Apocalypse How? Exploring the Use of Graphic Novelization in Neuroscience Pedagogy

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Abstract

The use of graphic novelization is a great tool to aid classroom learning (e.g., Niebert, Marsch, & Treagust, 2012). There has been evidence to suggest that more biologically-oriented content may be difficult to grasp due to its complicated vocabulary, so the use of graphic novelization has been implemented as a pedagogical tool to assist students who have weaker backgrounds in the natural sciences (e.g., Aleixo, & Sumner, 2017; Hosler & Boomer, 2011). While previous work has shown that graphic novelization enhances such content, it is uncertain as to whether metaphors must be visually-based, as opposed to being word-based. In addition to exploring the effectiveness of metaphor types, this study looked at whether feedback from a short-term test influenced long-term retention, as well as the number of prior exposures to materials participants experienced. The current study incorporated the use of metaphors (in the form of a zombie apocalypse) to convey the progression of neurodegenerative diseases. Results demonstrated that there was a significant memory benefit of graphic novel materials over the control condition, especially when questions assessed materials seen twice. These results imply that graphic novelization seems to be a promising method of disseminating information about neurodegenerative disorders.

Keywords: graphic novelization, metaphors, feedback, pedagogy

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A visual metaphor is a process of presenting two separate but related ideas in which one idea is used to conceptualize the other (Johnson & Lakoff, 2015). Thus, two items with different literary meanings are compared to one another and are said to be similar in a figurative manner (Phillips, 2000). Research on visual metaphors and their applications is imperative; educators are always looking for new ways to teach students complex and hard-to grasp concepts in the sciences. By learning information in a new, engaging way, students might exhibit higher levels of retention and recall, which would aid them in their understanding of complex topics. Often times, a visual metaphor is presented in the form of an advertisement (Mohanty & Ratneshwar, 2015). In this advertisement, the visual image that is presented does not make sense on a literal level, but on a figurative level, the reader can see a new connection that otherwise would have gone unnoticed. This allows the reader to look at the information in a new, invigorating way, which might help with memory retention.

In order to further explore this idea about visual metaphors, Phillips and McQuarrie (2004) conducted research on the presentation of visual metaphors. They found that when messages are covert and not easily seen (such as with the use of a metaphor), people pay more attention to the image, which results in higher cognitive processing and retrieval. It is also important to note that visual metaphors are useful for pedagogical purposes because students often feel like they are not doing work and that the metaphors are fun and engaging (Safetyti, 2012). This is important because if students are enjoying what they are doing, they will be more likely to continue using the metaphors as a method of learning. Visual metaphors are also helpful for learning because they draw on previously learned information and help to build connections to new information (Niebert, Marsch, & Treagust, 2012). This method, also known as the method of loci, builds on previously

established facts in memory, which leads to better memory recall (see Massen, Vaterrodt-Plünnecke, Krings, & Hilbig, 2009). Additionally, when students are reading and studying visual metaphors, they have to make comparisons and notice similarities, which aids in memory persistence (Saban, 2006).

When talking about memory retention, it is important to note the memory processes that occur. To begin learning something new, working memory must be utilized, which is an aspect of short-term memory that deals with the immediate processes at hand, as well as the attention that is required to keep it on a person's mind (Baddeley & Hitch, 1974). Once in working memory, visual information is retained with the use of the visuospatial sketchpad (inner-eye) (Baddeley & Hitch, 1974). This works to store and process visual information. The inner-eye is important not only for analyzing new information, but also for visual awareness for things around us, our body position in relation to other objects, and being able to visualize information that is held in one's long-term memory (Baddeley, 1986). After memories are transferred to working memory/short-term memory (STM), they then must be transferred to long-term memory (LTM) for the memory to persist for some time. The process by which memories are transferred from STM to LTM is known as long-term potentiation (LTP) (Goelet, Castellucci, Schacher, & Kandel, 1986). This process states that for memories to be transferred, more cells in the hippocampus, the brain structure responsible for declarative memories, need to be firing simultaneously. LTP works by increasing the synaptic connections between neurons, which results in an increase of signal transmission between neurons.

Furthering the study of long-term retention, one important phenomenon to assess is the presence or absence of feedback about what was previously learned. The testing effect is a noted occurrence that shows that the testing of information can have a positive effect on future retention of said material (see Carpenter & DeLosh, 2006). Researchers have determined that testing can

improve retention in a long-term interval with or without the presentation of feedback, but feedback can lead to an even greater memory benefit (Butler & Roediger, 2008; Karpicke & Roediger, 2007). Butler, Karpicke, and Roediger (2008) conducted a study looking at metacognitive (i.e., thinking about thinking) and memory errors on a general knowledge multiple-choice test. Their participants took an initial multiple-choice test and provided their confidence on their answer. They then received feedback (re-presentation of the multiple-choice question followed by the correct answer) on half of the questions. Retention of materials was then tested by another cued-recall test. The researchers determined that taking the initial test improved memory (in comparison to not having the initial test) and that feedback enhanced memory performance. Specifically, when feedback was presented after low-confidence questions, memory retention of those materials doubled, demonstrating the importance of feedback for both memory and metacognitive errors.

By building on previously learned information, people can make more connections, which leads to better memory retention. Increased memory retention is not only important for students, but it is also important for educators. If educators can increase memory retention for difficult materials, students can show a greater understanding of difficult topics in both a short-term and long-term interval (see Cooke & Bliss, 2006). By incorporating visual metaphors that draw on the method of loci, participants will be able to build on previously learned information to have better memory retrieval (Massen, Vaterrodt-Plünnecke, Krings, & Hilbig, 2009; Phillips & McQuarrie, 2004). Van Beveren and de Haan (2008) designed a study that used visual metaphors to depict the neural dynamics seen in schizophrenia. The visual metaphor was used to bridge molecular-biological and mental domains of schizophrenia. The researchers described a computer model of neural information processing, followed by two computer models on schizophrenia. They

concluded by showing the effects of dopamine neuromodulation, which is a common disturbance seen in schizophrenia. Van Beveren and de Haan (2008) found that the use of the visual metaphors allowed the complex information to be presented in a novel way and allowed participants to look at an abstract concept in a tangible manner, which is important for memory recall and retention.

Looking at the retention of materials, the picture superiority effect is a phenomenon that shows pictures and/or images are more likely to be remembered than words (Paivio, 1971; Paivio, Rogers, & Smythe, 1968). This is possibly because pictures draw upon image and verbal codes, while words only draw upon verbal codes (Paivio, 1971, 1986). This results in a redundant encoding, which is more likely to persist in memory. An alternative theory is that pictures are more memorable because they provide more distinct visual representations in comparison to words (Nelson, 1979). Alternatively, pictures can be categorized more quickly than words (Potter & Faulconer, 1975). Regardless of which reason is correct, all of these theories share the common theme that pictures produce a more elaborate code than words alone, which is why pictures are better remembered and persist longer in memory. This means that for pedagogical purposes, the use of pictures outweighs the use of words when trying to get the information to persist in memory for some time.

One method of bridging this gap could be through the use of directed visual aids that link to a theme (e.g., graphic novelization). The origination of graphic novels can be traced back to comic books and are considered to be an art form because of the combination of images and text-based information (see Sabeti, 2012). The depiction of graphic novels can be thought of as narrative storytelling (because each picture represents a small portion of an entire story). However, the images and texts of individual areas can be seen as stand-alone content for metaphor-based purposes, meaning that each panel of the graphic novel contains valuable information about the

story as a whole. This phenomenon has shown to be useful for science pedagogy because it can be utilized to strengthen reading comprehension and understanding of the content, in comparison to rehearsal of text-based materials (see Aleixo & Sumner, 2017; Hosler & Boomer, 2011).

Specifically, Hosler and Boomer (2011) used a scientific comic book to explain the process of evolution. The researchers looked at the differences in learning between science and non-science majors and found that at a pre-assessment, nonmajors scored the lowest scores on a content test, as well as general attitudes towards the content. However, after the implementation of the comic book, the nonmajors (especially those who initially showed low content and attitude scores) had significantly higher improvements in knowledge of content and attitudes towards the materials (which demonstrates a high engagement score and general liking towards the materials). Furthermore, Aleixo and Sumner (2017) utilized a similar comic book design to explain the psychobiology principles of sleep. They varied the presentation of materials, in that participants were randomly assigned to either a full-length graphic novel, basic text-based information, or an incongruous comic book format (meaning that some of the original comic book images were randomly replaced with images that did not pertain to the story). The researchers found that the congruent graphic novel led to significantly higher memory retention than both the text and incongruent novel conditions and that the text aided in higher memory benefits compared to the incongruent group. Both Hosler and Boomer (2011) and Aleixo and Sumner (2017) demonstrated that the use of comic books can be an effective method for the dissemination of materials, especially because of the emphasis on associating abstract information (i.e., strong biology content) with easily recognizable imagery.

Purposes of the Current Study and Hypotheses

Based on the graphic novel research by Hosler and Boomer (2011) and Aleixo and Sumner

(2017), the main purpose of the current study was to see if the memory benefits of graphic novel learning could be transferred to a different paradigm. Specifically, we wanted to show that graphic novels could be implemented to show the progression of neurodegenerative disorders in the form of a zombie apocalypse. This study focused on three different neurodegenerative disorders (Alzheimer's disease, chronic traumatic encephalopathy (CTE), Korsakoff's syndrome) and incorporated a metaphor by having each story take place in a different city around the country. Each city represented the brain that was destroyed by zombies; the zombies represented the various ways the brain is destroyed by the diseases (i.e., in Korsakoff's syndrome the brain does not get enough vitamins. Zombies destroyed all of the food trucks that were attempting to enter the city, which represented nutrients that were not able to enter the brain). Since graphic novels incorporate the use of both pictures and words, it was hypothesized that those who study the graphic novels would have better memory retention than both story and control contents (Aleixo & Sumner, 2017; Hosler & Boomer, 2011; Paivio, 1971). This study also looked to see if feedback from a short-term memory test influenced long-term retention of the content. Specifically, half of the participants were given the correct answers after the short-term memory test, while the other half was not. It was hypothesized that those who received the correct answers after the short-term memory test would score higher on a long-term memory test than those who did not receive feedback (Butler, Karpicke, & Roediger, 2008). We also varied the number of prior exposures for information for the test questions. Specifically, half of our questions were based on information was seen in both basic background reading and supplemented in the ancillary materials (two prior exposures), while the other half were taken from information only seen once (just in the background reading). It was hypothesized that since the information that was found in the ancillary materials was seen twice, those questions would lead to a significantly higher memory retention

than questions only found in the background materials (Massen, Vaterrodt-Plünnecke, Krings & Hilbig, 2009; Niebert, Marsch, & Treagust, 2012). Finally, it was hypothesized that the participants who read the graphic novels would rate that method of learning as being more engaging and creative than those who have one type of supplementary material (Safetyti, 2012).

Method

Participants

A total of 135 undergraduates from a small, liberal arts college in the southeastern United States were sampled from the psychology research participation pool and upper-level psychology courses and served as participants in exchange for extra credit or course credit, as determined by their instructor. The sample consisted of 110 females and 25 males and ranged in age from 17 to 38 years (M = 19.68, SD = 2.12).

Measures

An attitudinal survey was used to measure participants' attitudes towards the ancillary materials (See Appendix F). This item contained five Likert scale questions (e.g., *"I consider this ancillary material to be engaging for my understanding of neurodegenerative disorders"*) rated on a five-point Likert-scale, where 1 is "*Strongly Disagree*" and 5 is "*Strongly Agree*." Scores on this survey ranged from 5 to 25, with higher scores reflecting higher positive attitudes towards the materials.

Materials

Background Content: Participants were exposed to background readings on three different neurodegenerative disorders (Alzheimer's disease, chronic traumatic encephalopathy (CTE), Korsakoff's syndrome (See Appendix A). The content was approximately three pages long and

mimicked a textbook passage. This served as establishing a baseline level of content for all participants.

Ancillary Materials: Participants were randomly assigned to one of three ancillary material conditions: full graphic novel (See Appendix B), story (See Appendix C), or control (See Appendix D). The different conditions were implemented to assess the relative effectiveness of the content. The graphic novel condition received a seventeen-page graphic novel that depicted all three neurodegenerative disorders in the form of a zombie apocalypse. The story condition received the metaphor-based captions of the graphic novel, while the control condition read irrelevant information (e.g., content about puppies and kittens).

Short/Long-Term Test: A multiple-choice test was used to measure participants' short- and long-term retention of the content (See Appendix E). The test was composed of eighteen items; each question had four possible answer choices, but only one correct answer. Half of the questions assessed content based on two prior exposures of information (i.e., information that was found in both the background reading and the ancillary materials) (e.g., *"Symptoms of Korsakoff's Syndrome result from bodily deficits of?"*) while the other half assessed content with only one prior exposure (i.e., information that was only explicitly mentioned in the background readings) (e.g., "*The cell death in the brain as a result of CTE can shrink the brain by __% in size?"*). Scores ranged from 0 – 9 for each subscale (for a total combined score of 0 – 18) with higher scores reflecting a higher retention of the content (in either the short- or the long-term).

Design and Procedures

The current study employed a 3 x 2 x 2 x 2 mixed-subjects factorial design with ancillary material type (graphic novel, story, control) and feedback of correct answers (feedback, no feedback) as the between-subjects factor and testing interval (short- and long-term) and number of

prior exposures to information (one, two) as the within-subjects factors. Recognition scores on the short- and long-term tests served as the dependent measures. We also employed a single factor design with three levels with type of ancillary material as the between-subjects factor and engagement scores as the dependent measure.

Participants first read and signed an informed consent to participate in research form. After, they were exposed to the background readings about the three different neurodegenerative disorders. Participants had a total of eight minutes to read through that set of materials. Participants were then randomly assigned to one of the three ancillary materials conditions and had eight minutes to read their corresponding content. Participants then completed the short-term memory test, followed by the attitudinal survey and a demographics questionnaire. Half of the participants were instructed that their participation for the day was concluded, but that they would complete a follow-up questionnaire two weeks later. The other half received the correct answers of the short-term questionnaire in the form of hearing the questions and correct answers read out loud. They were then dismissed for their participation for the first half of the experiment. After two weeks, the researchers distributed the long-term memory test to all participants regardless of feedback of correct answers and then all participants were debriefed.

Results

Recognition percentages for multiple choice scores were calculated by dividing the number of correctly answered multiple choice test questions by the total number of possible correct responses. All descriptive statistics are reported as percent numerical values (range = 0.00% to 100%).

A 3 x 2 x 2 x 2 Mixed-Subjects Factorial ANOVA was conducted with ancillary material type (graphic novel, story, control) and feedback of correct answers (feedback, no feedback) as

the between-subjects factor and testing interval (short- and long-term) and number of prior exposures to information (one, two) as the within-subjects factors and recognition scores as the dependent measure.

There was a significant main effect of ancillary material type on recognition scores, $F(2,129) = 3.41$, $p = .036$. Follow-up independent samples t-tests revealed that those who received the graphic novel as an ancillary material ($M = 61.96$, $SD = 9.31$, $SE = 1.42$) did not have significantly greater recognition compared to those who received the story as an ancillary material ($M = 59.39$, $SD = 13.31$, $SE = 1.97$), $t(87) = .68$, $p = .50$, Cohen' $d = .22$, but they did exhibit greater recognition compared to those who received the control ancillary material ($M = 54.22$, $SD = 16.00$, $SE = 2.36$), $t(88) = 2.46$, $p = .016$, $d = .59$. Furthermore, the benefit of receiving the story materials over control materials on recognition scores approached significance, $t(89) = 1.67$, $p = .099$, $d = .35$.

There was a main effect of retention interval on recognition scores, $F(1,129) = 18.84$, $p < .001$, $d = .36$. Overall, scores after the short-term retention interval ($M = 60.94$, $SD = 14.56$, $SE = 1.28$) were significantly greater than scores after the long-term retention interval ($M = 55.39$, $SD = 16.11$, $SE = 1.39$). The benefit of short retention intervals over long retention intervals did not vary as a function of the type of ancillary material condition, as there was no significant interaction between retention interval and type of ancillary material, $F < 1$. Subsequent paired-samples t-tests revealed that for the graphic novel condition, scores on the short-term test ($M = 64.17$, $SD = 10.61$, $SE = 1.60$) were significantly higher than scores on the long-term test ($M = 57.94$, $SD = 13.73$, $SE = 2.07$), $t(43) = 2.566$, $p = .014$, $d = .51$. Similarly, those in the story condition had significantly greater recognition after the short-term test ($M = 61.61$, $SD = 14.16$, $SE = 2.11$) than after the long-term test ($M = 57.17$, $SD = 15.97$, $SE = 2.38$), $t(44) = 2.093$, $p = .042$, $d = .29$. Furthermore, for

the control condition, scores on the short-term test (M = 57.22, SD = 17.37, SE = 2.56) were significantly higher than scores on the long-term test (M = 51.22, SD = 17.72, SE = 2.61) $t(45) = 2.857$, $p = .006$, $d = .34$. Thus, regardless of ancillary material condition, recognition scores were always higher after the short-term retention interval than the long-term retention interval. Subsequent independent samples t-tests revealed that there were differences in recognition scores between the graphic novel and control conditions at both the short-term interval, $t(88) = 2.26$, $p = .026$, $d = .48$, and the long-term interval $t(88) = 2.013$, $p = .047$, $d = .42$. However, there were not significant differences between the graphic novel and story conditions at either the short-term, $t(87) = .995$, $p = .342$, $d = .20$ or long-term intervals $t(87) = .251$, $p = .802$, $d = .05$, nor between the story and control conditions at either the short-term, $t(89) = 1.311$, $p = .193$, $d = .28$, or long-term interval, $t(89) = 1.68$, $p = .096$, $d = .35$. Thus, regardless of retention interval, those in the graphic novel condition exhibited greater recognition scores than those in the control condition but not between the graphic novel and story, nor the story and control.

There was no significant main effect of feedback on recognition scores, $F(1,129) = 1.25$, $p = .27$. There was no also significant interaction between ancillary material condition and feedback on recognition scores, $F < 1$. For both feedback conditions, participants in the graphic novel condition recognized marginally significant more information than those in the control condition. Specifically, for those who received feedback, the recognition benefit for those in the graphic novel condition (M = 63.61, SD = 10.92, SE = 2.44) over those in the control condition (M = 56.03, SD = 15.69, SE = 3.28) approached significance, $t(41) = 1.81$, $p = .078$, $d = .56$. Furthermore, for those who did not receive feedback, there was also a recognition benefit for those in the graphic novel condition (M = 58.93, SD = 7.28, SE = 1.47) over those in the control condition (M = 52.42, SD = 16.47, SE = 3.44) that approached significance, $t(45) = 1.76$, $p = .085$, $d = .51$. While there was

not a significant interaction between ancillary material condition and feedback, there was a significant interaction between retention interval and feedback of correct answers on recognition scores, $F(1, 129) = 9.77$, $p < .001$. Subsequent independent samples t-tests revealed that collapsed across ancillary material condition and number of prior exposures, at the short retention interval, there was no difference in recognition scores between those who received feedback ($M = 60.17$, $SD = 14.94$, $SE = 1.83$) and those who did not receive feedback ($M = 61.67$, $SD = 14.22$, $SE = 1.72$), $t(133) = -.59$, $p = .55$, $d = -.05$. However, at the long-term retention interval, those who received feedback ($M = 56.61$, $SD = 17.56$, $SE = 2.17$) had significantly higher recognition scores than those who did not receive feedback ($M = 52.33$, $SD = 14.00$, $SE = 1.67$), $t(133) = 2.29$, $p = .023$, $d = .27$. Furthermore, this two-way interaction between retention interval and feedback did not vary as a function of type of material, for the three-way interaction between ancillary material type, feedback, and testing interval was not significant, $F(1,129) = 1.27$, $p = .28$. However, follow-up independent samples t-tests revealed that feedback did have an effect for those in the graphic novel condition at the long-term retention interval, in that those who received feedback within the graphic novel condition ($M = 63.89$, $SD = 15.78$, $SE = 3.50$) had significantly greater recognition after the long-term retention interval compared to those who did not receive feedback ($M = 53.00$, $SD = 9.56$, $SE = 1.94$), $t(42) = 2.82$, $p = .007$, $d = .83$. Feedback did not have any effect on recognition scores in the long-term interval for participants in either the story or control conditions, $Ps > .14$, nor was there an effect of feedback in any of the ancillary material conditions at the short-term retention interval, $Ps > .64$.

There was a main effect of prior exposure on recognition scores, $F(1,129) = 53.15$, $p < .001$, $d = .62$. Participants scored significantly higher on questions that had material seen twice (i.e., supplemented in the ancillary materials) ($M = 63.00$, $SD = 14.50$, $SE = 1.22$) compared to

question materials only seen once (M = 53.33, SD = 16.39 SE = 1.39). This benefit of more exposures did not vary as a function of type of ancillary material the participants received, as the interaction between prior exposure and ancillary material condition was not significant, $F(2,129) = 1.54$, $p = .22$. For those in the graphic novel condition, participants demonstrated significantly higher recognition scores for two prior exposures (M = 67.56, SD = 10.39, SE = 2.80) than the materials with only one prior exposure (M = 54.56, SD = 13.50, SE = 2.03), $t(43) = 5.61$, $p < .001$, d = 1.08. Similarly, for those in the story condition, there were significantly higher recognition scores for materials with two prior exposures (M = 63.56, SD = 13.94, SE = 2.08) than the materials with one prior exposure (M = 55.17, SD = 16.43, SE = 2.44), $t(44) = 3.76$, $p < .001$, d = .55. Consistent with those in the graphic novel and story conditions, those in the control condition had significantly higher recognition scores for the materials with two prior exposures (M = 58.11, SD = 16.92, SE = 2.49) compared to the one prior exposure (M = 50.33, SD = 18.67, SE = 2.76), $t(45) = 3.35$, $p = .002$, d = .44. However, there were no differences in recognition scores between the graphic novel and story conditions for materials with two prior exposures $t(87) = 1.51$, $p = .13$, d = .33, nor for the materials with one prior exposure, $t(87) = -.20$, $p = .84$, d = -.04. Additionally, the recognition differences between story and control in the two exposure condition only approached significance, $t(89) = 1.68$, $p = .096$, d = .35, with no significant difference in recognition between story and control for the materials with one prior exposure, $t(89) = 1.31$, p = .20, d = ..28. Finally, between the graphic novel and control conditions there was a difference for the materials with two prior exposures, $t(88) = 3.17$, $p = .002$, d = .67, but following previous trends, there was not a difference in recognition scores for the materials with one prior exposure, $t(88) = 1.21$, $p = .23$, d = .26. Thus, the only significant memory benefit occurred between the graphic novel condition and the control condition when question materials were seen twice.

In addition to a similar benefit of prior exposure across all ancillary material conditions, the benefit of more exposures did not vary as a function of whether they received feedback as to whether their answers were correct or not, as the interaction between prior exposure and type of feedback was not significant, $F < 1$. Follow-up paired-samples t-tests revealed that for both feedback conditions, participants exhibited greater recognition for information they were exposed to twice, compared to information only seen once. Specifically, participants who received feedback on the correct answers exhibited greater recognition for material with two prior exposures (M = 63.78, SD = 16.39, SE = 2.00) compared to information with only one prior exposure (M = 54.94, SD = 16.78, SE = 2.06), $t(65) = 4.33$, $p < .001$, $d = .53$. Similarly, those who did not receive feedback also exhibited higher recognition for information they were exposed to twice (M = 62.22, SD = 12.56, SE = 1.50) compared to information only seen once (M = 51.78, SD = 16.00, SE = 1.94), $t(68) = 6.09$, $p < .001$, $d = .73$. In addition to having a benefit of prior exposure across all ancillary types and both feedback conditions, there was also a benefit of prior exposure across both retention intervals, as the interaction between retention interval and prior exposure was not significant, $F(1,129) = 1.34$, $p = .25$. Follow-up paired-samples t-tests revealed that for both retention intervals, participants exhibited greater recognition for information they were exposed to twice, compared to information only seen once. Specifically, at the short-term retention interval, participants exhibited higher recognition for material that was seen twice (M = 65.44, SD = 17.22, SE = 1.44) compared to information only seen once (M = 56.67, SD = 18.22, SE = 1.56), $t(134) = 4.88$, $p < .001$, $d = .50$. Similarly, at the long-term retention interval, participants also exhibited higher recognition for material that was seen twice (M = 60.78, SD = 17.33, SE = 1.44) compared to information only seen once (M = 50.00, SD = 20.22, SE = 1.78), $t(134) = 6.49$, $p < .001$, $d = .57$. The three-way interaction between prior exposure, retention interval, and type of ancillary

condition was not significant, $F < 1$, nor was the three-way interaction between prior exposure, retention interval, and feedback condition, $F(2,129) = 1.64$, $p = .20$. As shown in Table 1, follow-up independent samples t-tests revealed that there was a recognition benefit of exposure to graphic novel ancillary material over control ancillary material for materials seen twice at both the short retention interval, $t(88) = 2.95$, $p = .004$, and long-term retention interval, $t(88) = 2.30$, $p = .024$. However, there was no significant recognition benefit of exposure to graphic novel ancillary material over control ancillary material for material seen once at either the short retention interval, $t(88) = .82$, $p = .41$, or at the long retention interval, $t(88) = 1.24$, $p = .22$. There was no recognition benefit of exposure to graphic novel ancillary materials over exposure to story materials at either retention interval for materials seen either once or twice, Ps $> .12$. Furthermore, there was no recognition benefit of exposure to story ancillary materials over exposure to control materials at either retention interval for materials seen either once or twice, Ps $> .14$.

[INSERT TABLE 1 HERE]

Finally, the four-way interaction between retention interval, prior exposure, type of ancillary condition, and feedback was not significant, $F < 1$. As shown in Figure 2, follow-up independent samples t-tests revealed that for information seen twice, there was a marginally significant recognition benefit of graphic novel exposure over control exposure for participants who received feedback on their answers at the short retention interval, $t(41) = 1.69$, $p = .098$, and a significant recognition benefit of graphic novel over control at the long retention interval, $t(41) = 2.26$, $p = .029$. Similarly, for information seen twice, there was a significant recognition benefit of graphic novel exposure over control exposure for participants who did not receive feedback on their answers at the short retention interval, $t(45) = 2.49$, $p = .017$, however, this effect was not seen at the long retention interval, $t(45) = 1.23$, $p = .23$. Furthermore, for information only seen

once, there was no recognition benefit of graphic novel exposure over control at either retention interval by feedback condition, *P*s > .30. There was a marginally significant benefit of graphic novel exposure over story exposure for materials seen twice when participants were given feedback on their answers at the long retention interval, $t(41) = 1.69$, $p = .099$. All other pairwise comparisons between graphic novel exposure and story were not significant in any of the remaining feedback by prior exposure conditions, *P*s > .24. There was a marginally significant benefit of story exposure over control exposure for materials seen twice when participants were not given feedback on their answers at the long retention interval, $t(43) = 1.82$, $p = .076$. There was also a marginally significant benefit of story exposure over control exposure for materials seen once when participants were not given feedback on their answers at the long retention interval, $t(43) = 1.78$, $p = .08$. All other pairwise comparisons between story exposure and story were not significant in any of the remaining feedback by prior exposure conditions, Ps > .24.

[INSERT FIGURE 1 HERE]

A One-Way ANOVA was conducted with ancillary material condition (graphic novel, story, control) as the between-subjects factor and the total engagement score as the dependent measure. As shown in Figure 2, there was a significant main effect of material condition, $F(2,132) = 7.083$, $p = .001$. Subsequently performed LSD tests revealed that those in the graphic novel condition ($M = 19.73$, $SD = 4.54$, $SE = .69$) gave significantly higher engagement scores than both the story ($M = 17.02$, $SD = 5.13$, $SE = .77$), $t(87) = 2.63$, $p = .01$, $d = .56$, and control ($M = 16.13$, $SD = 4.41$, $SE = .65$), $t(88) = 3.81$, $p < .001$, $d = .80$. However, there was not a significant difference in engagement scores between the story and control conditions, $t(89) = .89$, $p = .376$, $d = .19$.

[INSERT FIGURE 2 HERE]

To summarize, those who received the graphic novel as an ancillary material exhibited greater recognition compared to those who received the control ancillary material. For both feedback conditions, participants in the graphic novel condition recognized marginally significant more information than those in the control condition. Finally, between the graphic novel and control conditions, the questions that assessed materials with two prior exposures lead to greater a memory benefit than questions with materials with only one prior exposure. Thus, there was a main effect of the graphic novel ancillary material condition over control, regardless of the testing interval and marginally regardless feedback. However, when looking at number of prior exposures, the benefit of graphic novelization over control materials was only seen when question materials were seen twice.

Discussion

The purpose of the present study was to examine the relationship between ancillary material type, feedback of correct answers, number of prior exposures to information, and retention of materials at short- and long-term testing intervals. To summarize the results, we found that the graphic novel lead to greater retention scores when compared to control conditions regardless of the testing interval (in both the short- and long-term). Furthermore, we found the recognition benefit for graphic novelization marginally regardless of type of feedback (feedback for correct answers, no feedback about correct answers). However, when looking at prior feedback, graphic novels only lead to greater retention scores than the control condition when materials were seen twice, as opposed to a single exposure. Based on these data, we found partial support for our first hypothesis. Specifically, the use of graphic novels resulted in greater memory retention when compared to control conditions, but this effect was not found when compared to the story condition. Specifically looking at the research by Aleixo and Sumner (2017), we failed to find the

same effect that the graphic novel resulted in greater memory retention than either the text or control conditions. However, there are a few potential explanations for this finding. Our story condition was the same text that was found in the graphic novel; the only difference between the conditions was the inclusion of the drawn images. Since the writing was metaphorical, it is possible that the memory benefits seen with the graphic novel mostly came from the captions, as opposed to the text.

While we failed to demonstrate a main effect of feedback, we did show an interaction between testing interval and feedback, specifically that at the short-term interval, scores on the recognition test did not differ as a function of feedback type, but at the long-term testing interval, participants who received feedback recognized significantly more items than those who did not receive feedback. These results are consistent with prior research by Butler, Karpicke, and Roediger (2008) in that the inclusion of correct answers after a short-term memory test leads to higher retention at the long-term interval, when compared to a control condition that does not receive correct answers. However, in this study, this effect was only seen in the graphic novel condition at the long-term interval. Participants in the graphic novel condition who received feedback on correct answers scored significantly higher than those who did not receive feedback, but there were no differences in recognition scores as a function of feedback for either the story or control conditions. The lack of significance in the other two conditions could possibly suggest that feedback plays a bigger role depending on the amount of information initially learned. Since recognition scores were higher in the graphic novel than the other two conditions at the short-term interval, the feedback on correct answers could have helped to further solidity facts learned but did not make a difference for the conditions in which not as much information was initially learned (see Saban, 2006).

We also found support for our third hypothesis in that the information with two prior exposures was remembered significantly more than information with only one prior exposure. This is consistent with the findings of Massen and colleagues (2009) because for the questions with two exposures to information, participants were able to take the initial information learned and build upon those facts when reading the ancillary materials. Furthermore, this is also consistent with Niebert, Marsch, and Treagust (2012) in that the second exposure to materials was in a metaphor-based form that allowed participants to draw upon previously learned information in order to make connections, and thus, helped to solidify the information in one's memory.

Finally, we found support that the graphic novels were rated as a more engaging form of ancillary material than both the story and control conditions. This finding is consistent with Safetyti (2012) in that students find metaphor-based content to be an engaging and fun method of learning. Interestingly, there was not a significant difference in engagement scores between the story and control conditions. This demonstrates that while there may not have be a difference in recognition scores between the graphic novel and story, participants overall enjoyed using the graphic novel materials more and would prefer to use them in the future.

Although the results of the present study support the use of graphic novelization as a pedagogical tool, there are some noted limitations that need to be acknowledged. In terms of the overall sample sizes obtained, a larger collection of participants could improve the overall statistical power of the research study. It is important to note that despite smaller samples sizes, many of the effect sizes were large, indicating high practical significance of the differences found in memory performance between the different stimuli conditions. Another limitation of the study we did not address was an initial knowledge about neurodegenerative disorders. Some participants, through various means (e.g., prior exposure in a class, knowing someone with one of the

conditions, etc.) might have come into the study with a knowledge about some, or all of the neurodegenerative disorders covered. Therefore, future research could choose to implement a pre-test followed by a matched design to spread prior knowledge across the conditions. Additionally, while this study attempted to address the differences between a full graphic novel (i.e., metaphor-based pictures and text) and just the metaphor-based text, differences in regard to just the pictures could not be assessed. Hence, future research should incorporate a fourth condition composed of just the images from the graphic novel to fully elucidate the differences between the components of the graphic novel. In other words, the four conditions would be the three seen in the current study (graphic novel, story, control) plus an image condition to try and see which metaphorical components play important roles in memory retention of the content.

To summarize, the results of the current study provide support for using graphic novel techniques for the dissemination of neuroscience content, specifically neurodegenerative disorders. Educators are always looking for new and exciting ways to teach students about complicated content, so furthering this research carries a high importance, as it can impact both the way educators teach and students learn. Furthermore, our results imply that graphic novels, especially with their increased usage in higher education settings, shows promise as a pedagogical tool for teaching difficult material to students. Given the ever-growing emphasis on STEM-based learning at all levels of one's education, the benefits of graphic novelization as a learning supplement should be further explored.

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Table 1. *Sample Sizes, Means, Standard Deviations, and Standard Error for the Three-Way Interaction Between Prior Exposure, Retention Interval, and Type of Ancillary Material*

			n	Mean	SD	SE
Short-Term Retention Interval	2 Prior Exposures	Graphic Novel	44	70.45	13.33	2.01
		Story	45	65.43	16.45	2.45
		Control	46	59.90	19.80	2.92
	1 Prior Exposure	Graphic Novel	44	57.83	15.08	2.27
		Story	45	57.78	17.34	2.59
		Control	46	54.59	21.57	3.18
Long-Term Retention Interval	2 Prior Exposures	Graphic Novel	44	64.65	15.02	2.26
		Story	45	61.73	16.84	2.51
		Control	46	56.28	19.09	2.81
	1 Prior Exposure	Graphic Novel	44	51.26	18.59	2.80
		Story	45	52.59	21.11	3.15
		Control	46	46.14	20.55	3.03

Figure 1. Average Recognition Scores as a Function of Ancillary Material Type, Number of Exposures, and Feedback at the Short (top panel) and Long (bottom panel) Retention Intervals

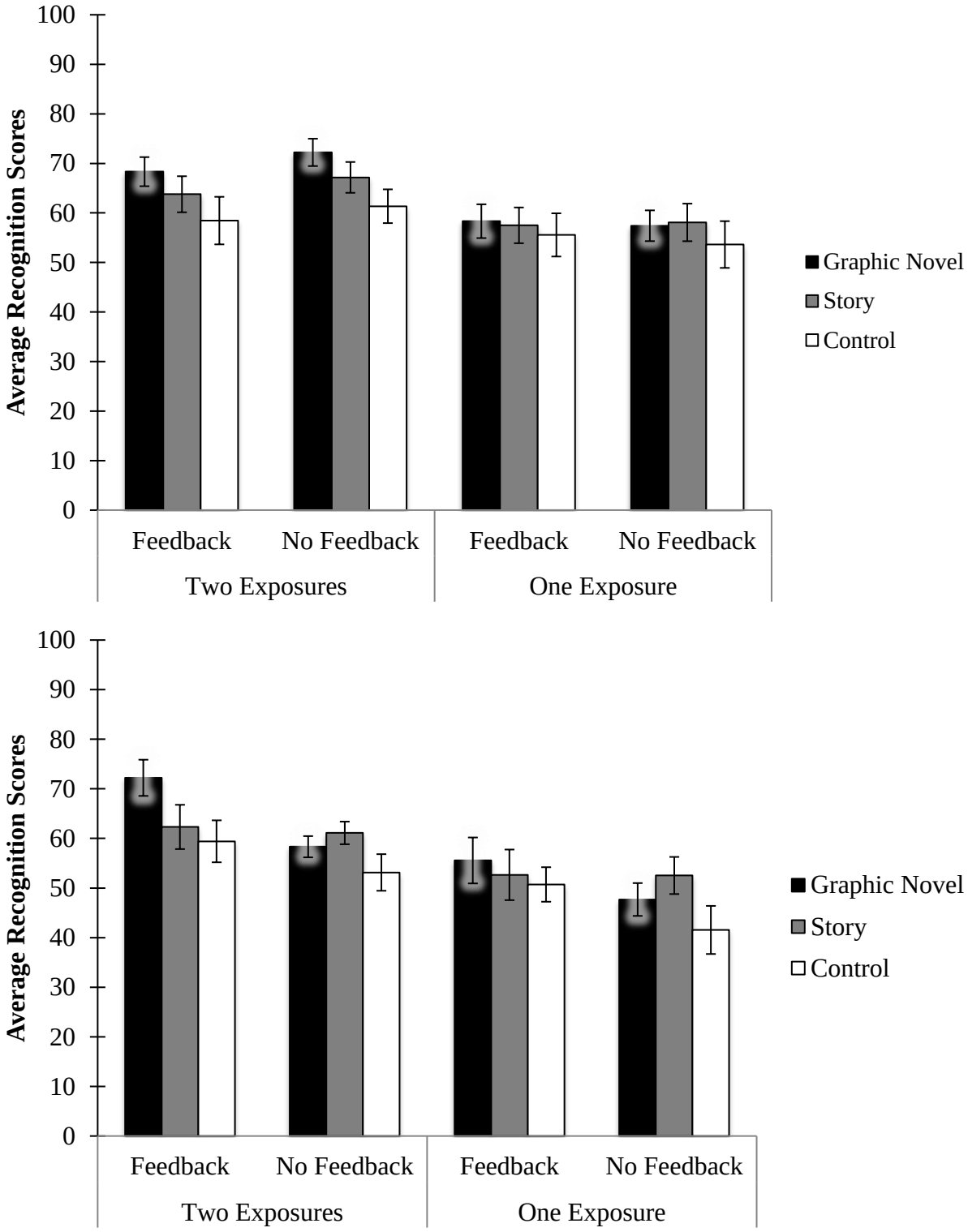
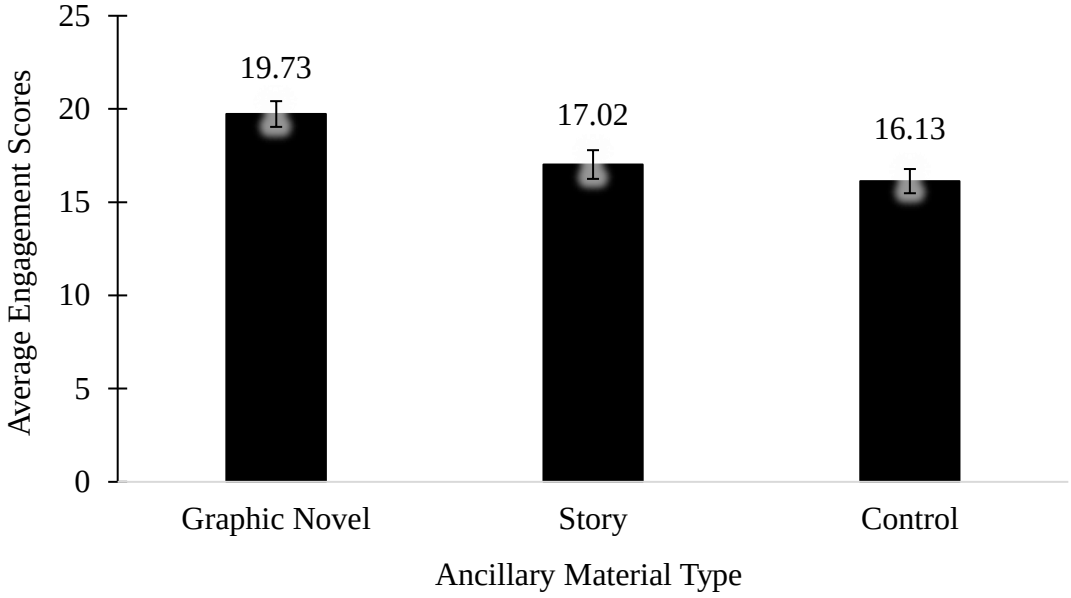


Figure 2. Average Engagement Scores as a Function of Ancillary Material Type



Appendix A

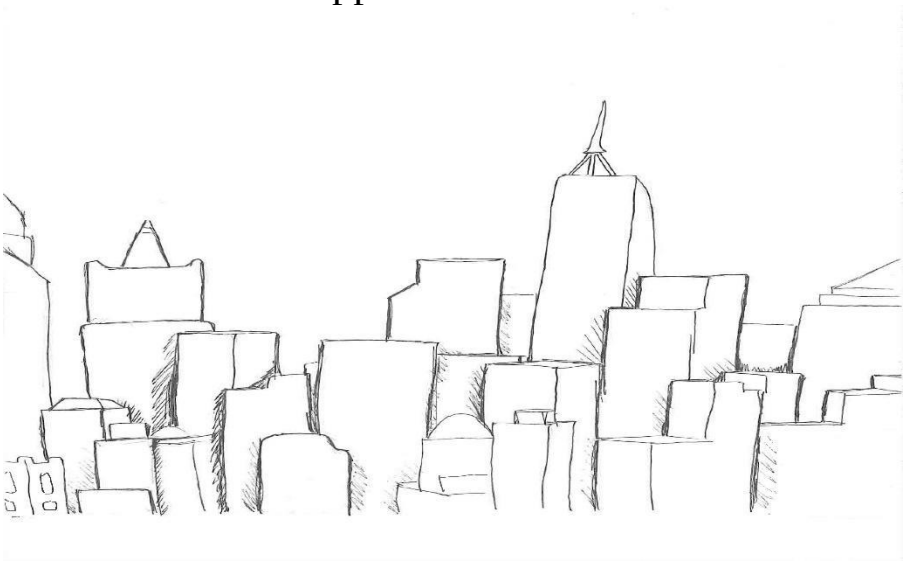
Alzheimer's disease begins with the buildup of beta-amyloid plaques between neurons, which results in altered cell functions, networks, metabolism, and repair. One type of protein, beta-amyloid 42, is toxic to the brain and when it builds up within the entorhinal cortex and hippocampus, memory deficits can occur. The entorhinal cortex is responsible for retrieving previously stored memories, while the hippocampus is responsible for storing memories for long-term retrieval. After affecting these two areas, the plaque then begins to affect the cerebral cortex. This leads to deficits in language, reasoning, behavior, and the completion of simple tasks. Glial cells perform many important functions in the brain, including clearing debris. However, for a person suffering from Alzheimer's, their glial cells are not able to do this appropriately. There are two glial cells that help with this process: astrocytes and microglia. These cells surround a neuron that has plague but are unable to perform the regular functions. Instead, the glial cells release a chemical (TREM-2) that causes chronic inflammation, further progressing the disease.

While this is occurring, there are things called "neurofibrillary tangles" that release a protein known as tau. In healthy neurons, the microtubules support the neurons by guiding nutrients and molecules from the cell to the dendrites and axon. However, in people with Alzheimer's tau detaches from the microtubules and blocks off the neuron's transport system. This leads to a beta-amyloid clog-up in the brain's arteries, causing vascular problems and the ultimate failure of the blood brain barrier (BBB). The BBB helps to protect the brain through selective permeability, keeping out harmful chemicals (e.g., chemotherapy) and allowing nutrients (e.g., glucose) to pass through. If there is an issue with the BBB, the brain will not receive an adequate amount of glucose, which impairs the brain's ability to rid itself of the beta-amyloid plaque and tangles. Following this, neurons are lost, and the transport systems begin to shut down, resulting in brain shrinkage and ultimate brain death.

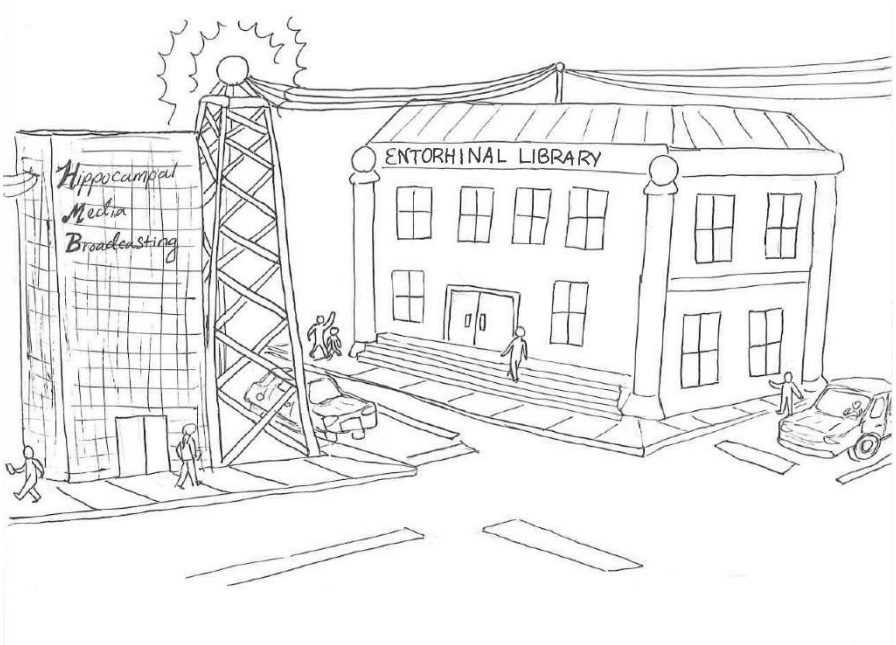
Chronic traumatic encephalopathy (CTE) is type of neurodegenerative disorder that is seen in individuals who have suffered repeated concussions and traumatic brain injuries (e.g., professional athletes, military veterans). The symptoms of CTE do not typically begin until years after the injury, so the extent of the damage often goes unnoticed or is misdiagnosed as another condition. Athletes who begin playing a contact sport at a younger age are at greater risk for developing CTE. Diagnosis for the disorder can only be done with an autopsy, which also plays a role in the undiagnosed nature of the disorder. As a result of the trauma, tau proteins begin to build up in the frontal lobe of the brain. The frontal lobe is primarily responsible for voluntary movement, but is also implicated in problem solving, language, judgement, and impulse control. Damage to the frontal lobe results in defective neurons with unstable cellular structures. As a result, the neurons cannot adequately communicate with other neurons, which results in memory impairment. The tau proteins then begin to build up in other areas of the brain, leading to gradual brain degeneration and loss of brain mass. One such area is the temporal lobe. Protein bundles build up in this area, which results in additional memory deficits, impaired judgment, depression, behavioral disturbances, and dementia. The tau proteins then begin to build up over the hippocampus (resulting in more memory impairment, such as the inability to store long term memories) and the amygdala (leading to outbursts of rage). The collective results of the tau buildup results in the entire brain being deformed and brittle. The tau deposits kill many nerve cells and shrink the brain by half of its original size.

Korsakoff's syndrome (KS) is a type of neurodegenerative disorder that is most often caused by frequent alcohol abuse. However, before the disorder progresses to Korsakoff's syndrome, it begins as Wernicke's Encephalopathy, which is caused by an inadequate supply of thiamine (B1), an important vitamin for proper bodily functioning. If Wernicke's Encephalopathy is left untreated, it can progress to Korsakoff's syndrome. This disorder is a further result of an inadequate dietary intake, which leads to an additional perpetuation of the thiamine deficiency. The demand for thiamine is likely to be increased when consuming alcohol because of increased requirements for alcohol metabolism. This may be increased even further during symptoms of alcohol withdrawal. Thiamine deficiency also causes excessive glutamate release. The damage caused by the combination of thiamine deficiency and alcohol metabolism affects thiamine transport at the blood brain barrier (BBB). This means that the vitamin is unable to cross the BBB, meaning the brain is not receiving adequate nutrients. Additionally, a person suffering from Korsakoff's syndrome experiences increases in the neurotransmitter GABA, which results in sluggishness. One also suffers from both anterograde amnesia and retrograde amnesia. Anterograde amnesia is the inability to consolidate and create new memories, while retrograde amnesia is the inability to access previously stored memories. Furthermore, Korsakoff's syndrome can lead to a disorientation in time and place, as well as impaired insight. Taken together, with the lack of nutrients, the brain will shrivel up and eventually starve to death.

Appendix B



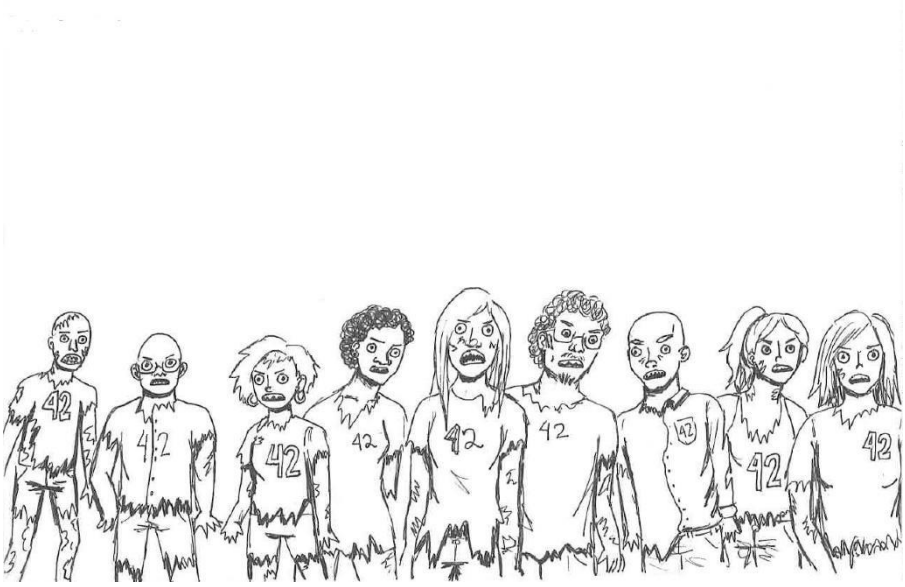
In the city of Neu York, a bustling megalopolis is defined by its cityscape architecture. The city is noted for its monuments including the Hippocampal Media Broadcast Building, the Entorhinal Library, and the various hubs of cerebrally-developed structures that help define the multicultural harmony of millions of people. The Hippocampal Media Broadcast Building helps citizens be cognizant of day-to-day moments that impact the city. The Entorhinal Library often keeps the history of the city's experience (for the sake of prosperity).



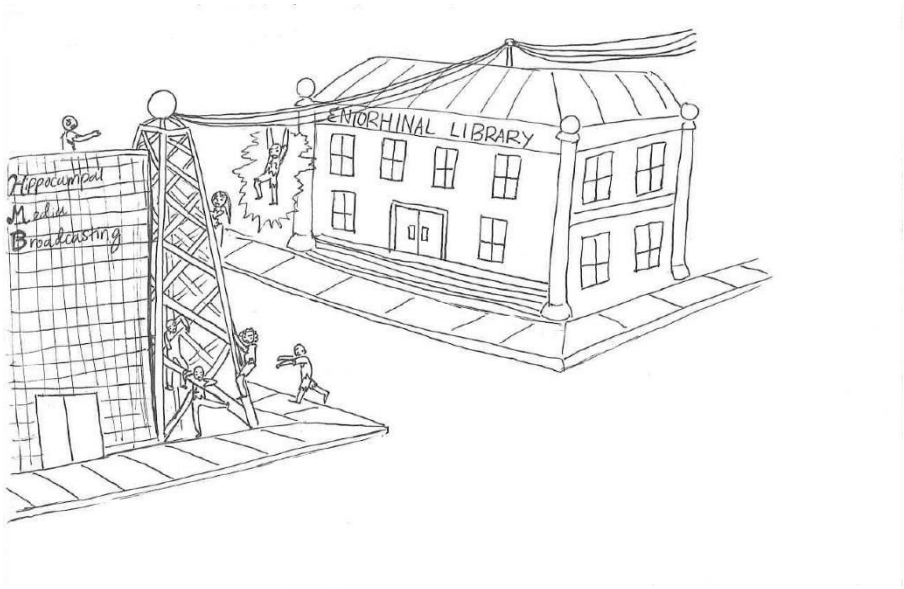
While these two centers are integral for the sake of remembrance, the accumulation of other centers enable the town to unify itself by providing links to communication of its citizens, laws

that maintain city structure, and standardize day to day operations that perpetuate city growth. When working fully, the city is bustling with constant activity. To ensure this, thousands of workers throughout the city do daily chores to maintain the city's efficiency. For instance, if there is ever waste or damage amongst the city's buildings, the A & M Glial Management system cleans all messes so that there is no delay in everyday life. Also, Microtubule Construction, Inc., transports essential building supplies throughout the city limits. This system of important entities is symbiotic within the city, as the companies enable the city to maintain itself, but, these companies are dependent on the communication within the city. Although complex, the city is able to thrive.

While defined as an iconic place for many years, there is an unsuspecting enemy that threatens to destroy the entire system of Neu York; an apocalypse is beginning to plague the city. Unbeknownst to millions, an army of enemy life forms begins to accumulate. Due to underground scientific experiments, a mutant virus, Beta Amyloid-42, infects citizens and causes them to become mindless zombies of destruction.

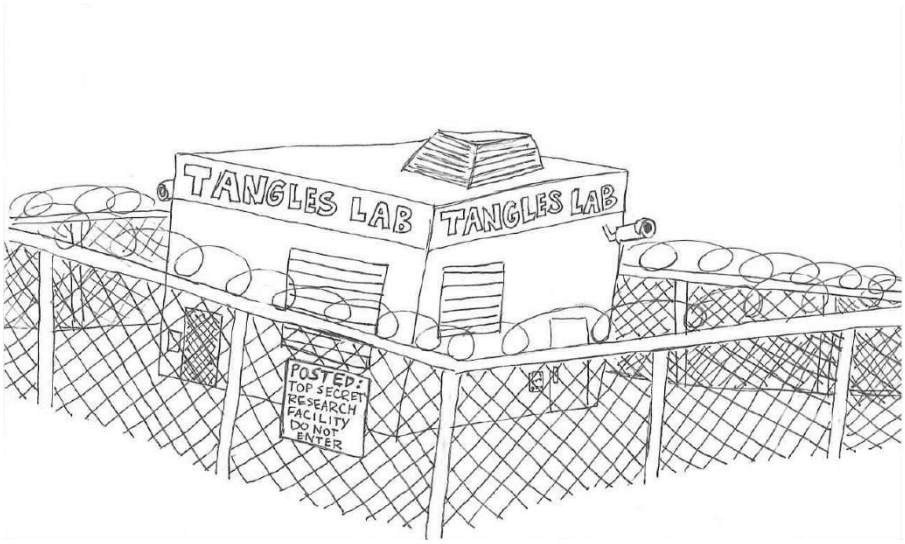


When the transformation is complete, these zombies are attracted to the energy waves that allow the city's entities to function, and they literally engulf any power supplies that keep the city entities connected.

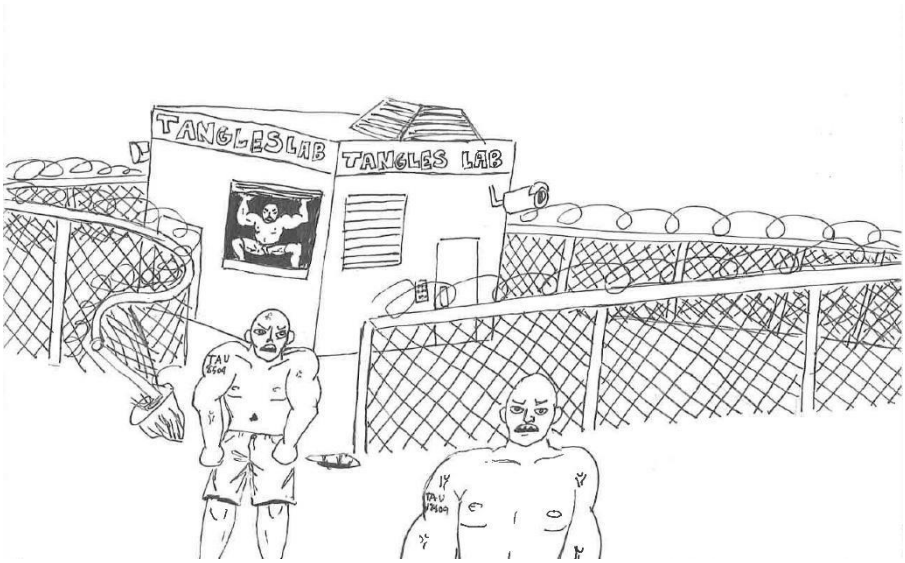


As a result, all structures that supply the city day-to-day information begin to fail. Chaos among the city's inhabitants occurs; wave 1 has begun, creating "plaques of decay" in the communication between vital parts of the city. This wave causes communication towers, wired pipelines of information, and electrical plants (that run communication) to deteriorate. The city's entities are now separated.

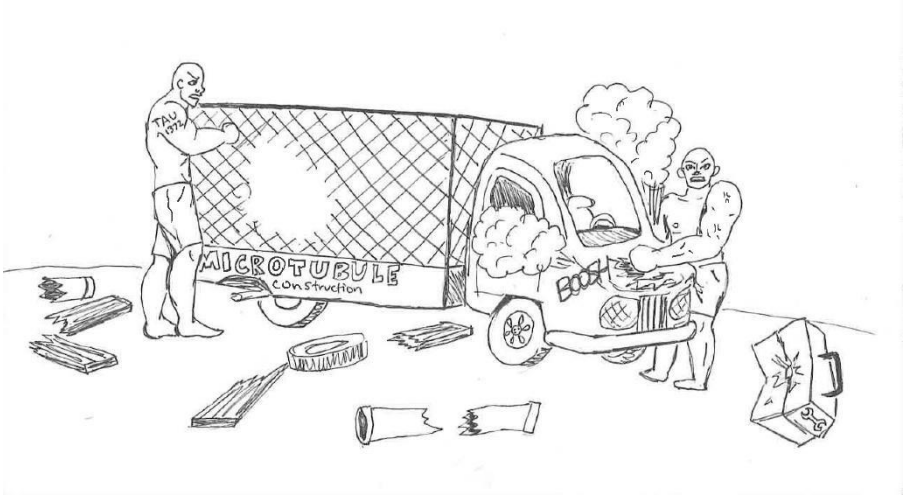
Unfortunately, a second wave of destruction befalls the city.



The rise of Beta-Amyloid infected zombies releases “tangles” that further infect citizens.



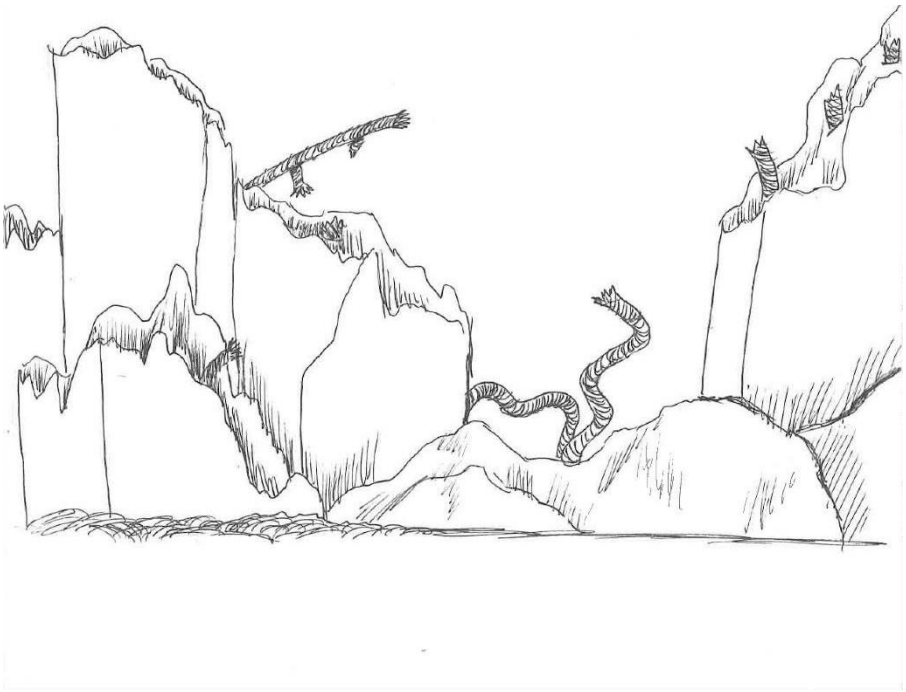
This residue, left all over the city, is communicable to other citizens, including the members of Microtubule Construction, Inc. As a result, these team members become infected with a Tau virus that makes them mindless and unable to help with the previous destruction. As a result, food and nutritive care is unable to be replenished throughout the city.

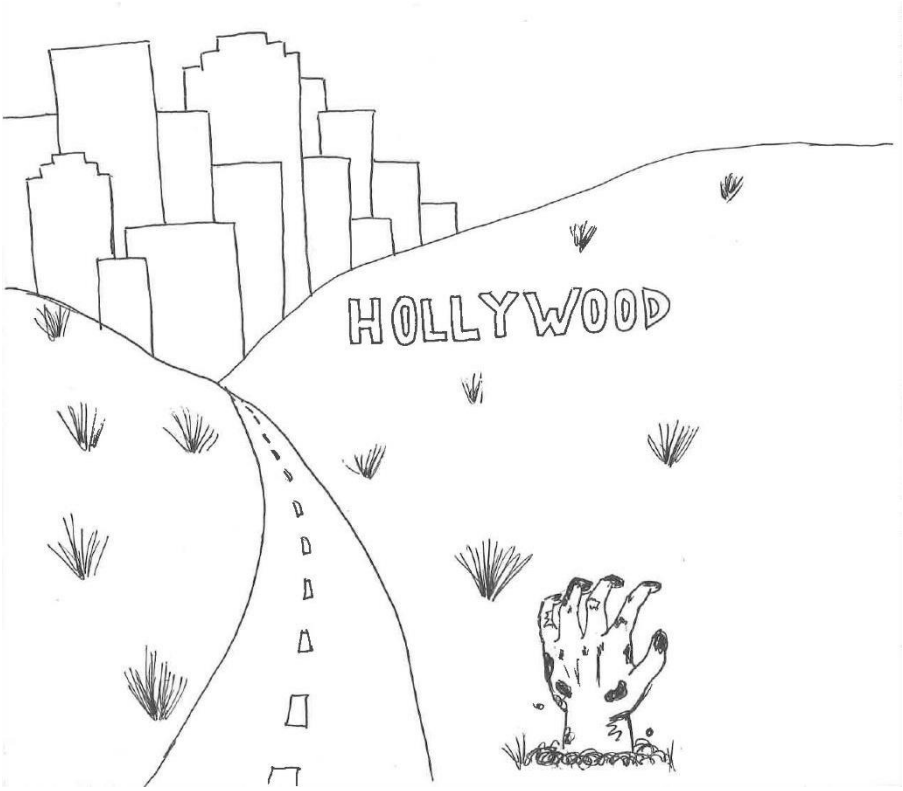


Without communication, many of the supportive members of the city have no idea what to do. For instance, A & M Glial Management, which relies on such communication, becomes confused as to what the city needs on a broad scale, and, as a result, relies on an internal communication system, TREM-2.

However, this system is failing, and the management team cannot help with the ongoing damage. To make matters even worse, the Beta-Amyloid virus infects so many people, that, on the border of the city, a further barrier between it and the rest of the country has been blocked, preventing imports of things that the city desperately needs.

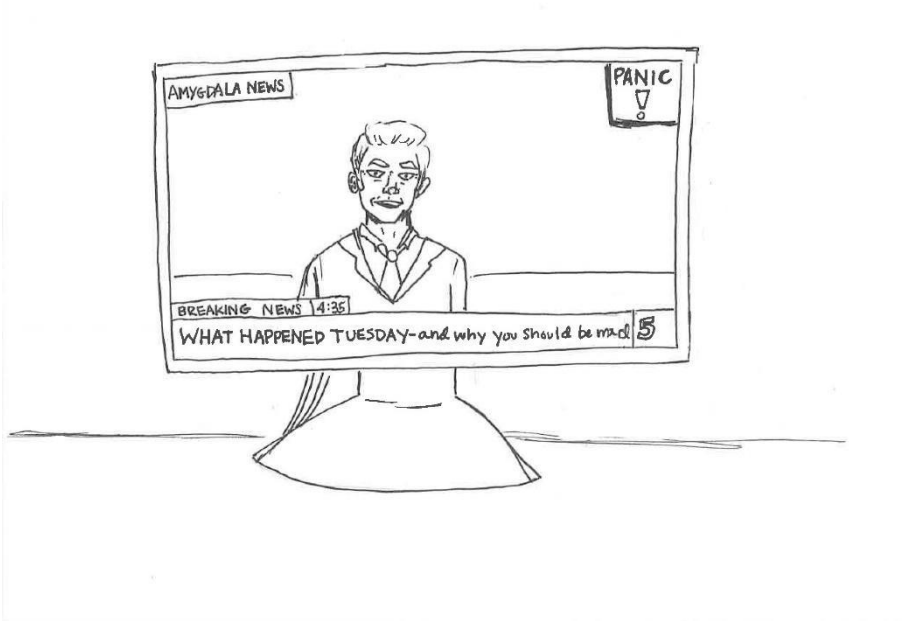
As a result, the city continues to deteriorate, and a once infallible city-structure is destroyed.



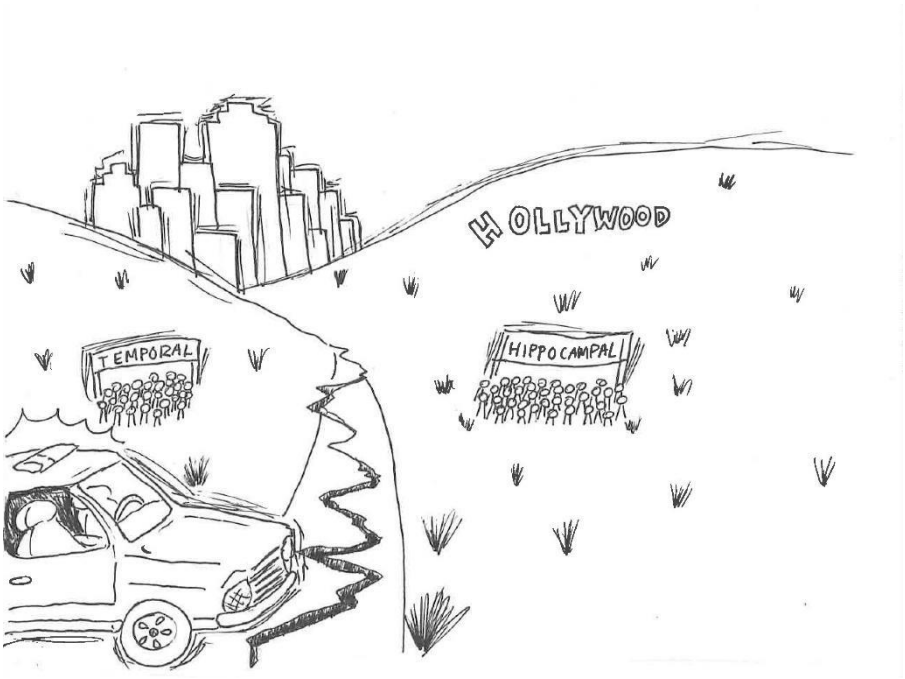


In the CiT-EE of Angels, there is sometimes an uneasy quiet to maintain a society. While the city maintains a day to day operation to function, sociocultural events have made the general society uneasy. When events beyond anyone's control may make matters worse, the tension among the city can produce devastating consequences. Such is the story of this city. The history of uneasiness based on people not getting along has created a racial and socioeconomic divide. Communication among citizens has maintained a social unrest between certain racial and socioeconomic groups and the law enforcement who maintain a false sense of security within the overall community. With broadcasts from the Temporal and Hippocampal Communications Center, certain groups within the community have developed a medial platform for inequity, and these groups have become even more uneasy with continual portrayals of unrest.

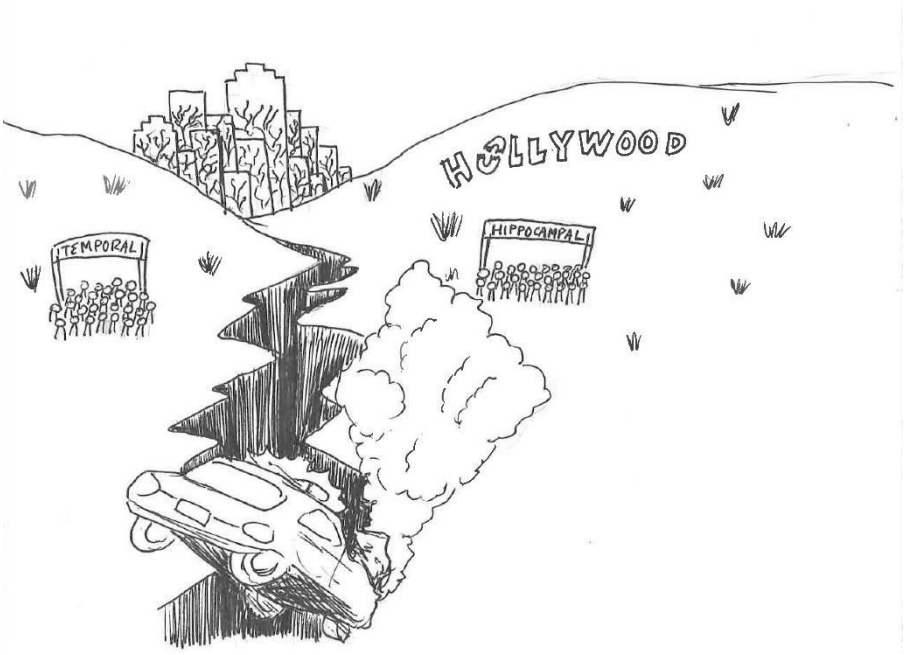
To add to this, media forums like Amygdala Telecommunications incites a strong sense of fear and rage with these members of the community. As a result, the society (depending on the side of the conflict) is ready to create physical destruction if the time is right. In the event that an environmental stress occurs, the members of the city are primed to destroy the foundations of the city, regardless of rational opposition to maintain stability. The city is clearly in peril.



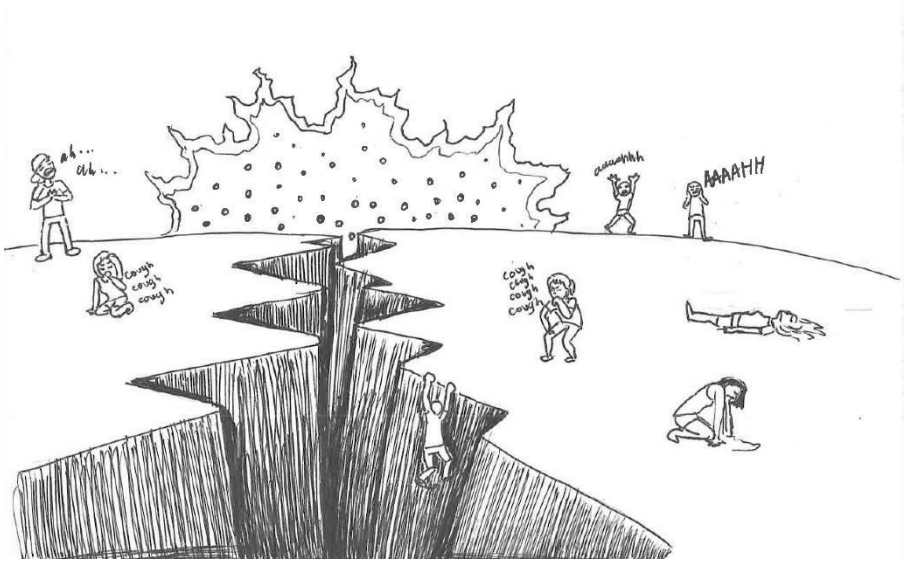
Unfortunately, an environmental catalyst can easily make a situation even worse. Due to geographical placement, the city is sensitive to physical unrest. Members of this city have chosen to exist in a place where major earthquakes are inevitable, and if such earthquakes occur, the memories and emotions of citizens may lead the city to a more destructive solution. If the city unfolds, the unrest may lead to further riot and destruction to the structures that have held the city together for many years. On this day, the lack of social structure can lead to cataclysmic destruction of the entire society.



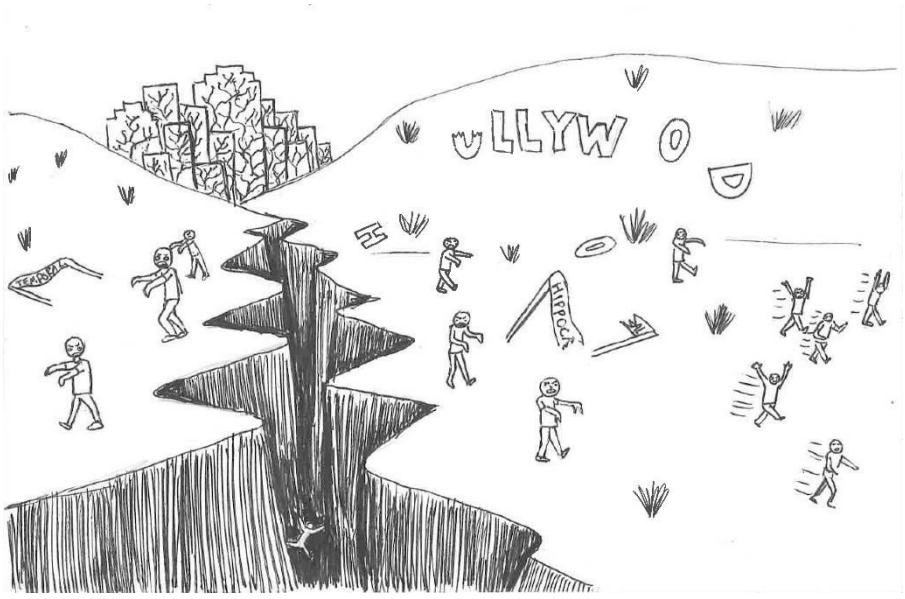
As earthquakes accumulate, the damage to the architecture of the city is apparently affected. However, these waves of earthquakes are creating a new threat. The rise of geographic activity has unearthed a mutant virus that has been lying dormant for many years.



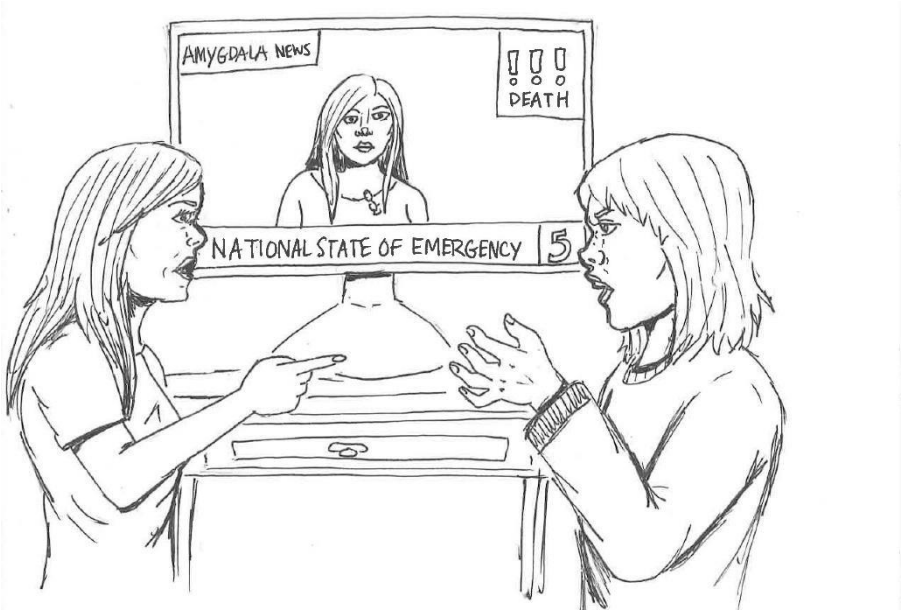
The tau virus in the earth has become active, and regular activity beneath the earth's surface has caused splits from underneath the crust. As a result, the virus becomes unleashed into the air (and to the citizens) exposing members of the community to the mindless, primal sentiment that one sees in a zombie.



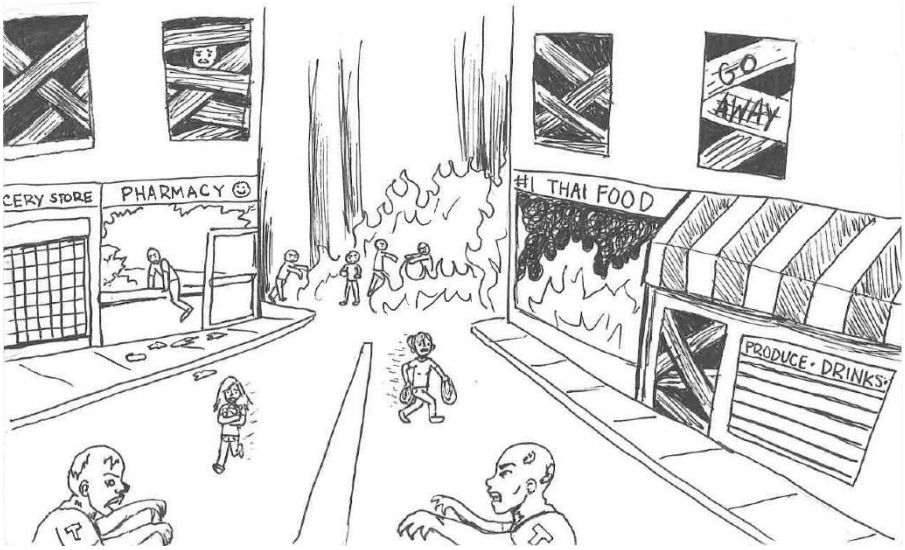
As the rumbling in the earth's crust continues, more members of the society are infected, and their levels of rational thought turn to mindless fear and aggression.



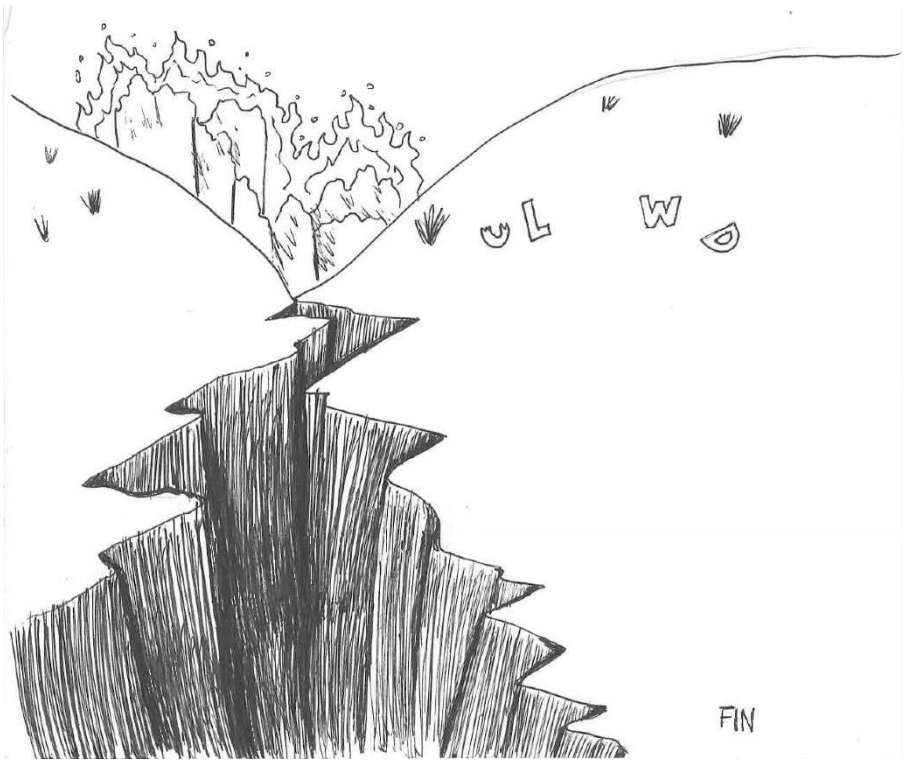
These environmental influences serve as the source of bias for stories produced by the Temporal and Hippocampal Communications Center and by Amygdala Telecommunications, who collectively raise community hysteria.

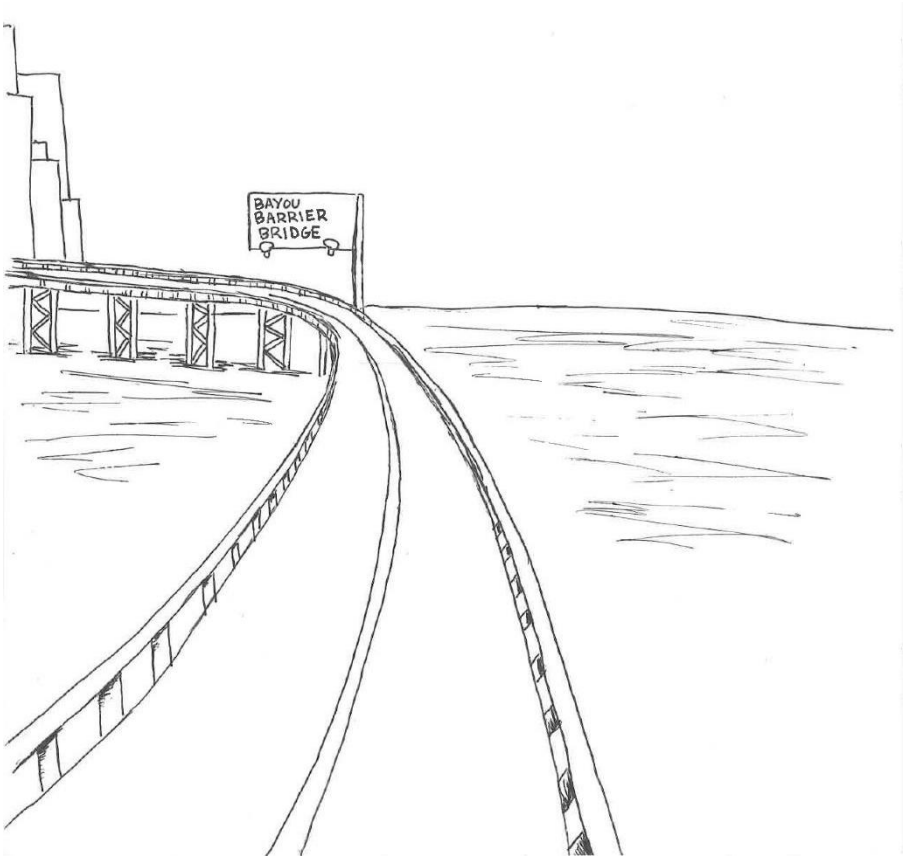


Moreover, many of these members are infected by the Tau Virus, and their lack of rationale judgement increases the chance of community outbreak within the city. Overall, many previously logical parties are infected, and their message causes paranoia, fear, and rage against a perceived threat. These community parties encourage other mutated persons to create riots and destruction throughout the structures of the city.



As a result, the city works against itself, and community parties actively (and blindly) destroy the city in a way that it permanently diminishes structure in society and architecture. The city begins to implode, causing a once great city to crumble to half of its size.





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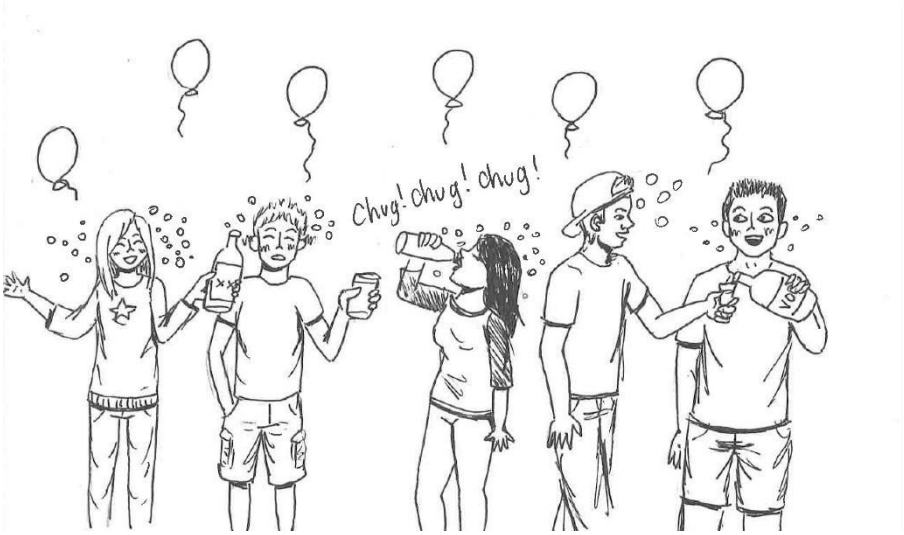
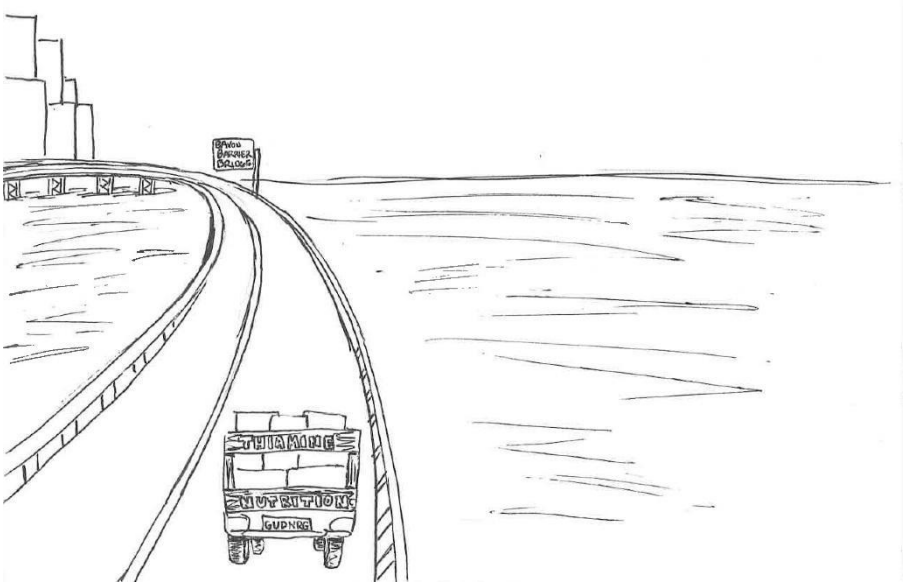


Unfortunately, such drunkenness does not match the biological needs of its inhabitants, and, as a result, nutrients to maintain proper health are lacking. More specifically, the Thiamine Nutrition Company (TNC), the supplier of the city's vitamins and nutrients for the entire city, must cross the Bayou Barrier Bridge (BBB) on a regular basis.

These dedicated TNC workers continue to push through the BBB in order to feed the needy people.



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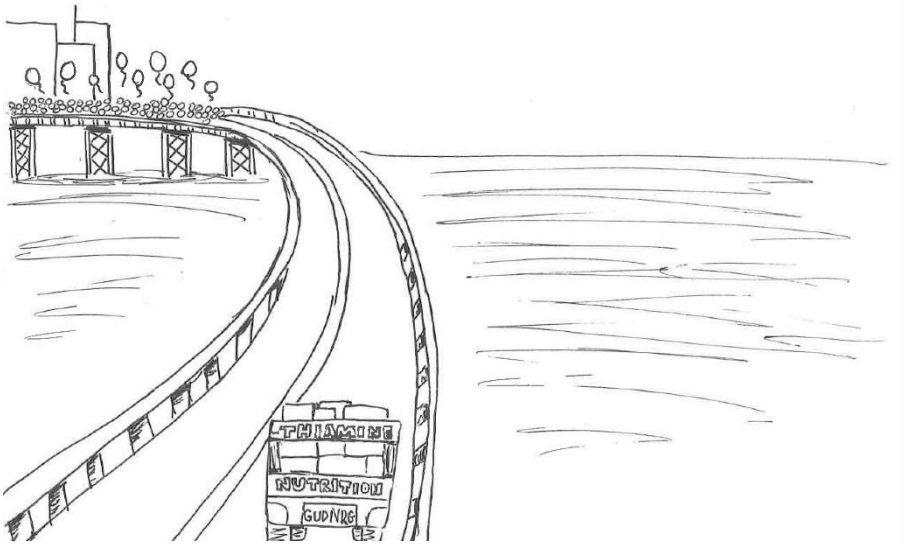

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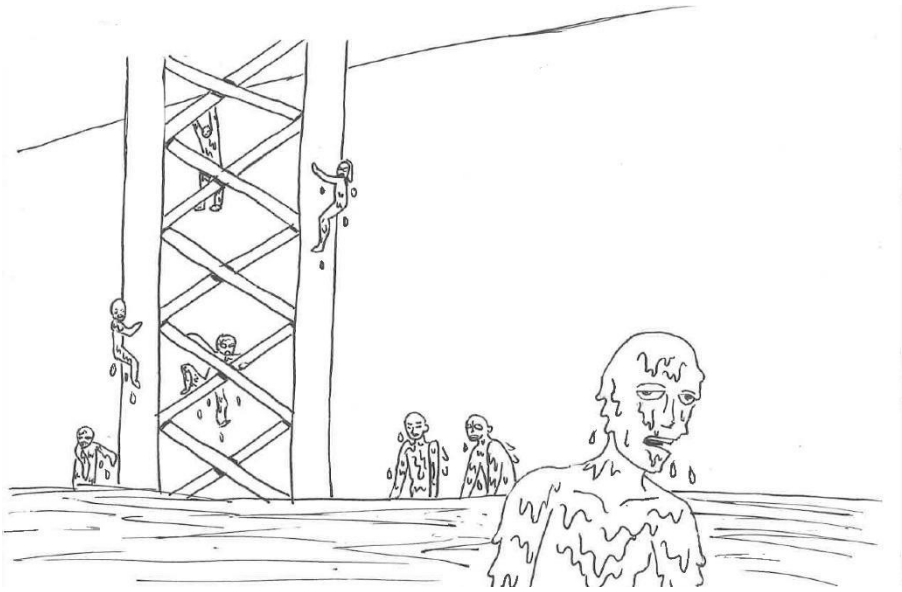
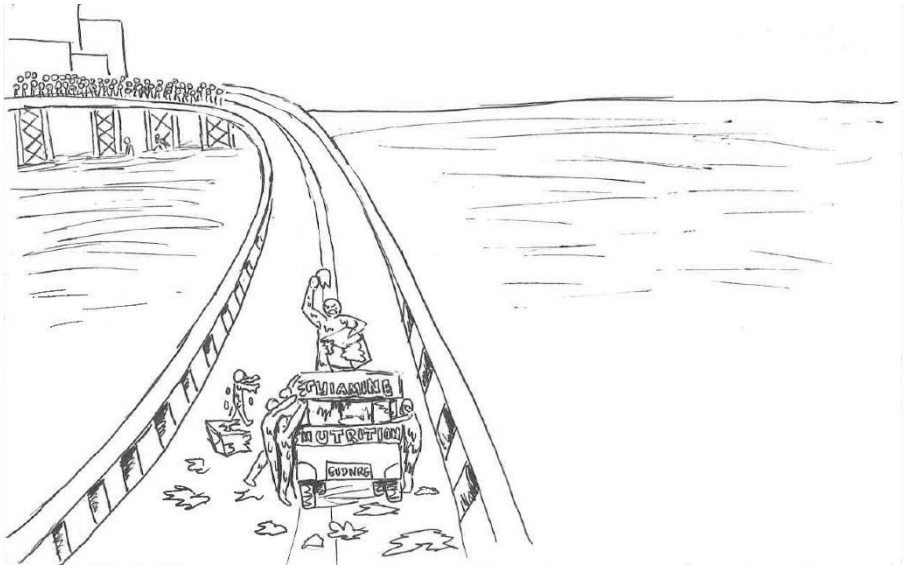
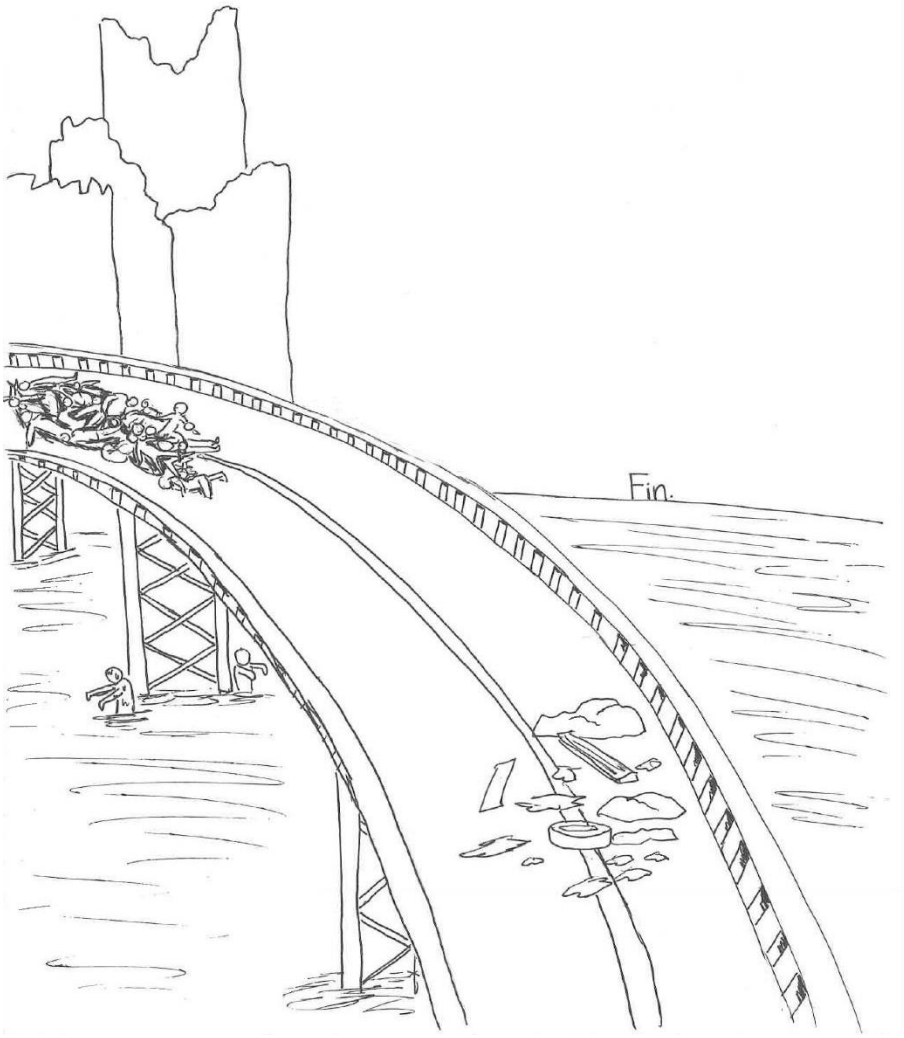
Then, the unthinkable happens. From the reaches of the BBB, zombies become unearthed, causing the TNC workers to either flee or perish.



These zombies attack the workers and destroy the food supplies, which results in the last remaining hope of feeding the city perishing.



As the dazed crowd continues, millions of people gradually starve to death, and this once great city is turned to ruins. The party is over.



Appendix C

In the city of Neu York, a bustling megalopolis is defined by its cityscape architecture. The city is noted for its monuments including the Hippocampal Media Broadcast Building, the Entorhinal Library, and the various hubs of cerebrally-developed structures that help define the multicultural harmony of millions of people. The Hippocampal Media Broadcast Building helps citizens be cognizant of day-to-day moments that impact the city. The Entorhinal Library often keeps the history of the city's experience (for the sake of prosperity). While these two centers are integral for the sake of remembrance, the accumulation of other centers enable the town to unify itself by providing links to communication of its citizens, laws that maintain city structure, and standardize day to day operations that perpetuate city growth. When working fully, the city is bustling with constant activity. To ensure this, thousands of workers throughout the city do daily chores to maintain the city's efficiency. For instance, if there is ever waste or damage amongst the city's buildings, the A & M Glial Management system cleans all messes so that there is no delay in everyday life. Also, Microtubule Construction, Inc., transports essential building supplies throughout the city limits. This system of important entities is symbiotic within the city, as the companies enable the city to maintain itself, but, these companies are dependent on the communication within the city. Although complex, the city is able to thrive.

While defined as an iconic place for many years, there is an unsuspecting enemy that threatens to destroy the entire system of Neu York; an apocalypse is beginning to plague the city. Unbeknownst to millions, an army of enemy life forms begins to accumulate. Due to underground scientific experiments, a mutant virus, Beta Amyloid-42, infects citizens and causes them to become mindless zombies of destruction. When the transformation is complete, these zombies are attracted to the energy waves that allow the city's entities to function, and they literally engulf any power supplies that keep the city entities connected. As a result, all structures that supply the city day-to-day information begin to fail. Chaos among the city's inhabitants occurs; wave 1 has begun, creating "plaques of decay" in the communication between vital parts of the city. This wave causes communication towers, wired pipelines of information, and electrical plants (that run communication) to deteriorate. The city's entities are now separated.

Unfortunately, a second wave of destruction befalls the city. The rise of Beta-Amyloid infected zombies releases "tangles" that further infect citizens. This residue, left all over the city, is communicable to other citizens, including the members of Microtubule Construction, Inc. As a result, these team members become infected with a Tau virus that makes them mindless and unable to help with the previous destruction. As a result, food and nutritive care is unable to be replenished throughout the city.

Without communication, many of the supportive members of the city have no idea what to do. For instance, A & M Glial Management, which relies on such communication, becomes confused as to what the city needs on a broad scale, and, as a result, relies on an internal communication system, TREM-2. However, this system is failing, and the management team cannot help with the ongoing damage. To make matters even worse, the Beta-Amyloid virus infects so many people, that, on the border of the city, a further barrier between it and the rest of the country has been blocked, preventing imports of things that the city desperately needs. As a result, the city continues to deteriorate, and a once infallible city-structure is destroyed.

In the CiT-EE of Angels, there is sometimes an uneasy quiet to maintain a society. While the city maintains a day to day operation to function, sociocultural events have made the general society uneasy. When events beyond anyone's control may make matters worse, the tension among the city can produce devastating consequences. Such is the story of this city. The history of uneasiness based on people not getting along has created a racial and socioeconomic divide. Communication among citizens has maintained a social unrest between certain racial and socioeconomic groups and the law enforcement who maintain a false sense of security within the overall community. With broadcasts from the Temporal and Hippocampal Communications Center, certain groups within the community have developed a medial platform for inequity, and these groups have become even more uneasy with continual portrayals of unrest. To add to this, media forums like Amygdala Telecommunications incites a strong sense of fear and rage with these members of the community. As a result, the society (depending on the side of the conflict) is ready to create physical destruction if the time is right. In the event that an environmental stress occurs, the members of the city are primed to destroy the foundations of the city, regardless of rational opposition to maintain stability. The city is clearly in peril.

Unfortunately, an environmental catalyst can easily make a situation even worse. Due to geographical placement, the city is sensitive to physical unrest. Members of this city have chosen to exist in a place where major earthquakes are inevitable, and if such earthquakes occur, the memories and emotions of citizens may lead the city to a more destructive solution. If the city unfolds, the unrest may lead to further riot and destruction to the structures that have held the city together for many years. On this day, the lack of social structure can lead to cataclysmic destruction of the entire society.

As earthquakes accumulate, the damage to the architecture of the city is apparently affected. However, these waves of earthquakes are creating a new threat. The rise of geographic activity has unearthed a mutant virus that has been lying dormant for many years. The tau virus in the earth has become active, and regular activity beneath the earth's surface has caused splits from underneath the crust. As a result, the virus becomes unleashed into the air (and to the citizens) exposing members of the community to the mindless, primal sentiment that one sees in a zombie. As the rumbling in the earth's crust continues, more members of the society are infected, and their levels of rational thought turn to mindless fear and aggression. These environmental influences serve as the source of bias for stories produced by the Temporal and Hippocampal Communications Center and by Amygdala Telecommunications, who collectively raise community hysteria. Moreover, many of these members are infected by the Tau Virus, and their lack of rationale judgement increases the chance of community outbreak within the city. Overall, many previously logical parties are infected, and their message causes paranoia, fear, and rage against a perceived threat. These community parties encourage other mutated persons to create riots and destruction throughout the structures of the city. As a result, the city works against itself, and community parties actively (and blindly) destroy the city in a way that it permanently diminishes structure in society and architecture. The city begins to implode, causing a once great city to crumble to half of its size.

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Then, the unthinkable happens. From the reaches of the BBB, zombies become unearthed, causing the TNC workers to either flee or perish. These zombies attack the workers and destroy the food supplies, which results in the last remaining hope of feeding the city perishing. As the dazed crowd continues, millions of people gradually starve to death, and this once great city is turned to ruins. The party is over.

Appendix D

A puppy is a juvenile dog. Some puppies can weigh 1–3 lbs (0.45–1.36 kg), while larger ones can weigh up to 15–23 lbs (6.8–10.4 kg). All healthy puppies grow quickly after birth. A puppy's coat color may change as the puppy grows older, as is commonly seen in breeds such as the Yorkshire Terrier. In vernacular English, *puppy* refers specifically to dogs, while *pup* may often be used for other mammals such as seals, giraffes, guinea pigs, or even rats. Born after an average of 63 days of gestation, puppies emerge in an amnion that is bitten off and eaten by the mother dog. Puppies begin to nurse almost immediately. If the litter exceeds six puppies, particularly if one or more are obvious runts, human intervention in hand-feeding the stronger puppies is necessary to ensure that the runts get proper nourishment and attention from the mother. As they reach one month of age, puppies are gradually weaned and begin to eat solid food. The mother may regurgitate partially digested food for the puppies or might let them eat some of her solid food. The mother dog usually refuses to nurse at this stage, though she might let them occasionally nurse for comfort. At first, puppies spend the large majority of their time sleeping and the rest feeding. They instinctively pile together into a heap and become distressed if separated from physical contact with their littermates, by even a short distance. Puppies are born with a fully functional sense of smell but can't open their eyes. During their first two weeks, a puppy's senses all develop rapidly. During this stage the nose is the primary sense organ used by puppies to find their mother's teats, and to locate their littermates, if they become separated by a short distance. Puppies open their eyes about nine to eleven days following birth. At first, their retinas are poorly developed and their vision is poor. Puppies are not able to see as well as adult dogs. In addition, puppies' ears remain sealed until about thirteen to seventeen days after birth, after which they respond more actively to sounds. Between two and four weeks old, puppies usually begin to growl, bite, wag their tails, and bark.

Puppies develop very quickly during their first three months, particularly after their eyes and ears open and they are no longer completely dependent on their mother. Their coordination and strength improve, they spar with their littermates, and begin to explore the world outside the nest. They play wrestling, chase, dominance, and tug-of-war games. Puppies are highly social animals and spend most of their waking hours interacting with either their mother or littermates. When puppies are socialized with humans, particularly between the ages of eight and twelve weeks, they develop social skills around people. Those that do not receive adequate socialization during this period may display fearful behavior around humans or other dogs as adults. The optimum period for socialization is between eight and twelve weeks; professional animal trainers and the American Kennel Club advise puppies should be introduced to 100 People by 12 Weeks and have encountered a wide and varied selection of people and environments.

A kitten, also known as a kitty or kitty cat, is a juvenile cat. After being born, kittens are totally dependent on their mother for survival and they do not normally open their eyes until after seven to ten days. After about two weeks, kittens quickly develop and begin to explore the world outside the nest. After a further three to four weeks, they begin to eat solid food and grow adult teeth. Domestic kittens are highly social animals and enjoy human companionship. The word "kitten" derives from the Middle English word *kitoun*, which in turn came from the Old French *chitoun* or *cheton*. Juvenile big cats are called "cubs" rather than kittens; either term may be used for the young of smaller wild felids, such as ocelots, caracals and lynx, but "kitten" is usually more common for these species. A feline litter usually consists of two to five kittens born after a gestation lasting between 64 and 67 days, with an average length of 66 days. Kittens emerge in a sac called the amnion, which is bitten off and eaten by the mother cat.

For the first several weeks, kittens are unable to urinate or defecate without being stimulated by their mother. They are also unable to regulate their body temperature for the first three weeks, so kittens born in temperatures less than 27 °C (81 °F) can die from hypothermia if their mother does not keep them warm. The mother's milk is very important for the kittens' nutrition and proper growth. This milk transfers antibodies to the kittens, which helps protect them against infectious disease. Newborn kittens are unable to produce concentrated urine, and so they have a very high requirement for fluids. Kittens open their eyes about seven to ten days after birth. At first, the retina is poorly developed and vision is poor. Kittens are not able to see as well as adult cats until about ten weeks after birth.

Kittens develop very quickly from about two weeks of age until their seventh week. Their coordination and strength improve. They play-fight with their litter-mates and begin to explore the world outside the nest or den. They learn to wash themselves and others as well as play hunting and stalking games, showing their inborn ability as predators. These innate skills are developed by the kittens' mother or other adult cats, who bring live prey to the nest. Later, the adult cats demonstrate hunting techniques for the kittens to emulate. As they reach three to four weeks old, the kittens are gradually weaned and begin to eat solid food, with weaning usually complete by six to eight weeks. Kittens generally begin to lose their baby teeth around three months of age and have a complete set of adult teeth by nine months. Kittens live primarily on solid food after weaning, but usually continue to suckle from time to time until separated from their mothers. Some mother cats will scatter their kittens as early as three months of age, while others continue to look after them until they approach sexual maturity. Kittens are highly social animals and spend most of their waking hours interacting with available animals and playing on their own. Play with other kittens peaks in the third or fourth month after birth, with more solitary hunting and stalking play peaking later, at about five months.

Elephants are large mammals of the family Elephantidae and the order Proboscidea. Male African elephants are the largest extant terrestrial animals and can reach a height of 4 m (13 ft) and weigh 7,000 kg (15,000 lb). Elephants are herbivorous and can be found in different habitats including savannahs, forests, deserts, and marshes. They prefer to stay near water. They are considered to be keystone species due to their impact on their environments. Other animals tend to keep their distance from elephants while predators, such as lions, tigers, hyenas, and wild dogs, usually target only young elephants (or "calves"). Females ("cows") tend to live in family groups, which can consist of one female with her calves or several related females with offspring. The groups are led by an individual known as the matriarch, often the oldest cow. Elephants have a fission–fusion society in which multiple family groups come together to socialize. Males ("bulls") leave their family groups when they reach puberty and may live alone or with other males. Adult bulls mostly interact with family groups when looking for a mate and enter a state of increased testosterone and aggression known as musth, which helps them gain dominance and reproductive success. Calves are the center of attention in their family groups and rely on their mothers for as long as three years. Elephants can live up to 70 years in the wild. They communicate by touch, sight, smell, and sound; elephants use infrasound, and seismic communication over long distances. Elephant intelligence has been compared with that of primates and cetaceans. They appear to have self-awareness and show empathy for dying or dead individuals of their kind. African elephants are listed as vulnerable by the International Union for Conservation of Nature (IUCN) while the Asian elephant is classed as endangered. One of the biggest threats to elephant populations is the ivory trade, as the animals are poached for their ivory tusks.

Appendix E

1.) The function of the hippocampus is to:
a.) retrieve memories that have been previously stored
b.) link emotional reactions to memories that one experiences
c.) enable one to develop working memory of procedural events
d.) enable awareness of events that get stored as memories

2.) The function of the entorhinal cortex is to:
a.) retrieve memories that have been previously stored
b.) link emotional reactions to memories that one experiences
c.) enable one to develop working memory of procedural events
d.) enables awareness of events that get stored as memories

***3.) Which part of a neuron does a beta-amyloid protein destroy?**
a.) myelin b.) dendrite c.) myelin sheath d.) soma

***4) Which part of a neuron does a tau protein destroy?**
a.) myelin b.) dendrite c.) myelin sheath d.) soma

5.) The genetic variation of beta amyloid that links to dementia is beta-amyloid- ___
a.) 16 b.) 28 c.) 42 d.) 64

***6.) A defective gene known as TREM-2 causes ____ in the brain, resulting in further dementia.**
a.) inflammation by glial cells c.) toxins entering adjacent neurons
b.) degeneration of axons d.) increase of tangles in the soma

***7.) _____ are cell components that maintain the structure of the cell body.**
a.) Vacuoles b.) Microtubules c.) Telomeres d.) Endoplasmic reticula

***8.) Two glial cells that attempt to aid in removing plaques from the brain are:**
a.) radial glia and oligodendrocytes c.) astrocytes and microglia
b.) astrocytes and radial glia d.) oligodendrocytes and microglia

9.) Symptoms of dementia as a result of chronic traumatic encephalopathy (CTE) also result in bouts of fear and rage that alter the ____ in the brain.
a.) stria terminalis b.) hippocampus c.) amygdala d.) substantia nigra

***10.) The conditions of chronic traumatic encephalopathy (CTE) are a result of repeated:**
a.) mini-strokes within the brain c.) mechanical collisions of the skull
b.) exposure to toxic chemicals in one's diet d.) exposure to effects of MRI scans

***11.) The cell death in the brain as a result of CTE can shrink the brain by __% in size.**
a.) 10 b.) 25 c.) 50 d.) 75

12.) The buildup of the ___ protein results in the shrinkage of the brain (due to cell death).
a.) apolipase b.) tau c.) huntingtin d.) prosenelin

13.) The cortex that is most affected by CTE symptoms is the ____ lobe.
a.) frontal b.) parietal c.) temporal d.) occipital

14.) Symptoms of Korsakoff's syndrome result from bodily deficits of:
a.) thiamine b.) riboflavin c.) calcium d.) water

15.) In order for the brain to receive necessary nutrition, glucose must enter the brain through the:
a.) meningeal system b.) blood-brain barrier c.) ventricular system d.) corticotrophin cortex

16.) Increases of _____ signal sluggishness in persons who develop Korsakoff's syndrome.
a.) L-DOPA b.) GABA c.) 5-HT d.) Pax 6

***17.) With symptoms of Korsakoff's syndrome, one suffers symptoms of anterograde amnesia, which is an inability to:**
a.) retrieve previous memories when speaking c.) consolidate new memories from the present
b.) be consciously aware of one's emotional state d.) recognize faces of friends and family

***18.) Korsakoff's syndrome creates an inability to detect when one is hungry, which affects function of the _____ in the brain:**
a.) hypothalamus b.) medulla oblongata c.) hippocampus d.) cerebellum

*denotes questions that were only seen in the background reading

Appendix F

You are being asked to complete the following survey. These responses will be aggregated and cannot be traced back to you in any way (i.e., your identity will not be known). Please be open and straightforward in your responses to all questions below.

PLEASE ANSWER THE FOLLOWING QUESTIONS IN TERMS OF HOW THEY PERTAIN TO YOUR UNDERSTANDING OF THE NERVOUS SYSTEM AND NEURODEGENERATIVE DISORDERS

I consider this ancillary material to be engaging for my understanding of neurodegenerative disorders:

Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly
1	2	3	4	5

I feel that this ancillary material WOULD useful to better understand classroom lectures:

Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly
1	2	3	4	5

I believe this ancillary material creatively explores the content of brain and behavior:

Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly
1	2	3	4	5

I believe that more ancillary material like this should be available in my psychology classes:

Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly
1	2	3	4	5

I would consider purchasing more ancillary material in this format if taking a neuroscience course:

Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree strongly
1	2	3	4	5