Auditory Stimuli Preferences and Their Impact on Reading Comprehension in the Classroom

by

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There are many theories as to what physical qualities of a classroom improve learning and comprehension, ranging from air quality and type of light to feelings of belonging and seating arrangement present in the room. Here, I adopt an evolutionary perspective on physical learning environments, specifically drawing on stimulus preference research (Ulrich, 1983, 1986), context dependent memory studies (Godden & Baddeley, 1975; Smith & Vela, 2001) the savannah hypothesis (Barkow et al., 1995), and the biophilia hypothesis (R. Kellert & O. Wilson, 1995). A part of evolutionary landscape preference theory and stimulus preference research (Ulrich, 1983, 1986), which proposes that human beings function better when in close proximity to natural resources, such as sunlight, fresh air, water, food, and shelter. Learning, in human beings' ancestral pasts, has always been conducted outside as a highly experiential, adaptive, and social endeavor. Only in recent human history has learning moved indoors and become less collaborative and hands-on, and more restrictive in how people learn. In today's physical classroom environment, features like air quality and lighting have already shown a positive benefit on learning (Amirul, 1993). In this work, I further this concept and test the savannah hypothesis and the influence of auditory stimuli in the classroom: how does natural versus unnatural sound stimulus impact learning? 245 psychology students at the University of Pittsburgh took three reading comprehension tests in classrooms while listening to background sound stimuli of natural, city, and classroom soundscapes, as well as answered questions about their stress levels, study habits,

sound stimuli preferences and demographic information. The overall difference between the three soundscapes is not significant when submitted to an ANOVA test. There is no significant difference between the mean values of the three soundscapes. Additionally, there is no significant effect of stress, stimuli preferences, and demographic information on performance in different sound conditions. There is a significant effect of places students prefer to study and performance in different sound conditions that provides evidence for context-dependent learning on a more general scale rather than specific situations.

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1.0 Introduction: The classroom we all know (and probably don't love)

Everyone who has ever been a student is familiar with the classroom. Rows of desks or tables and chairs line the room, and all face an instructor at the front, who, on a chalkboard, whiteboard, or screen, teaches any variety of subjects. This classroom format is expected and has even become a comfort to some. The history of the classroom and education systems as we know them today are complex and are heavily impacted by colonialism, globalism, and the need to educate the masses. Classrooms are designed around ease of education rather than how we learn. Recently, researchers, scholars, teachers, curriculum writers, and others have interrogated the traditional classrooms, teaching methods, and education practices that we are all familiar with in search of practices that better cater to how human beings learn — and have learned since the early days of our species.

If we trace the paths of education through ancient civilizations, we find that education was commonly used for two purposes: to become literate and to learn about the region's dominant religion. Both of these topics were almost always stratified to the higher levels of society and wealthy individuals. In Mesopotamia, a select few (almost always the sons of royalty, or those with positions of economic power) were taught to be scribes of cuneiform, the first recorded written language (Karmel Thomason, 2005). The same is true for Ancient Egypt, where between 1% and 5% of the population was expected to be literate (Baines, 2007, p. 67, 94).

In ancient Israel, schools were mandated in order to teach the Torah; however, it was only available to men, and most never learned to write. Similarly, the Quran was taught in schools in nearly every major Muslim empire spanning from the 7th to 19th century (T.S. Al-Hassani, 2007). In ancient India, the Vedic principles were taught, and later, Hindu principles, as well as oral

traditions, medicinal knowledge, and so forth. In contrast to most schooling at the time, the education of women was held in high esteem (Gupta, 2007, p. 73-76). Legend claims China to have been home to the first ever schools in the 23rd and 24th centuries, and the first education system in the Xia dynasty (2076–1600 BC) (Mark, 2016).

Education remained relatively private and restricted to the highest rungs of society until well into the 19th century. In the Middle Ages, the rise of the Roman Catholic Church saw the arrival of more widespread schooling, specifically for religious education purposes (Riché, 1976). Charlemagne, King of the Franks from 768 to 814 AD, did actually attempt to create public education for young children during the Carolingian Renaissance, but was not entirely successful in implementing his education plan in every part of his empire (Duckett, 2012). Universities began popping up all over the world at this time as well — in the Islamic empire, Europe, China, and India especially.

In the Americas, the Inca ensured that every citizen of the empire learned the official language, Quechua. Education was seen as a right, and while not everyone attended, school was made accessible for nobles and the general population alike. However, the quality of education differed between nobles and the rest of the learning population. The Aztecs are the founders of the first known public schools as we recognize them today. Parents or guardians schooled their children on their own until the age of 14 and at the age of 15, all students — regardless of gender, wealth, or social status — were required to attend school (*Aztec Education*, 2014).

After the 15th century, the global nature of education began to transform schools into larger institutions along with the spread of colonialism, globalization, and the need for global trade to sustain empires. Private schools for the most part remained the dominant form of education and, in the majority of the world, they largely taught religious subjects. In certain areas of the world,

those who were too poor to afford private education would on occasion be provided with a teacher (Orme, 2006). During this period, all over the world, there was a small literacy spike— and a general forced assimilation into European standards of education in many places as a result of colonization (Nóvoa, 1995). In the 16th century in Germany, Martin Luther was an avid supporter of compulsory school in order to spread Lutheranism and build national identity, especially to those who were not already Lutheran or had not yet received religious education due to gender discrimination (Woessmann & O. Becker, 2008).

In the United States, schools were largely based on religious motives, and levels of literacy in the thirteen colonies relied heavily on the presence of religious communities and religious schools. Horace Mann was credited with inventing the standardized public school, or "common school," in Colonial New England in 1837, which included Unitarian and Bible teachings. Mann argued that schools were necessary to uplift the American people in order to make them competent voting citizens and to educate them for productivity in the workforce. In light of the national tensions building to what would eventually be the United States Civil War, Mann viewed school as a form of "social redemption". By shaping the most impressionable individuals in society, schooling had the potential to diminish class conflict, prevent anarchy, improve civic participation, and above all, instill ethical practices. Mann was inspired by Prussian classrooms. The common school was based on a factory analog, built to be efficient, easily replicable, and educate the masses — not to cater to the individual (Warder, 2014).

Up until this point, public schooling was scarce in Western contexts. After 1837, literacy boomed once again, and countries all over the world followed suit, making public education available or even required for all children. Class sizes grew and school buildings grew along with them, becoming massive facilities to house children for 7 or 8 hours a day as a form of childcare

in response to the growing workforce. When capitalism rose in the United States after World War II, school systems' new goals were to be as efficient as possible in childcare, as well as preparing those children for the workforce. In the modern day, the most common goal of schools is to prepare children for college, which in turn leads to more opportunities within the global job market (Goldin, 1999).

The school as we know it today educates for this purpose. Time in school is structured more than it needs to be (Tucker, 2012) and learning has deviated from hands-on experience and life skill building to working towards standardized testing score goals (Posner, 2004). Time spent in school is much higher than ever before (OECD, 2022), and in order for students to learn as best they can, the environment that their time is spent in should be a safe, healthy space conducive to enjoyment and pleasure while learning (Lucardie, 2014).

1.1 Today's Classrooms

In recent years, scholars have called into question whether or not the traditional classroom set up is the best environment to allow productivity, creativity, and learning in the classroom. Young children have shorter attention spans than adult students, and therefore require more interactive and hands-on curriculums for learning (Mahone & Schneider, 2012). Researchers are now investigating new methods to teach students and new classroom designs and environments to promote social and emotional wellbeing, as well as improved learning practices (Barrett et al., 2015; Hannah, 2013; McLeod et al., 2017).

Student-focused learning rather than teacher-focused classrooms have been included in discussions on how to cater to learners with diverse backgrounds and learning styles (Brown, 2003;

Schreurs & Dumbraveanu, 2014). Methods such as incorporating play have also launched to the forefront of the discussion in early-childhood learning reform (Golinkoff, 2020). Classrooms for young children often have bright colors, tables with chairs facing each other for social collaboration, bright lighting, and engaging toys and textures (carpeted floors, etc). Classes are engaging, interactive, and collaborative, often allowing students to work with one another, letting students gain hands-on experience with the topic, and incorporating play and fun into the school day.

As students age, these bright colors, collaborative spaces, and experiential learning practices fade to textbooks, desks in rows, and dense, packed lectures in buildings and rooms. The same questions of what classroom designs support learning have not been asked about those of adolescent and adult students.

A dip in interest in learning in high school (Ford, 2014) is common. As interest in high school is one of the driving factors in students applying for and attending college, remedies to this problem are of the utmost importance to schools, curriculums, teachers, and parents (Bryan et al., 2011). A quick Google search offers possible causes: procrastination, vices (videogames were a common gripe of worried parents), wanting to spend time with or make new friends, lack of support from peers or teachers, or even passive learning styles (Spielgaben, 2013). Solutions to all of these causes usually focus on things the parent or child can do to fix the problem. However, it may be prudent to consider things that schools and education systems can do to solve these problems at their root, such as teaching healthy study and homework habits, supporting the child at home and at school, or making textbooks and lessons more engaging. Causes are generally reflected back on the child rather than acknowledging larger systemic problems at play — that the

education system as we currently know it is does not engage students in the way that would open paths for students towards higher education or following their passions.

Americans spend about 15% of their lives in school, assuming that they complete kindergarten through 12th grade (OECD, 2022). If they attend college, that percentage rises. By comparison, in the EEA, and even just 200 years ago, learners spent much less time in an institutional setting built for learning and more time learning during everyday activities. Learning in the EEA was very hands-on, material taught was incredibly different from what we teach children today, and time spent learning in a structured institutional environment was much less before school was required in many parts of the world. To spend so much time in an institution learning means that that facility must be conducive to a healthy, fun, supportive, motivating learning environment that students can feel comfortable and happy in.

College lecture halls are often the epitome of a teacher-focused classroom format: a lecturer stands at the front, and rows of chairs fill the rest of the room. Dull colors, a lack of windows, and a focus on the screen in the front and center of the classroom remain consistent as the recent trends in American college classrooms and lecture halls — they are the exact opposite of a stimulating environment for learning. In a world where having a college degree is becoming increasingly necessary and expected in order to have a job and support oneself (Seidman, 2012), learning practices need to improve in adult settings, like colleges and universities, just as much as they need to improve for younger children.

The layout and design of the classroom can affect students' enjoyment, health, and learning. A classroom that is well-organized, well-lit, and has comfortable seating can promote a positive learning environment (Barrett et al., 2015). Amirul (1993) found that, in primary school classrooms in Malaysia, lighting, temperature, noise, air quality, furniture and facilities have

significant impacts on students' academic achievement, with the first three factors being the most important physical attributes that affect students' learning outcomes. The study found that classrooms with natural light and adequate lighting levels promote better learning outcomes. Similarly, classrooms that are well-ventilated and have an appropriate temperature range (around 73°F) benefit learning. The study also found that excessive noise levels (above 60 decibels) negatively affect students' academic performance.

1.2 Learning in the EEA

When the term environment of evolutionary adaptedness (EEA) was first coined by British psychologist John Bowlby (Holler et al., 2018) it was meant as the conditions present in the environment when a species' adaptations were naturally selected for. The meaning of the EEA is frequently misconstrued as a time or a place that we can put our fingers on: maybe 20,000 years ago in Africa comes to mind.

However, the EEA specifically focuses on "environment" as a more abstract concept, specifically focusing on pressures that forced human beings to adapt, whether those pressures were social, linguistic, reproductive, etc. The EEA is best viewed as a "statistical composite" of these pressures (Kurzban, 2012). Therefore, it is impossible to pin down a time or place in which all adaptations for human beings occurred, as it is most likely they all occurred at different times and as a result of different environmental pressures. For example, the human use of language occurred much later than when human ancestors began to walk on two feet (Badcock, 2000).

Our modern day classroom and methods of learning — where a teacher lectures from the front of a room to a group of students sitting in rows — could not be farther from how human

beings learned in the EEA. In the EEA, learning took place in much smaller groups that were highly social, collaborative, and experiential. It brings forth the question: can we improve learning outcomes if we make classroom-style learning more similar to humans' environment of evolutionary adaptedness?

Human beings and our ancestors lived in small, nomadic groups for an estimated 2 million years before beginning to live in larger societies about 10,000 years ago (Singh & Glowacki, 2022). That 10,000 years is a miniscule amount of time compared to the amount of time that human beings and our ancestors have existed, and an even smaller portion of that time is when human beings moved learning from outside, into Horace Mann's classroom. While we may be used to sitting in classrooms and taking standardized tests now, is that really the best way for us to accumulate information and learn skills needed for the workforce and the rest of our lives?

1.3 Stress, Green Space, and Connections to Nature

College and stress are often seen as synonymous — students usually perceive higher levels of stress during their college years (Conley et al., 2013). Stress and emotional wellbeing are linked, especially in a college environment (Clabaugh et al., 2021), and stress has a significant effect on academic performance (Sohail, 2013).

A source of stress could be the surrounding environment. Green space on campus has recently become a more focal issue in college campus design, and correlations between available green space, a reduction of stress and other mental health issues (Grahn & Stigsdotter, 2003), and increased academic success have been found (Browning & Rigolon, 2019; Liu et al., 2022).

Perceived emotional connection to nature also has a significant impact on psychological well-being (Huynh & Torquati, 2019).

One of the hypotheses that can explain these effects is the biophilia hypothesis, which provides the argument that humans have an "innate affinity" for the natural world, and that our fixations on "life and lifelike processes might be a biologically based need, integral to our development as individuals and as a species" (R. Kellert & O. Wilson, 1995). The biophilia hypothesis has been supported by a growing body of research showing that exposure to natural environments can have positive effects on our wellbeing. Studies have found that spending time in nature can reduce stress, improve mood, enhance cognitive function, and lower blood pressure (Kondo et al., 2018). These effects have been observed in a range of settings, from parks and gardens to forests and oceans.

The biophilia hypothesis has important implications for architecture and urban planning. Architects and designers can create spaces that promote human health and wellbeing by incorporating elements of nature into the built environment. For example, buildings that feature green roofs and living walls can help to reduce air pollution and provide a calming natural backdrop for people working or living in urban environments (Williams et al., 2019).

Later studies and reviews of the extant literature show that there is evidence for a psychological need for a relation with nature as the world becomes more urbanized. Air quality, green spaces, and access to public transportation are all important predictors of well-being, highlighting the need for policies and interventions that address these environmental determinants of health and mental health, especially in urban areas (Baxter & Pelletier, 2019).

1.4 Visual stimuli preferences

One of the fundamental theories in evolutionary psychology concerns visual preferences, specifically landscape preference theory. One of the most prominent researchers in landscape preference theory and the impact of natural visual preferences is Roger S. Ulrich, a healthcare design researcher in the field of environmental psychology. Evidence shows that people have preferences toward natural landscapes over urban ones, and preferences of urban landscapes increase when higher amounts of vegetation and trees are present (Ulrich, 1986). Both explicit and implicit preferences have been found, in that participants actively state a preference towards one landscape or another, as well as physiological and emotional preferences.

There is also evidence that human beings have visual preferences for certain kinds of landscapes that align with landscapes similar to those we would have had to adapt to in the EEA — in humanity's case, the African savanna. The Savannah Hypothesis is a hypothesis proposed by G.H. Orians that suggests that humans have an innate preference for savannah-like environments. According to this theory, early humans evolved in open grasslands, where they had to adapt to life on the savannah and develop specific behavioral and cognitive strategies to survive in this environment.

The Savannah Hypothesis has important implications for our understanding of human behavior and the built environment. It suggests that an innate preference for savannah-like landscapes explain why we are drawn to certain types of architecture and urban design. For example, urban parks and green spaces, with their open grassy areas and tree-lined paths, may appeal to our innate preference for savannah-like environments.

When different age groups were tested for landscape preferences, elementary school children more often gravitated towards savannah scenes, whereas from mid-adolescence and into

adulthood, people showed an equal preference towards more familiar natural environments as well as the savanna. Results were interpreted as providing limited support for the hypothesis that humans have an innate preference for savanna-like settings that arises from their long evolutionary history on the savannas of East Africa (Balling & Falk, 1982).

Exposure to natural environments and harmonious designs has been found to improve cognitive performance, enhance creativity, and reduce stress levels (Ulrich et al., 1991). This has implications for classroom design, where the use of natural materials, plants, and artwork can create a more pleasant and productive environment for students. Viewing natural visual stimuli can also benefit and restore attention and improve performance on attentional measures (Tennessen & Cimprich, 1995).

Exposure to natural stimuli can even have long lasting biological effects (Ulrich, 1984). Hospital patients with rooms overlooking natural scenes, such as trees and water, had shorter hospital stays, required fewer pain medications, and experienced fewer postoperative complications than those with rooms facing brick walls. These findings have led to the incorporation of natural views in hospital design as a means of improving patient outcomes.

Human beings have visual stimuli preferences for certain parts of landscapes (Ulrich, 1983). In various studies, five significant variables were identified as significant factors in visual preferences:

- *Focality*: the degree to which a scene contains a focal point or area that attracts the viewer's attention
- *Ground surface textur*e: the perceived homogeneity or heterogeneity of the landscape
- *Depth*: the ability to see across distances

- *Mystery*: the degree to which one can gain more information by proceeding further into the scene
- *Complexity*: the degree to which a landscape is perceived to be rich and intricate

Ulrich stressed the importance of informational determinants and the need to create a more complete model including color, water, clouds, sunsets, and other landscape elements.

While Ulrich argued visual preference was most impacted by mystery, a majority of studies maintain complexity as the significant mediator of visual preference (Ulrich, 1977). These studies identified an optimal range of visual complexity, with the stimuli that were perceived to be of medium complexity being the most favored.

1.5 Auditory Stimuli and Context Dependent Memory

Ulrich's research primarily focuses on visual stimuli preferences, however, similar effects of medium complexity preferences in auditory stimuli were found in infants. This information was used in a study which found a "Goldilocks effect" in stimuli preference in infants (Kidd et al., 2014), meaning too much or too little complexity in stimuli isn't preferred; rather, a medium amount of complexity is optimal for processing.

Auditory stimuli effects have not been studied through an evolutionary lens to the extent that visual stimuli have. Early hominids relied heavily on their auditory system to detect and respond to potential dangers, such as predators and hostile groups. As such, the ability to accurately process auditory information and respond quickly to relevant sounds conferred a distinct survival advantage (Heffner & Heffner, 1992). Later on, our auditory processing adapted to process

language. The effects of music are still being studied as a key role in the development of human creativity and cultural expression (Fitch, 2006; Patel, 2010).

Natural sound stimuli have been found to have the same sort of physiological and emotional effects as natural visual stimuli (Buxton et al., 2021), however, studies have not yet determined the extent to which natural sounds may improve cognitive function, attention, and learning. Sounds do have a significant effect on memory, however and music has even been used as an implicit advertising strategy (Alexomanolaki et al., 2007). Music was also found to increase autobiographical memory retention in patients with Alzheimer's disease (Irish et al., 2006). There is a gap in the literature on whether natural auditory stimulus impacts memory or learning.

However, there is more general evidence that memory is context dependent. Memory studies show that information learned in a specific context is recalled better in that same context. One of the most famous examples of this phenomenon is a study in which memory tests were given to scuba divers underwater, as well as on land. Participants who memorized material underwater tested better underwater, while participants who learned material on land tested better on land (Godden & Baddeley, 1975). A meta-analysis of the existing literature (Smith & Vela, 2001) upheld the context-dependent memory theory that environments in which people learn a skill or an idea are the environment they will best recall that skill or idea in. Context-dependent memory has also been theorized to have evolutionary origins, as it may have allowed early humans to remember skills and thoughts quickly in the presence of explicit cues such as environment. Whether this effect persists when just sound stimuli is present has not yet been examined.

Context-dependent memory has significant evidence pointing towards its benefits, and while it isn't necessarily an issue for children who are younger and spend more time in a classroom learning and less time outside of class studying, it is a point of concern for college students. College

students spend the majority of their time learning and studying outside of class, and only attend a class a few times a week for an extremely limited period of time.

1.6 Present Study

The present study investigates the relationship between auditory stimuli preferences and reading comprehension tasks. 245 university students at the University of Pittsburgh participated in a reading comprehension survey in class while listening to background audio that included three sound conditions: city sounds, nature sounds, and classroom sounds. I hypothesize that students will perform best overall on reading comprehension tests taken in natural sound conditions, and that students will perform well (but not best) on reading comprehension tests taken in the classroom sound condition. I hypothesize that the city sound condition will result in the worst performance on reading comprehension tests. Better scores in the natural sound condition could be due to reduction in stress and implicit evolutionary preferences, while better scores in the classroom sound condition could be due to context-dependent memory and general familiarity with the setting.

2.0 Method

2.1 Participants

Twenty-seven psychology courses, with total enrollment of over 600 students, at the University of Pittsburgh participated in this study. Prior consent was obtained from all participants before the experiment. The experiment was presented to the entire class, and many chose to opt out. After data cleaning, students who did not complete at least one of the reading comprehension tests were eliminated, leaving us with a final number of 245 participants. Numbers of 1st years (19), graduate (1) and nontraditional students (6) were low, while 2nd-years (54), 3rd-years (73), and 4th-year (91) students made up the majority of the participants. 11% of participants reported that they were not native English speakers. Of the 245 participants, 180 were from the suburbs, 37 were from a city, and 28 were from rural areas. Gender, age, race, and ethnicity descriptive statistics were not collected. However, because this was an undergraduate sample, most participants were likely between 18 to 23 years old.

2.2 Procedure

Students in classrooms listened to three different sound stimulus conditions, which were presented auditorily to the class a whole, while they completed a timed online Qualtrics survey (see Appendix A). I presented the survey in a classroom environment that students were familiar with (at the point in the semester in which students took the survey, students had already completed

between a month and a month and a half in the classroom), in order to make the study ecologically valid for a school and classroom setting.

A member of the research team went to each class in person to conduct the survey and to inform participants that they were free to opt out at any time. The survey took around 15 minutes on average. Professors generally allowed the survey in the first 15 minutes or the last 15 minutes of their classes, or in the 15 minutes after their class in which the classroom was vacant, to allow for students to easily opt out. The survey was timed in order to keep students in sync with the background audio, as well as to keep students moving quickly through the study. After the students consented to participate in the survey, each question auto advanced in time with the audio. Once the audio was finished, the students would also be finished with the reading comprehension tests, and they were free to complete the last questions providing additional information for potential moderators on their own time.

The three sound stimuli included city noises, nature noises, and classroom noises, taken and constructed from a variety of recorded sounds found online and sounds I recorded myself. In each class, a single audio file was used that included survey instructions read out loud, followed by each sound stimulus while participants read and answered questions on each text. All sound conditions were adjusted for volume and complexity to ensure they would all be of the same level of sound complexity and would hopefully serve as background sound stimulus in a classroom test-taking environment and that sudden sounds in a sound stimulus file could not be distractors or confounder variables in the study. Complexity of sounds was equated by having a small sample of 10 individuals involved in the process of choosing sounds and determining whether sounds were over or underbearing.

The natural sound condition was modeled after what would be unfamiliar forest sounds in a North American setting. The audio included bird, insect, and amphibian and reptile sounds from South America. The sounds of rain and wind were also included in the audio. The city condition was a New York City soundscape, combining ambulance sirens, honking, and various traffic noises. Any sounds of people talking or yelling with discernable words were omitted to avoid interfering with reading processing, and due to the fact that human beings are more likely to perceive speech due to evolutionary preferences towards speech-like sounds (Vouloumanos et al., 2010). The classroom noises served as an overall stimuli control, and included the sounds of paper shuffling, people shifting in their seats, and pencil scratching. The classroom sounds were meant to emulate a relatively silent testing environment.

Students were first asked to select which course they were taking the survey in. They then answered 4 questions in an abbreviated version of the Perceived Stress Scale (Cohen et al., 1983) to measure their baseline stress levels prior to the influence of the sound stimulus conditions. The abbreviated stress scale used by many universities and hospital systems of just 4 questions was used to cut down on overall time it would take to complete the survey. Participants were asked to evaluate their feelings and thoughts during the last month at the time of taking the survey. In each case, participants indicated their response by selecting the option representing how often they felt or thought a certain way. Options included “never” (0), “almost never” (1), “sometimes” (2) “fairly often” (3), and “very often (4).” The questions in the abbreviated stress scale were as follows:

1. In the last month, how often have you felt that you were unable to control the important things in your life?
2. In the last month, how often have you felt confident about your ability to handle your personal problems?

3. In the last month, how often have you felt that things were going your way?
4. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

After answering the questions on stress levels, students proceeded to listen to each sound condition and take the reading comprehension tests. The assignment of text topics to sound conditions was counterbalanced across participants, as was the order of conditions. The within subjects design of this study controls for individual differences, and therefore allows us to draw stronger causal claims. Texts were approximately 400 words long, and were about comets, dinosaurs, and acupuncture (Norberg, 2022). Students were given 2 minutes and 18 seconds to read each passage, and after were given 1 minute and 18 seconds to answer 5 questions about each passage. Reading times were determined based on average reading time for college educated adults, which is generally around 260 words per minute (Brysbaert, 2019). After each set of text and questions, students answered a question on how many questions out of five they believed they answered correctly in order to measure metacognition for each text subject or sound condition.

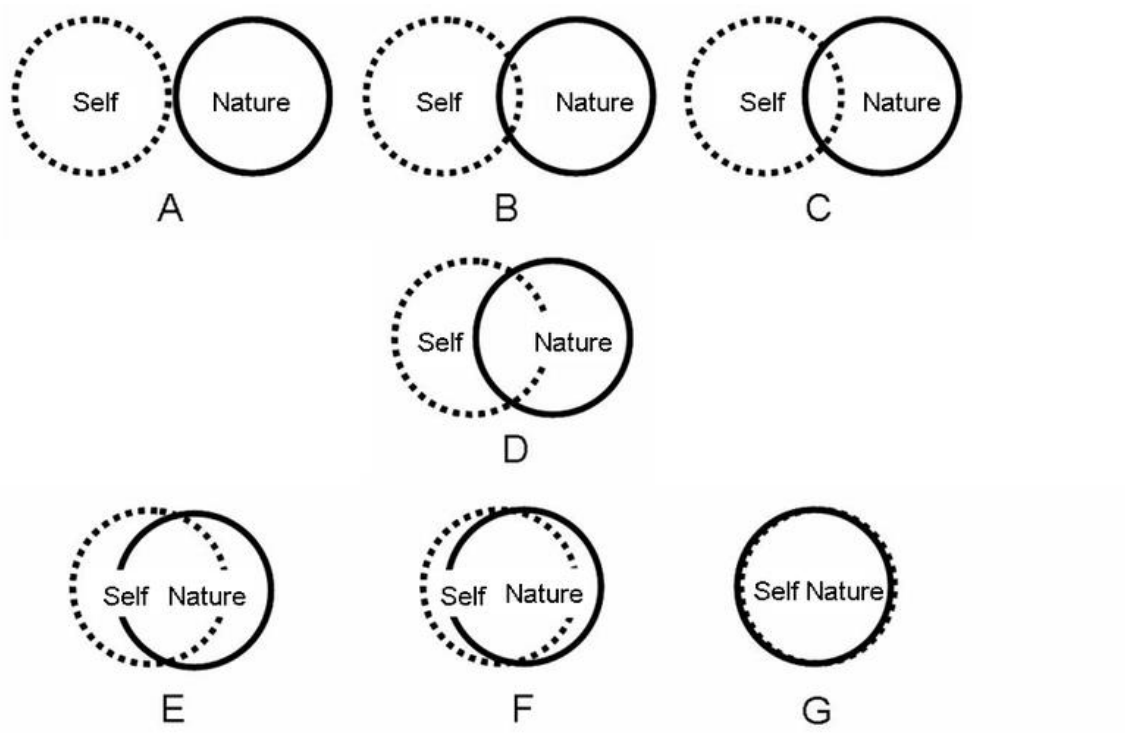
At the end of the audio and reading comprehension section, students were instructed to complete the closing questions of the survey. The questions included what sound condition the students preferred, what year of school the student was in (1st-4th, graduate school, nontraditional student) to determine if wear in school and familiarity with complex texts had any effect on reading comprehension scores. Students also answered the Inclusion of Nature in Self scale (INS; Schultz, 2001) in order to determine if connection to nature was a moderator in how well students did within each sound condition. Students were also asked their explicit preferences on sound conditions during the survey, as well as if they listened to music while they studied in general in order to gauge if students were used to processing auditory stimuli while learning. Participants were also

asked where they usually preferred to study: in quiet places indoors like in a bedroom, dorm, home office, or silent floor of a library, in noisier indoor places such as louder levels of libraries, coffee shops, coworking or public spaces, or if they preferred to study outside. Students also reported whether they grew up in a city, suburb, or rural area to further assess sound profiles the students may be more comfortable with.

Participants were also asked to select which pair of concentric circles they thought best represented their relationship to nature in the Inclusion of Self In Nature Scale (See *Fig. 1*). This scale has been previously shown to measure relationships to nature regardless of cultural influences of connection to nature (Milfont, 2012). Although there are limitations to conceptualizing one's relationship to nature in an abstract way, the scale did allow students to quickly assess their connection to nature without answering multiple questions.

2.2.1 Figure 1

Inclusion of Self in Nature Scale (Schultz, 2001)



3.0 Results

3.1 Overall Comprehension Accuracy

I obtained the mean and standard deviation values for reading comprehension accuracy within the three different soundscapes (see Table 1): City, Nature, and Classroom. The soundscape with the highest mean was the city soundscape (M=2.16, SD = 1.28). The next highest was the Nature soundscape (M = 2.03, SD = 1.10), followed by the classroom soundscape (M = 1.96, SD = 1.12). The sample size for this analysis is N=216, which includes people who did at least one comprehension test and could be placed in an identified class. Since the class was needed to match people's Qualtrics performance to the external sound file, I could only include people if I knew which class they were in, either because (a) they answered this question in the survey, or (b) they skipped the question, but the timestamp allowed us to figure out which class they were in (because only one class was doing the experiment at the time).

The overall difference in reading comprehension accuracy between the three soundscapes was not significant when submitted to an ANOVA test, $F(2,331) = 0.99$, (p = .37). Nevertheless, I also examined planned contrasts between each of the City and Nature soundscapes and the baseline Classroom soundscape. The City soundscape lead to slightly higher accuracy than the Classroom soundscape (p = .17), and the Nature soundscape lead to slightly lower accuracy than the Classroom soundscape (p = .66), but neither difference is significant at conventional levels. In sum, these findings did provide evidence that people, as whole, show increased reading comprehension accuracy while listening to any of the tested particular soundscapes, whether it be City, Nature, or Classroom.

3.1.1 Table 1

Means and Standard Deviations of Reading Comprehension Scores in Sound Conditions

	Mean	Standard deviation
City	2.16	1.28
Nature	2.03	1.10
Classroom	1.96	1.12

Note: n = 216

3.2 Moderator Variables

Additional exploratory moderation analyses were conducted to assess whether some of the other measures collected earlier were associated with reading comprehension accuracy overall or in conjunction with experimental conditions.

Individuals' preferred study location significantly interacted with soundscape condition, $F(2, 257) = 3.55$, $p = .03$. This interaction was driven by the fact that individuals who preferred to study outside had higher reading comprehension scores in the natural condition on average (M = 2.31) than in the city (M = 2.21) and classroom conditions (M = 1.78). By contrast, this was reversed among participants who preferred to study inside, who had higher reading comprehension

scores in the classroom condition on average (M = 2.13), compared to participants in the city (M = 2.17) and natural conditions (M = 1.96).

There was also a significant main effect of closeness to nature such that the more students reported feeling closer to nature, the lower their comprehension accuracy overall (p = .008). However, there was no significant interaction between this variable and the soundscape condition.

Other potential moderators such as native language, stress levels, hometown, sound stimuli preference, and whether participants liked to listen to music while they studied all did not moderate the effect of soundscape condition, nor did they have significant main effects on reading comprehension scores (ps > .05).

3.3 Metacognitive Accuracy

Lastly, a measure of metacognitive calibration was calculated by subtracting each student's reading comprehension scores from their self-assessed comprehension scores. The resulting measure is positive if people are overconfident, 0 if they're exactly accurate, and negative if they're unconfident. This resulted in an interesting pattern of results: students were most overconfident in their testing scores in the classroom condition (0.421), somewhat overconfident in the natural condition (0.344), and the most accurate in predicting their performance in the city sound condition (0.0392). Although this difference did not reach conventional levels of significance, $F(2,270)$ = 1.95, p = .14, these data might imply a familiarity and trust in the current classroom system: the sounds of the classroom are what we are used to associating with academic successes or failures.

4.0 Discussion

After students took a reading comprehension survey in class while listening to background audio that included three sound conditions: city sounds, nature sounds, and classroom sounds, it was concluded that there was no significant evidence for my initial hypothesis that students would perform best overall on reading comprehension tests taken in natural sound conditions, and that students would perform well (but not best) on reading comprehension tests taken in the classroom sound condition. There is also no evidence to support the hypothesis that the city sound condition will result in the worst performance on reading comprehension tests. Indeed, there were no differences in performance in sound condition due to sound condition alone, or the potential mediators except connection to nature and preferred study location.

The numerical improvement in performance with the City soundscape could suggest that context-dependent memory had an effect on the city soundscape due to students living in a city campus and being familiar with working, studying, and learning in similar sound environments. It is also important to note that the results may not generalize to the larger population, as those who decided to complete the full experiment may not be a random sample. Further research in a lab, or where every individual in a classroom was guaranteed to complete the study, as well as complete different tasks could provide additional information about the effects of different soundscapes on performance and preference could provide more insight into the effects found in this study. Another limitation is that these subjects were tested in the classroom. While being an ecologically valid environment, it does have its own distractions, such as sounds from the hallways and streets outside the classroom and building, as well as inconsistent pairings with visual stimuli.

Metacognitive results suggest that students may be overconfident in the classroom soundscape, perhaps because participants were most familiar with it. The accuracy in reading comprehension scores and confidence in scores in the city sound condition were extremely close, possibly due to city sounds not necessarily being associated with a learning environment, but due to context-dependent memory. The University of Pittsburgh's campus is directly next to a hospital and in a city setting, and the sounds of sirens, helicopters, and traffic are commonplace, and can be heard from just about anywhere on campus regardless of if an individual is inside a building. Closeness to nature did have an effect on reading comprehension scores, with students who reported feeling closer to nature performing worse overall on all three sound conditions.

However, when integrated with the results from where students preferred to study, there is evidence to support a context-dependent memory effect in learning practices. There was a significant effect of preferred study locations on reading comprehension scores in the three sound conditions. People who preferred to study outside scored higher on the natural sound condition and lower on the classroom sound condition, whereas the opposite was true for students who preferred to study indoors. These results support the hypothesis of context-dependent memory: students perform better in the environments in which they learn. The present results build upon and extend this principle because past studies of context-dependent memory studies are generally focused specifically on memory, while this study provides evidence that context dependent memory could apply to more general environments and learning. Past studies have focused on where individuals reproduce the context where they learned specific information (e.g., a list of words), whereas this study investigates whether the soundscape condition resembles where people like to study in general while likely never having seen the texts used for comprehension tests.

To expand on the research conducted in this study, it would be advantageous to recognize that the sound stimuli were presented only as auditory recordings, and were not paired with their sources or the environments in which those sources would typically be present, meaning students weren't actually sitting in a forest while taking the reading comprehension test. Further, different kinds of natural sounds, as well as speech, could also be examined, as well as different cognitive tasks performed while listening to sound stimuli. Testing participants on a variety of different skills that rely more heavily on different parts of processing (e.g., the phonological loop versus the visuospatial sketchpad) (*Visuospatial Sketchpad - an Overview | ScienceDirect Topics*, n.d.) could provide interesting insights into accomplishing other kinds of tasks in the classroom in subjects other than reading. Future work could also pair sound stimuli with other physical classroom attributes that have already been shown to benefit learning, such as air quality, lighting, and classroom design.

5.0 Conclusion

In the classroom, there are plenty of ways to improve learning. Sound stimuli are still being explored as a potential learning tool. Context-dependent memory is a mechanism shown to enhance learning and test scores. Utilizing this in the classroom and when studying is just a small step forward in designing our classrooms, curriculums, and personal learning experiences for the better.

Appendix A

Classroom Reading Comprehension Survey

Start of Block: INTRO

Thank you for your interest in our study! This is a research study conducted by the University of Pittsburgh designed to increase our understanding about reading comprehension. This study is a 10 minute reading comprehension survey with background sound. You will have a fixed amount of time to read each passage, and answer each set of accompanying questions.

If you have already completed this survey in another course, or do not wish to participate in this survey, please exit Qualtrics now, and have a nice day!

There are a few other things you should know:

1. All participants must be **18 years of age or older** and fluent speakers of English.

2. There will be no foreseeable risk associated with this project, nor any direct benefits to you.

3. This is an anonymous questionnaire, so your responses will not be identifiable in any way.

4. Your participation is voluntary, so you may stop at any time.

5. This study is being conducted by Dalia Maeroff and Scott Fraundorf, who can be reached at DAM291@pitt.edu and sfraundo@pitt.edu if you have any questions.

Again, if you have already completed this survey in another course, or do not wish to participate in this survey, please exit Qualtrics now.

If you do wish to participate in this study, and this is the first time you are completing this survey, please wait to press the arrow below when the audio says "begin".

End of Block: INTRO

Start of Block: COURSE

The questions in this scale ask you about your feelings and thoughts during THE LAST MONTH. In each case, please indicate your response by selecting the option representing HOW OFTEN you felt or thought a certain way.

	Never	Almost never	Sometimes	Fairly often	Very often
In the last month, how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
In the last month, how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
In the last month, how often have you felt that things were going your way?	○	○	○	○	○
In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

End of Block: PSS BLOCK

Start of Block: TIMING 1

You will read brief texts on various scientific topics.

There are three reading passages corresponding multiple choice questions for each passage. You will have approximately 2 minutes to read each passage, after which the survey will automatically advance to the corresponding questions.

You will then have a little over 1 minute to answer the questions. Please move through the text and questions quickly, but answer to the best of your ability.

End of Block: TIMING 1

Start of Block: Dinosaur Block

Please read the following passage:

Were Dinosaurs Dumb?

Dinosaur Brains

Beliefs about dinosaur intelligence have changed over the years primarily because of a change in understanding of stupidity and its correlation with size. Brain mass (weight) relative to body size, known as the encephalization quotient (EQ), correlates with intelligence. A higher ratio generally means greater intelligence. To put this in perspective, the Brontosaurus is 12x larger than a human, but its skull is 4x larger.

Part of the discrepancy may be that there wasn't evolutionary growth in brain size among dinosaurs over time, unlike in mammalian and bird groups. Instead, dinosaurs evolved a "second brain" (a bundle of neurons in their tails) to help speed up processing. Also, only the correlation of brain size with body size among similar animals (all reptiles, all mammals, for example) is reliable because brain size increases less than body size and at different rates among different types of animals, so when calculating EQ, an adjustment for brain to body growth rates has to be made based on animal type. Further, we must conclude that large animals require relatively less brain to do as well as smaller animals. The current view doesn't claim that dinosaurs are highly intelligent, only that they had the right brains for their bodies.

Dinosaur Behavior

Beyond brain size, behavior is another way of determining dinosaur intelligence. If dinosaurs were intellectually capable, we should find evidence of behavior that demands social and mental coordination. Indeed, we do. Multiple trackways have been uncovered, with evidence for more than twenty animals and multiple species traveling together. At the Davenport Ranch sauropod trackway, small footprints lie in the center and larger ones at the edge. As a further indication of herd life, upwards of thirty juveniles have been found next to a single adult dinosaur as well. That is among plant-eaters, but similar signs are present among meat-eaters, too. A group of Velociraptors were found in a quicksand pit next to an Iguanodon.

Further, few reptiles today are involved in the lives of their young, although the crocodile and pythons are notable exceptions. A finding of dinosaur bones next to unhatched eggs was once believed to be evidence of one dinosaur eating another's eggs. Multiple similar findings have changed that belief. Care for young may have been particularly important among dinosaurs. The Tyrannosaurus Rex hatched from an egg the size of a pigeon. It would take some time to grow from that small size to the 40-foot-long and eight-ton beast of the adult.

Page Break

Please answer the following questions:

1. Which of the following is true about large animals?

- a. Larger animals typically have lower brain to body ratios than smaller animals
- b. EQ should not be used to compare intelligence between small and large animals.
- c. Larger animals do not need as much intelligence as smaller animals to survive

2. Which of the following best states the relationship of brain size to body size?

- a. The brain grows at two-thirds the rate of the body.
- b. Brain size is not related to body size.
- c. If an animal has a bigger body, they will have a smaller EQ.

3. Which of the following is a potential problem for judging dinosaur intelligence based on EQ?

- a. The ratio of brain size to brain mass works within animal types (e.g., mammals) but not across animal types because of variation in brain to body growth rates.
- b. The ratio of brain size to brain mass is less relevant among animal types which have not have not experienced an evolutionary increase in brain size over time.
- c. The ratio of brain size to brain mass is off among dinosaurs because they had “second brain” at the base of their spine that reduced the need for a large brain

4. Why are the Davenport Ranch Sauropod Tracks evidence of dinosaur intelligence?

- a. They demonstrate coordinated efforts among the herd.
- b. They demonstrate that some dinosaurs lived in large herds.
- c. They demonstrate that dinosaurs had cross-species social organization

5. What can be assumed about the relationship between parental care and dinosaurs?

- a. Dinosaurs looked after their young until the young were large enough to survive on their own.
- b. Dinosaurs looked after their young until the young had learned enough to survive on their own.
- c. Dinosaurs may have watched their eggs, but they likely did not "raise" their young.

6. Which of the following is implied about dinosaurs?

- a. Dinosaurs in herds may have cared for each other's young.
- b. Raising the large numbers of young produced by a single dinosaur would have taken a lot of mental coordination.
- c. Dinosaur parental behavior was unique among reptiles.

Page Break

Select how many questions you think you answered correctly:

- ○ 0 out of 5 correct
- ○ 1 out of 5 correct
- ○ 2 out of 5 correct
- ○ 3 out of 5 correct
- ○ 4 out of 5 correct
- ○ 5 out of 5 correct

End of Block: Dinosaur Block

Start of Block: ACU BLOCK

Please read the following passage:

Needles & Nerves

Acupuncture and Vision

Acupuncture is the practice of inserting tiny, hair-thin needles into the skin at specific points to treat pain and illness. Doctors and acupuncturists give millions of treatments each year in the U.S., usually for pain control. But studies show that acupuncture is also extremely useful for the type of nausea caused by chemotherapy and pregnancy. It can even reverse effects of eye degeneration which typically cannot be helped by Western medicine. Acupuncturists believe eye degeneration is caused by problems with Qi flowing through the spleen, liver, and kidney. However, the area they apply the needles to treat the problem is in the outside of the foot.

To understand if a point in the foot could affect the eyes, physicist Zang-Hee Cho strapped volunteers into an fMRI (functional magnetic resonance imaging) machine to get a photograph of their brain activity. Cho flashed a light in front of the volunteers' eyes so the fMRI image would show him what regions of their brain were involved in vision. Then, Cho had an

acupuncturist stimulate the side of the foot. The very same areas of the brain lit up on the fMRI. To remove the possibility of a placebo effect, Cho also stimulated a nonacupoint in the big toe. This time, there was no response in the areas of the brain related to vision.

Acupoints and Pain Management

Although a medical reason for all of acupunctures benefits has not been found, scientists agree about how it reduces pain. The points at which acupuncture needles are inserted are likely the spots where nerves are gathered together. According to neuroscientist Bruce Pomeranz, many studies have shown that acupuncture stimulates nerves in the muscles. Researchers believe the stimulated nerves send signals up the spinal cord to the pituitary gland which produces and stores chemicals called endorphins. With a strong enough signal, the pituitary gland will begin releasing endorphins.

Endorphins are a well-understood chemical primarily involved in blocking pain signals from reaching the brain. Pain is a chemical message which travels from the source of a nerve through multiple cells on its way to the brain. Endorphins bind to opiate receptors which triggers the release of additional chemicals that block the reception of chemicals created by distressed nerves. Because of this, endorphins also trigger a positive feeling throughout the body and are responsible for the feeling of a "runner's high." However, unlike a runner's high, the brain keeps releasing endorphins up to 24 hours after acupuncture. This can improve blood flow, reduce inflammation, and allow the body to heal more rapidly.

Please answer the following questions:

1. Why might acupuncture therapy continue to reduce pain even weeks after treatment?

- a. Endorphins can reduce inflammation and give the body time to heal.
- b. It causes the body to start consistently releasing more endorphins, which block pain signals from being sent to the brain.
- c. It stimulates endorphins in the muscles which promote relaxation and healing.

2. Why might multiple needles be needed during acupuncture?

- a. Because prolonged release of endorphins requires a buildup of signals from the body
- b. Because many areas of the body need to be pierced with a needle for treatment to work
- c. Because the area being treated is large and requires a greater release of endorphins

3. How might acupuncture and runner's highs be similar?

- a. They both stimulate the same areas of the brain.
- b. Western medicine is not able to explain their health benefits.
- c. They both provide a short-term rush of endorphins.

4. Why do acupuncturists believe acupuncture improves degenerative eye disease?

- a. It improves the functioning of the spleen.
- b. It releases endorphins, which reduce eye inflammation.
- c. It helps to unblock Qi within the eye.

5. Acupuncture may help with all of the following EXCEPT:

- a. Nausea from the flu
- b. Morning sickness
- c. Blurred vision

6. Why do acupuncturists use the acupoints on the outside of the foot to treat degenerative eye disease?

- a. They are connected via meridians to the spleen.
- b. They are connected via meridians to the eye.
- c. They are connected via meridians to areas of the brain involved in vision.

Page Break

Select how many questions you think you answered correctly:

- ○ 0 out of 5 correct
- ○ 1 out of 5 correct
- ○ 2 out of 5 correct
- ○ 3 out of 5 correct
- ○ 4 out of 5 correct
- ○ 5 out of 5 correct

End of Block: ACU BLOCK

Start of Block: COM BLOCK

Please read the following passage:

A Comment on Comets

Comet Light

Most of the time, a comet only has a dark nucleus. The bright portions, called the coma and tail, are temporary and depend on the distance from the Sun and Earth. The Sun's heat causes frozen material to evaporate, and the resulting cloud formation around the nucleus is called the coma and can be larger than Earth. As the comet moves towards its closest point to the Sun, the perihelion, the momentum of solar photons creates radiation pressure as it meets dust in coma. The speed of each dust particle as it meets the radiation pressure varies according to its size which creates a tail of dust. Gas particles break away because the magnetic field of plasma of the outward bound solar winds attracts magnetized ions in the gas.

If a comet reaches its nearest point to Earth after its perihelion, it will be much brighter than if it reaches its nearest point to Earth while it is still relatively cold. However, the tails, which are sometimes longer than the Earth's distance to the Sun, and coma last only while the comet is fairly close to the Sun. After each pass, the nucleus of the comet is smaller and will eventually evaporate.

Comet Research

After the explosion that created our solar system about four billion years ago, some of the materials that were pushed farthest from the Sun froze together. Comets are believed to be made-up of these materials. Because comets spend most of their time in the outer reaches of space, they have remained relatively unchanged and are thought of as a "fossil record" of the solar system. Comets may even carry the secret to life. Water and some organic materials may have been brought to Earth by comets hitting our planet during its earliest days.

Scientists are unlocking these answers by studying comets directly rather than through a telescope. For example, a collection of tiny dust particles left behind by a comet led to the discovery of a previously unknown mineral. Even more recently, the Rosetta probe caught up with a comet beyond the asteroid belt after a ten-year flight. It sent back data from water vapor surrounding the comet that was fundamentally different from water on Earth. The probe also found organic compounds that could be the building blocks for DNA. Unfortunately, the solar battery died two days after landing in a crater, and no additional data was collected.

Page Break

Please answer the following questions:

1. What might cause a comet near the Earth to be less visible to astronomers?

- a. If it approaches Earth before it has moved closest to the Sun
- b. If it approaches Earth after it has moved closest to the Sun
- c. If its tails have begun to separate as they are attracted by magnetic fields in the Sun

2. Which of the following are true about the tail of a comet?

- a. The tails are created by radiation pressure blowing dust off the coma and solar winds ionizing and attracting the gasses.
- b. The tail is created when material is, in essence, blown off the coma by solar winds and magnetized ions force separation of the dust and gas particles.
- c. The tails become smaller during each orbit around the sun as the nucleus loses more and more material.

3. What direction is a comet tail pointed as the comet travels around the Sun?

- a. Away from the Sun
- b. Away from the Sun as it approaches and toward the Sun as it departs
- c. The dust tail points away from the sun while the ionized gas tail is attracted towards the sun

4. Why did the Rosetta probe only collect data for 2 days after it landed on the comet?

- a. The probe happened to land in a crater, blocking it from view of the sun.
- b. The probe had used a lot of battery power to reach the comet and had little left after its arrival.
- c. The probe landed harder than expected, causing its battery to malfunction.

5. Why are comets considered a “fossil record”?

- a. The materials that make up the nucleus are unchanged since the origin of the solar system.
- b. During their orbits, they pick up material from many regions of the solar system and can document its evolution.
- c. Material from comets helped create many of the planets, so they hold the key to understanding planet origins.

6. Which of the following were NOT found by the Rosetta probe?

- a. A previously undiscovered mineral
- b. Organic compounds similar to parts of DNA
- c. Water vapor

Page Break

Select how many questions you think you answered correctly:

- ○ 0 out of 5 correct
- ○ 1 out of 5 correct
- ○ 2 out of 5 correct
- ○ 3 out of 5 correct
- ○ 4 out of 5 correct
- ○ 5 out of 5 correct

End of Block: COM BLOCK

Start of Block: POST BLOCK

Which soundscape did you like the best?

- ○ City sounds
- ○ Nature sounds
- ○ Classroom sounds

Page Break

Is English your first language?

- ○ Yes
- ○ No

What year of school are you currently in?

- ○ 1st year
- ○ 2nd year
- ○ 3rd year
- ○ 4th year
- ○ Graduate Student
- ○ Non-traditional Student

Page Break

Do you listen to music while studying?

- ○ Yes
- ○ No

Where do you like to study? Mark all that apply.

- ☐ Silent libraries
- ☐ Coffee shops
- ☐ Outside
- ☐ Non-silent library and university building spaces
- ☐ In dorm, home office, or bedroom
- ☐ Other: _____

Which environment would you say most closely resembles where you grew up?

- ○ City
- ○ Suburb
- ○ Rural

End of Block: POST BLOCK

Do you listen to music while studying?

- ○ Yes
- ○ No

Where do you like to study? Mark all that apply.

- ☐ Silent libraries
- ☐ Coffee shops
- ☐ Outside
- ☐ Non-silent library and university building spaces
- ☐ In dorm, home office, or bedroom
- ☐ Other: _____

Which environment would you say most closely resembles where you grew up?

- ○ City
- ○ Suburb
- ○ Rural

End of Block: POST BLOCK

Do you listen to music while studying?

- ○ Yes
- ○ No

Where do you like to study? Mark all that apply.

- ☐ Silent libraries
- ☐ Coffee shops
- ☐ Outside
- ☐ Non-silent library and university building spaces
- ☐ In dorm, home office, or bedroom
- ☐ Other: _____

Which environment would you say most closely resembles where you grew up?

- ○ City
- ○ Suburb
- ○ Rural

End of Block: POST BLOCK

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