulus. They were tested on six blocks of trials: Two

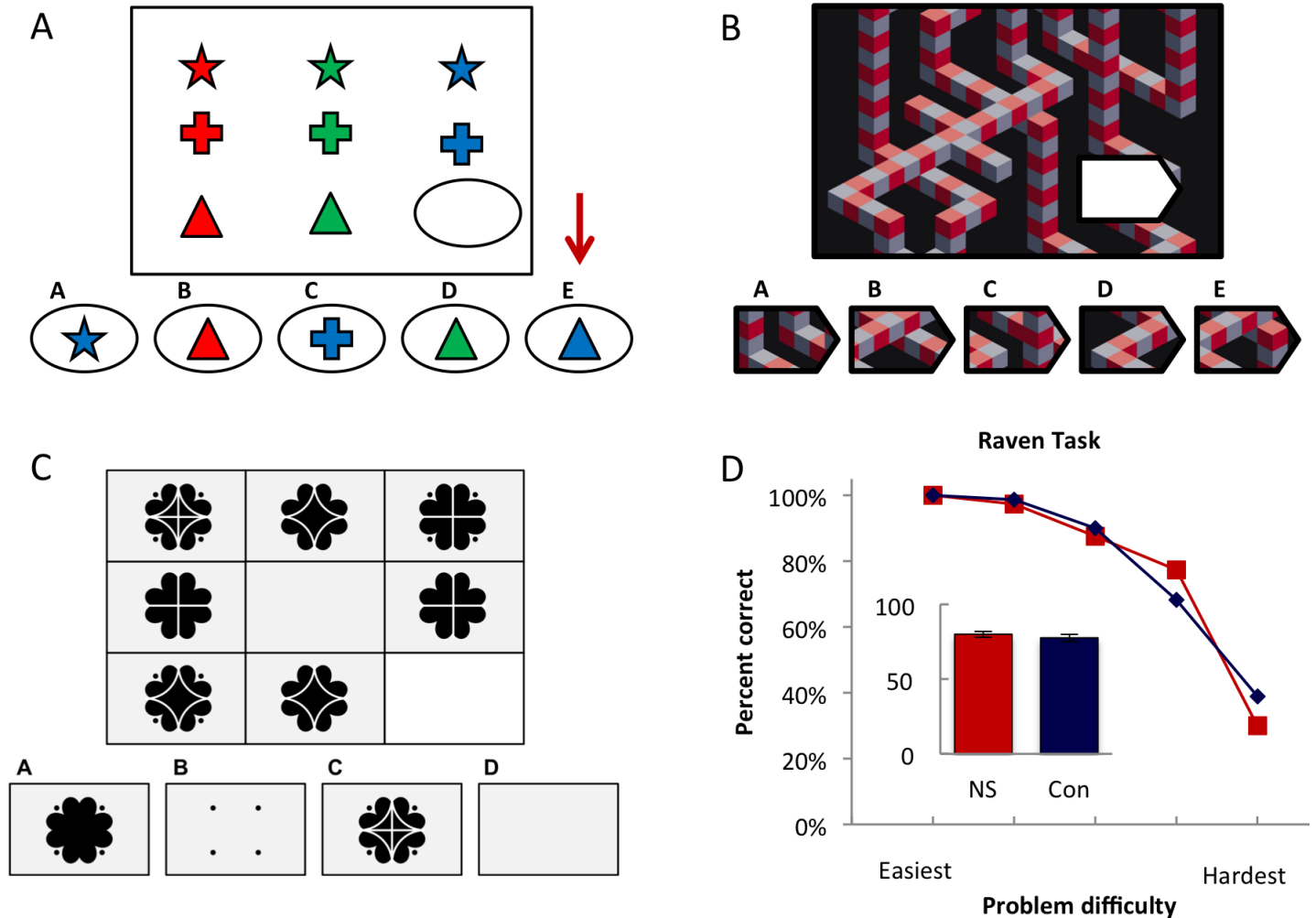


Figure 2. The modified Raven task is a series of non-verbal problems in which a missing element is identified by marking a letter on a machine-readable data sheet. Some of the problems were very simple (A); whereas others were moderately difficult (B) and some were quite difficult (C). (D) There was no difference between groups on the Raven Task (insert; mean±sem). Since the problems become progressively more difficult, it was possible to examine the relationship between difficulty and performance. (Answers to problems presented: E, D, & A).

blocks measured simple reaction time and the other four blocks measured choice reaction time. Participants sat in front of a computer and were read a set of instructions that explained the computer task.

Executive Function. Executive function was assessed with the Stroop task (Stroop, 1935; MacLeod, 1991). In this automated version of the Stroop task, participants were shown a colored word or block on a laptop computer. The participants indicated the color by pressing keys on the keyboard. The keys were labeled with colored tape. The participant then pressed the key corresponding to the color of the stimulus. This task involves participants naming the color of a word, regardless of the word written. For example if the word “red” was written in “blue” the participant would have to select “blue.” In the first block of trials, the displayed color and the written color were the same (Congruent). For example, the word “red” was written in a red font. In the next block of trials, colored bars were presented, so the participant only had to identify the color of the bar (Neutral). In the final block of trials, the

displayed font color and the written color were mismatched (Incongruent). Participants were administered the Stroop task using a computer program on a laptop computer using the same program (PsychLab) as used in the reaction-time task.

Prefrontal EEG activity. Putative prefrontal EEG was measured using Mindflex® by Mattel, a brain-computer game serving as an inexpensive neurological feedback system (Mindflex®). The rationale was that if NeuroSonic® improves focus, and the MindFlex measures focus, then the NeuroSonic® should result in better performance on MindFlex™. The goal of the MindFlex™ game is to move an elevated ball across the length of the console. The ball moves faster (times are shorter) if the headset detects brainwaves consistent with focused concentration.

The participants were first fitted with a headset. The MindFlex™ headset is an elastic band with an EEG electrode located over the left frontal lobe and an electrical ground clipped to the ear. Once they were comfortable, they were given instructions on how to play per MindFlex™

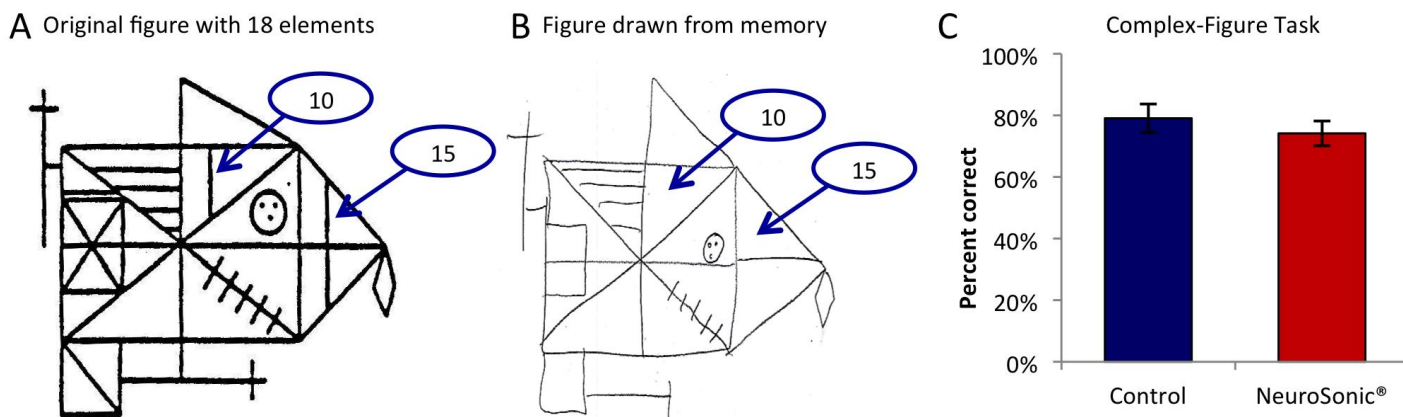


Figure 3. The Complex-Figure task (Rey-Osterrieth) involves copying a figure (A) then redrawing it later from memory. It is scored with a simple point system. Each component in the original drawing is assigned a number and memory was assessed as the number of correctly drawn elements over the total number of elements. (B) The redrawn figure is missing elements number 10 and 15. (C) There was no difference between the two groups for the percent correct on the complex figure task (mean \pm sem).

instructions. They were told to focus their concentration on the blue ball and that the better they focused, the faster the ball would move across the console. Each participant was given a practice run and three test trials.

Materials

Drink. Test participants were given either 13 ounces of NeuroSonic® (the approximate serving size listed on the bottle) or a “placebo” (control) drink. The student experimenters worked collaboratively to carefully devise the control drink to be similar in appearance and taste to NeuroSonic® without containing its proprietary blend. The control drink was a concoction of flavored water (Coconut-Pineapple Sparkling ICE®), strawberry-flavored powdered vitamin supplement (Emergen-C®) and seltzer water. Neither the participants nor the experimenters were able to identify the drinks by sight or taste. The drinks were kept in insulated beverage coolers at 38 degrees Fahrenheit. The drinks were given to the participants in red or blue plastic cups in a random fashion. The beverage cups were filled by the faculty supervisor to help eliminate possible experimenter bias which could result from the student researchers being aware of which beverage was served in which color of cup.

Questionnaire. All participants answered a number of open-ended questions regarding their own personal caffeine use and attitudes toward drinks advertised as cognitive enhancers.

RESULTS

Cognitive reasoning. Cognitive reasoning as assessed with the modified Raven task was measured by the percent of correct responses out of either 25 or 40 problems. The percent correct for the two groups was compared with an independent groups *t*-test. There was no difference between groups ($t(20) = 0.75$, $p = 0.231$, $X_{\text{NeuroSonic}} = 80\% \pm 2$, $X_{\text{Control}} = 78\% \pm 2$ s.e.m.). Since the problems were of varying difficulty, we then examined the performance of the two groups by problem difficulty. As can be seen from Figure 2, performance in the NeuroSonic® and Control

groups are virtually overlapping, indicating that there was no benefit from NeuroSonic® at any of the difficulty levels.

Visuospatial Memory. Visuospatial memory was tested using the Rey-Osterrieth task. The mean number of correct elements out of a possible 18 was compared between the two groups (Fig. 3). Again, there was no difference between the control drink group ($t(20) = -0.83$, $p = 0.42$, $X_{\text{NeuroSonic}} = 79\% \pm 5$, $X_{\text{Control}} = 74\% \pm 4$).

Short-Term Memory. The control group outperformed the NeuroSonic® group (Fig. 4) on the short-term memory task. This difference was significant ($t(20) = 2.82$, $p = 0.011$, $X_{\text{NeuroSonic}} = 5.1 \pm 0.21$, $X_{\text{Control}} = 6.1 \pm 0.28$) using a two-tailed independent groups *t*-test. In addition to the bar chart, we also plotted the performance for string length (Fig. 4C). All participants correctly remembered the string of letters when the string was less than five and none of the participants remembered more than nine letters.

Reaction Time. NeuroSonic® did not have an effect on reaction time as measured by the Donders Reaction time task (Fig. 5). These data were analyzed with a mixed design 2-way ANOVA (Drink X Trial Type). As expected, reaction times were slower for the trials when the participant had to make a decision compared to the simple reaction times ($F(2,22) = 16.9$, $p < 0.001$). There was no effect of drink nor was there an interaction between task and drink. Next we plotted the reaction times for each individual on a scatterplot. The lines of best fit for Control and NeuroSonic® are nearly overlapping demonstrating that there was no difference in latencies.

Executive Function. There was no effect on executive functioning as measured using the Stroop Task. The Stroop task involves naming the color of a font while ignoring the meaning of a word (Fig. 6A). Using a 2-way ANOVA, there was no interaction between drink and trial type ($F(2,14) = 2.9$, $p = 0.07$), nor was there an effect of either drink ($F(1,14) = 1.1$, $p = 0.31$) or trial type ($F(2,14) < 1$, $p > 0.05$) on performance as assessed by percent correct (Fig. 6B). Next, we examined the reaction times. As expected, a 2-way ANOVA yielded a main effect for condition difficulty ($F(2,14) = 12.2$, $p < 0.001$); however,

there was no interaction ($F(2,14) < 1$) or effect of drink ($F(1,14) < 1$) (Fig. 6C).

Prefrontal EEG activity. Putative prefrontal EEG was measured using Mindflex®, an inexpensive device sold for entertainment (Fig. 7A). In this task, there was a trend for

better performance in the NeuroSonic® group relative to control group, but this was not significant $X_{\text{NeuroSonic}} = 21.5 \pm 3.1$, $X_{\text{Control}} = 15.2 \pm 1.9$, ($t(11) = 1.8$, $p = 0.10$) (Fig. 7B).

DISCUSSION

Experimental Conclusions

Results did not yield significant effects which indicate any cognitive benefit of NeuroSonic® on any of the tasks. There was, however, a detriment on the short-term memory task. The primary psychoactive ingredient in NeuroSonic® is caffeine, and over half of participants reported daily caffeine use (Fig. 8). Although we asked participants to control caffeine consumption many reported drinking a caffeinated beverage in the prior 24 hour period. The effects of NeuroSonic® may have been affected by participants' tolerances for caffeine and/or their consumption of caffeine shortly before the experiment. By not controlling for caffeine consumption, the study had greater external validity but lower internal validity.

The findings of the study are not consistent with prior research on L-Theanine and caffeine, and the student researchers concluded that this could be due, in part, to dosing issues. Each bottle of NeuroSonic® contains 178 mg of "proprietary blend" (100 mg caffeine, 50 mg L-theanine, choline alphoscerate, phosphatidylserine & resveratrol; Reza Maloumi, personal communication, (<http://drinkneuro.com/>). A combination of caffeine (150 mg) and L-theanine (250 mg) improved self-report of alertness and decreased self-reports of fatigue in addition to enhancing performance on cognitive tasks (Haskell et al., 2008). In another study, 97mg of L-theanine and 40

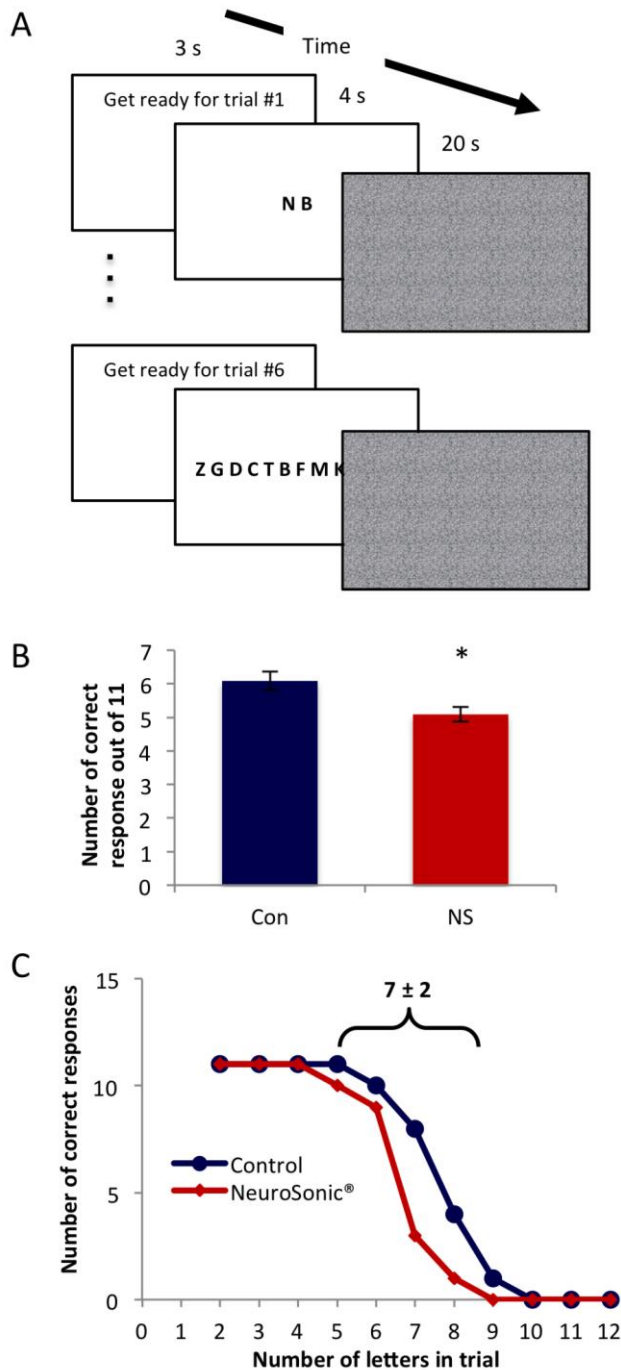


Figure 4. Short-term memory was measured by projecting strings of letters on a screen in the front of the room. (A) A series of three screen displays were presented per trial. One at three seconds to alert the user of trial initiation, one at four seconds containing the string of letters to be remembered and a blank one at 20 seconds to separate trials. (B) The control group showed significantly better short term memory as measured by this task ($*p = 0.011$; mean \pm sem). Performance for string length (C), was perfect for less than five letters, none of the participants remembered more than nine letters.

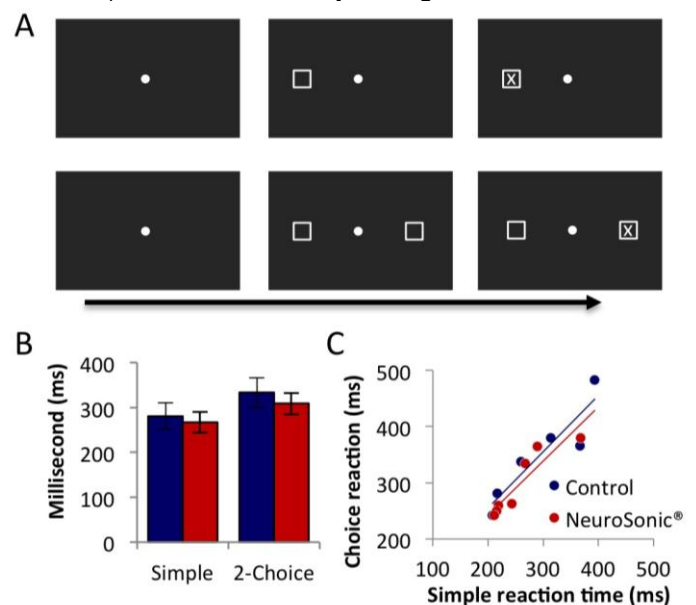


Figure 5. Reaction times were measured with either a simple (A top) or choice (A lower) reaction time task. (B) The response latencies in this task were longer for the choice relative to the simple reaction times, but did not differ between the control and NeuroSonic® conditions (mean \pm sem). (C) Since the reaction times were quite variable between individuals, we compared simple and choice reaction times for each individual. The lines of best fit were virtually overlapping for the two conditions.

mg of caffeine increased attention and self-report alertness (Giesbrecht et al., 2010). It is notable the amount of L-theanine in NeuroSonic® is lower than those reported to produce effects in earlier studies. If the L-theanine content of NeuroSonic® is simply too low to be effective, then it is possible that a larger serving size of the drink would have produced an effect on one or more cognitive tasks. Moreover, it is important to note that the caffeine to L-theanine ratio in NeuroSonic® is opposite of the ratios

used in earlier studies. For instance, a combined treatment in which L-theanine content exceeded that of caffeine demonstrated faster simple reaction time (Haskell et al., 2008). Thus, the failure of NeuroSonic® to produce a detectable effect on performance could be due to the overall, as well as relative, content of the two principal components of the proprietary blend.

Based on the results of the study, the researchers cannot recommend NeuroSonic® as a cognitive enhancer for their fellow college students. They do, however, recommend doing future studies with larger or more optimized servings of NeuroSonic® to investigate the possibility that increasing the “dose” of the drink would be helpful. Further, it may facilitate cognition to “spike” NeuroSonic® with additional L-theanine to bring the dose of the beverage up to the appropriate level used in earlier studies.

Pedagogical Conclusions

Many undergraduate psychology programs have limited opportunities for students to apply knowledge of research

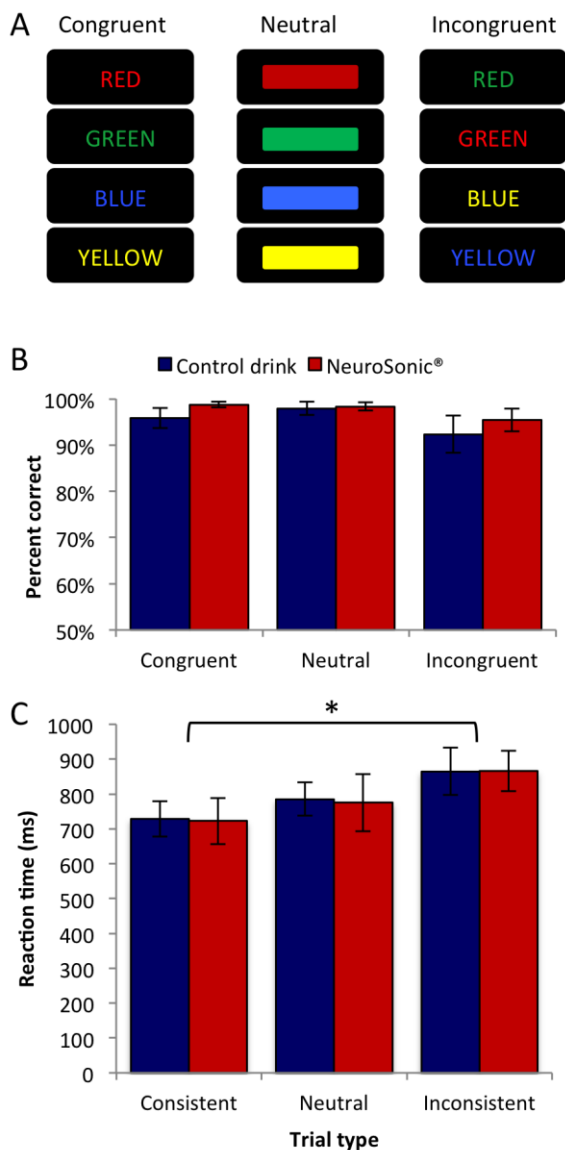


Figure 6. In the Stroop task, stimuli were presented on a computer monitor. Participants pressed a key indicating the color of the stimulus. **A)** There were three trial types: Congruent, Neutral, and Incongruent. In the Congruent trials, the font matched the word presented. In the Neutral trials, only a colored bar was presented, no word. In the Incongruent trials, there was a mismatch between the word presented and the font color. **B)** There was no difference in percent correct between either the groups or conditions. **C)** Reaction times were longer for Incongruent trials relative to Congruent trials ($*p < 0.001$), but there was no difference between the two drink conditions (mean±sem).

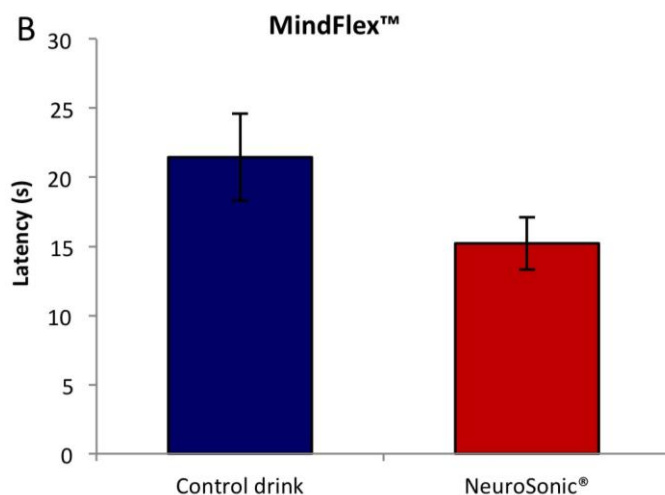


Figure 7. The MindFlex™ **(A)** is a device that records brain waves and sends a signal to a console. Waves matching a specific frequency cause a ball, elevated with a fan, to move across the console. Brainwaves consistent with focused concentration move the ball more quickly, resulting in faster times. **(B)** There was a trend for better performance in the NeuroSonic® group relative to control (mean±sem).

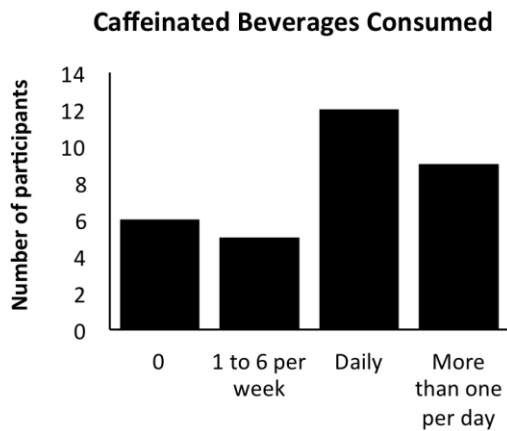


Figure 8. All participants were given a drink preference questionnaire. Over half of the participants (66%) reported drinking caffeine daily.

methods and statistics to course-related topics. At some institutions, psychology students may conduct a study in a research methods course and never complete another project unless they pursue an independent study. Other courses may discuss research only in the abstract, rather than directly involving students in a full-scale research project. At large research institutions undergraduates may serve as lab assistants and may only see a very small part — typically data collection — of a larger project. Although these are worthwhile experiences, the students do not have the opportunity to develop an idea and see a project through to completion. At some universities, this sort of research can be integrated into coursework with a bit of ingenuity. For instance, one instructor created an entire “practical research methods course” in which students completed five separate studies (Ball and Pelco, 2006). Unfortunately these opportunities are scarce and may require more resources than those typically available.

This project provided a unique experience for undergraduate neuroscience students to carry out a research project from conception to completion. Each student designed and completed his or her own experimental task to answer one common question. The undergraduates developed the control drink as a team, synthesized their literature reviews, and actively participated in writing portions of the IRB proposal. They collected and analyzed their data individually. Finally, they delivered their findings in poster presentations at a campus-wide undergraduate research conference. Two of the students from this project were recognized as finalists for the “Best Psychology Poster” and one student was selected as the eventual winner. Best of all, two student researchers presented the findings from the entire project at the annual Society for Neuroscience conference (Erickson et al., 2013).

Having each individual student researcher devise a specific task to answer the same research question allowed for a more valid test of the seemingly vague construct of “cognitive function.” Researchers were also

able to utilize an independent groups design that maximized the amount of data collected from each participant. One advantage of this approach over strictly individual projects is that the students collaborated to write the IRB proposal; each student wrote the description of his or her own task for the proposal, and submitting a single proposal to the IRB allowed for quicker, more efficient review.

This group project can easily be manipulated to test other types of cognitive enhancers such as glucose. They may examine the effects of arousal by having participants walk a tightrope or attempt a climbing wall prior to testing. Students may want to assess the effects of distractors such as music, movies (how many students study while watching videos?) or playing an electronic game. It is easy to include other measures of cognitive function such as the “Trails-B” or motor skill learning such as the mirror-tracing task.

Overall, this approach to conducting a class project seemed more effective than traditional group projects in ensuring equal contribution from each student toward the final project. The students learned about all aspects of the research process, including experimental design, external and internal validity, the importance of sample size, statistical analyses, and conference presentation protocol. During the design process, the students discussed the relative benefits of between and within subjects experimental designs. Most importantly, the students learned that that research is fun. The students participating in this project certainly worked much harder than their classmates who opted to write an essay; however, all of them were very glad they had participated in the project. The students truly were able to see the project through to completion, including contributing to the present paper. Although the authors cannot recommend NeuroSonic® as a means of improving cognitive function, we do recommend adopting this class project model as a way of involving undergraduates in neuroscience research.

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The program, “PsychLab,” used to display and collect reaction time data was downloaded for free from Richard Abrams, Washington University, St Louis, MO, <http://www.artsci.wustl.edu/~rabrams/psychlab/index.htm>.

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