CRESST REPORT 836

AUTOMATICALLY SCORING SHORT ESSAYS FOR CONTENT

DECEMBER, 2013

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Abstract

The Common Core assessments emphasize short essay constructed response items over multiple choice items because they are more precise measures of understanding. However, such items are too costly and time consuming to be used in national assessments unless a way is found to score them automatically. Current automatic essay scoring techniques are inappropriate for scoring the content of an essay because they rely on either grammatical measures of quality or machine learning techniques, neither of which identifies statements of meaning (propositions) in the text. In this report, we explain our process of (1) extracting meaning from student essays in the form of propositions using our text mining framework called SemScape, (2) using the propositions to score the essays, and (3) testing our system's performance on two separate sets of essays. Results demonstrate the potential of this purely semantic process and indicate that the system can accurately extract propositions from student short essays, approaching or exceeding standard benchmarks for scoring performance.

Introduction

The impending implementation of Common Core assessments across the United States brings with it a shift in large-scale assessments from multiple choice items to short essay constructed response items as measures of student knowledge of a given concept (Wu, 2012). Short essay constructed response items consist of a targeted prompt, such as "Explain how fractions and decimals are related," and the written response of each student to that prompt. The prompts measure deeper understanding (Baker, Aschbacher, Niemi, & Sato, 1992) and are more precise (Huang, Tsai, Hsu, & Pan, 2006; Jacobs-Lawson & Hershey, 2002; Klein, Chung, Osmundson, & Herl, 2002) than multiple choice items in measuring a student's understanding of a given topic. However, short essay items are also significantly more difficult to score than multiple choice items because the need for human raters makes the process both time-consuming and expensive (Magliano & Graesser, 2012; Wu, 2012).

Automated, unsupervised methods of scoring student textual responses would significantly reduce the heavy workload currently associated with large-scale scoring of constructed response items (Villalon & Calvo, 2009), as well as the often prohibitive costs of such scoring (O'Neil & Klein, 1997; Rozali, Hassan, & Zamin, 2011). Additionally, automatically extracting content could mitigate the subjectivity of human raters and reduce bias against poorly written works that are conceptually correct (Smith & Humphreys, 2006), which could result in more accurate assessments of knowledge for students who are English Language Learners or who struggle with writing, and reduce the positive bias towards students who are better at writing but might not understand the content as well.

However, automatically scoring the accuracy of students' textual responses is a particularly challenging problem (Graesser, McNamara, & Louwerse, 2009; Valerio & Leake, 2006). Research to date has focused largely on either grading essays based on grammar, coherence, and style or grading the content of short answer questions based on bag-of-words approaches or machine learning techniques (Landauer, Laham, & Foltz, 2003; Mohler & Mihalcea, 2009; Shermis, Burstein, Higgins, & Zechner, 2010).

These approaches are increasingly successful at identifying the quality of writing and the general content area being covered in the text, but they cannot extract the basic statements of meaning, or *propositions* (Kintsch, 1974), that indicate the precise level of conceptual understanding evinced in a given essay. If student textual responses are going to be used as large-scale assessments of student content knowledge in areas such as math or science, where writing quality is not the metric of concern, the automatic extraction of propositions from student texts is necessary.

In this report we propose a system that automatically extracts propositions from student writing based solely on the semantic content of the response. To examine the ability of the system to automatically score student writing for content, we:

1. Automatically generate propositions from grammatical structures in the text using a domain-independent rule-based natural language processing framework.
2. Propose a simple but effective essay grading system based on the generated propositions.
3. Evaluate our system on two data sets.[1]
4. Discuss ways that the system can be improved in the future.

Related Work

One of the most common methods of extracting propositions from text is a lightweight summarization approach (Vargas-Vera & Moreale, 2005) that uses part-of-speech tagging to

[1] Data sets and other supporting information can be found in the appendices or online at http://semscape.cs.ucla.edu/mapper/downloads.html

identify nouns in the text and then uses machine learning techniques to determine whether or not there is a semantic relationship between the identified nouns based on the relative proximity of the nouns to each other and the frequency of their co-occurrence in the same sentence. Cañas et al. (2005), Chen, Kinshuk, Wei, and Chen (2008), Gaines and Shaw (1994), Lau, Song, Li, Cheung, and Hao (2009), Smith and Humphreys (2006), and Tseng, Chang, Rundgren, and Rundgren (2010) all use this approach. However, this lightweight summarization approach often results in unlabeled relationships (Huang et al., 2006), because the proximity and co-occurrence measures allow for the identification of the existence of a link between nouns but do not provide information about the link. Some methods expand on this technique by adding information from dependency graphs to access more linguistic information, but this process is still not fully linguistic (Bailey & Meurers, 2008; Mohler, Bunescu, & Mihalcea, 2011).

Fully linguistic methods of proposition extraction are more accurate than statistical lightweight summarization methods, but are also less common due to the difficulty involved in implementing them efficiently and effectively (Vargas-Vera & Moreale, 2005). However, linguistically based studies often place artificial constraints on the process to achieve an acceptable level of accuracy in link identification. These constraints result in the identification of only a subset of the propositions stated in the text. Some studies constrain the links to a predetermined set of verbal relationships (Valerio & Leake, 2006) or use ontological domain information to constrain the verbal relationships for each noun (Richardson, Srinavasan, & Fox, 2008), while others constrain the verbal relationships to those in which nouns in the content area of interest are the subject of the link (Zouaq & Nkambou, 2008).

Constraints that limit the verbal relationships to a predefined set of relationships or to information stored in a specific ontology result in techniques that are domain-specific, as the constraints applied in one domain often do not generalize to other domains (Kowata, Cury, & Boeres, 2010). The few linguistic studies that were domain-independent applied linguistic methods only at the concept extraction stage, while the link extraction stage remained based upon co-occurrence (Tseng et al., 2010; Wang, Cheung, Lee, & Knok, 2008).

Methods

Data Set

The corpus used in this study consisted of two preexisting, pre-scored sets of short essay responses by fourth and fifth grade students explaining the hearing process and the vision process. The students replied to the following hearing prompt:

> Imagine your friend comes to you with a problem. She has missed the last two months of school and wants you to explain how ears work. You need to explain all about the ear and the hearing process.
>
> Think about all of the important things you've learned about hearing and how our ears work. Also think about the relationships between the different parts of the ear and how the ear as a whole goes together. Then write an explanation to your friend so that she can understand hearing.

The same students also replied to the following vision prompt on a different date:

> Imagine your friend comes to you with a problem. She has missed the last two months of school and wants you to explain how eyes work. You need to explain all about the eye and the vision process.
>
> Think about all of the important things you've learned about vision and how our eyes work. Also think about the relationships between the different parts of the eye and how the eye as a whole goes together. Then write an explanation to your friend so that she can understand vision.

The hearing corpus consisted of 55 short essays containing 5,095 words in 415 sentences. The vision corpus consisted of 54 short essays containing 4,714 words in 391 sentences. Each essay had already been scored on a 1 to 5 scale by two human raters using a holistic rubric, where a score of 5 indicated an essay that covered all the main scientific principles on the rubric and contained no conceptual errors and a score of 1 indicated an essay that was off-topic and covered none of the main scientific principles in the rubric. Interrater reliability was high (α = .95), and where disagreements occurred, a consensus was reached on a final score, rather than taking the mean of the two different scores (Klein et al., 2002). Only one student received a score of 1 (writing an essay about resolving a fight on the playground instead of about the hearing process), but the remaining scores were fairly evenly distributed, with a mean score of 3.57 and a standard deviation of 0.96 in the hearing corpus and a mean score of 3.33 and a standard deviation of 0.90 in the vision corpus.

The scientific principles listed in the rubric were in the form of complete sentences. These sentences were combined in paragraph form to create the *target essay* for the automatic scoring process. The target essay for hearing was:

> The outer ear (auricle) catches sound waves. Sound waves travel through the ear canal to vibrate the eardrum. The vibrating eardrum passes vibrations on to the middle ear, which is made up of the hammer, anvil, and stirrup. The middle ear passes vibrations to the inner ear, via the stirrup. The stirrup vibrates the oval window. The vibrating oval window causes the fluids in the cochlea to vibrate. The cochlea converts the sound waves to electrical impulses via the fibers in the cochlea. The electrical impulses from the cochlea travel to the brain via the auditory nerve. The brain interprets the vibration as sound.

The target essay for vision was:

> Light bounces or reflects off an object into your eye. Light goes through the pupil, iris, and cornea. Then light hits the lens, which focuses light on the retina. The retina contains cones and rods. The image on the retina is inverted, or upside down. The image travels via optic nerve to the brain. The brain recognizes the image.

SemScape Overview

This study uses SemScape (Mousavi, Kerr, & Iseli, 2011) to extract propositions from free text using grammatical information present in the text. In SemScape, the syntactical information is first generated using the Stanford parser (Stanford NLP Group, 2013) which converts each sentence into one or more parse trees that can be indexed so each word's relative position to other words in the sentence can be easily identified. An example of a portion of a parse tree can be seen in the second box in Figure 1 (with its corresponding indexing in the third box). The parse tree labels each word with its corresponding part of speech and embeds words within phrases. Once a sentence has been parsed and indexed, SemScape uses the three-step process shown in the rest of Figure 1 to mine propositions from the parse trees of the text. Those three steps are: main-part identification, TextGraph generation, and proposition extraction.

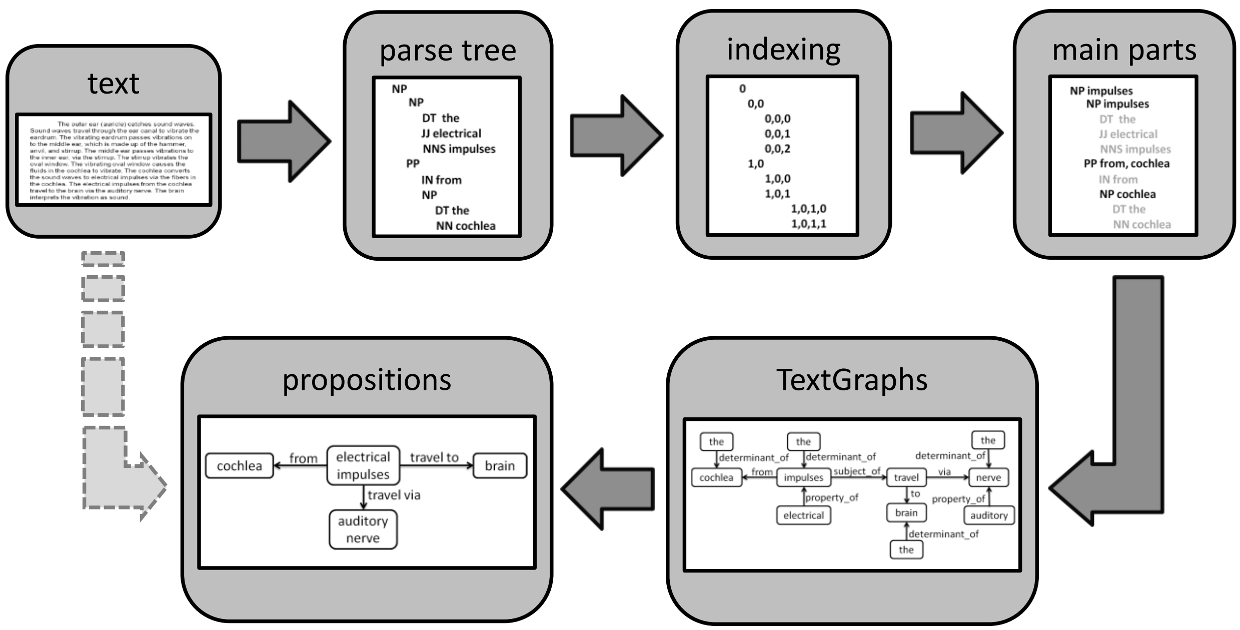

Figure 1. SemScape proposition extraction process.

Main-Part Identification in SemScape

The main-part of each phrase is identified using approximately 130 main-part rules that examine the grammatical structure of the parse tree and use that information to carry the main-parts of the leaves of the parse tree up to the parent nodes. For example, the rule in Figure 2 examines each noun phrase (NP). If the noun phrase includes a determinant (DT), followed by an adjective or adjective phrase (JJ|ADJP), followed by a noun (NN|NNS), the noun located at index 0,2 will be copied up to the noun phrase head located at index 0.

This rule would identify the main-part of the noun phrase “the electrical impulses” as “impulses” and the main-part of the noun phrase “the auditory nerve” as “nerve.” Carrying the main-part information up to the branches allows subsequent rule sets to be far more parsimonious because variations in leaf structures for each branch are already accounted for.

PATTERN	Index	Example (*main-part*)
(NP	0	(*impulses*) ←
(DT)	0, 0	the
(JJ|ADJP)	0, 1	electrical
(NN|NNS)	0, 2	impulses
)		
RESULT:		
< [0], [0, 2] >		

Figure 2. Example main-part rule.

The main-part identification process also draws on an ontology that is generated automatically using another SemScape component called OntoHarvester (Mousavi, Kerr, Iseli, & Zaniolo, 2013). OntoHarvester starts with an initial ontology (a *seed*) of a few terms and a body of text about the topic of interest. The seed for the hearing ontology consisted of ten common hearing concepts: *ear*, *vibration*, *hammer*, *anvil*, *stirrup*, *oval window*, *cochlea*, *brain*, *sound*, and *cells*. The body of text for the hearing ontology consisted of a chapter about the hearing process from a seventh grade science textbook (*Focus on Life Science*, 2007). The seed for the vision ontology consisted of three common vision concepts: *eye*, *light*, and *vision*. The body of text for the vision ontology consisted of a chapter about the vision process from the same textbook (*Focus on Life Science*, 2007).

OntoHarvester uses the TextGraph generation process described in the following section to identify taxonomical relationships (such as *Part_Of* or *Type_Of*) between terms already in the seed and other terms in the text. If any such terms are found, they are added to the seed and another pass is run to identify additional taxonomical relationships between the terms in the expanded seed and other terms in the text. The iteration continues until no additional terms are found, at which point the ontology is considered complete.

This process results in a list of single-word and multi-word terms that apply directly to the concept of interest. This information is then used in the main-part identification process to identify multi-word terms. Therefore, if “electrical impulses” was a term in the ontology, the main-part for the example in Figure 2 would be identified as “electrical impulses,” but if “electrical impulses” was not a term in the ontology, the main-part would be identified as “impulses.” This allows conceptual terms like “electrical impulses” to be distinguished from descriptions of terms such as “faint sounds.” There were 20-single word terms and 22 multi-word terms in the final hearing ontology and 26 single-word terms and 13 multi-word terms in the final vision ontology (see Appendix A), plus the terms in the initial seeds.

TextGraph Generation in SemScape

The grammatical relationships between words in the text are identified using approximately 270 tree domain rules that make use of both parse tree and main-parts information. These relationships are converted into a *TextGraph* wherein the nodes are the words in the sentence and the links are the grammatical relationships between those words. For example, the rule shown in Figure 3 would identify every occurrence of a noun phrase (NP) followed directly by a verb phrase (VP) and link the main-part of the noun phrase to the main-part of the verb phrase with the link “subjectOf.”

PATTERN	Index	Example (*main-part*)
(NP)	0	(*electrical impulses*)
(VP)	1	(*travel*)

RESULT:
< [0], subjectOf, [1] >

Figure 3. An example of a text domain rule.

This is a lossless process meant to extract the grammatical structure of the sentence exactly as it is written. Semantic meaning is not inferred at this point and because the rules are entirely based on grammar they do not have to be modified for different conceptual domains, though additional rules would have to be created for styles of writing that do not have the same grammatical structures, such as poetry or plays. Given the example sentence “The electrical impulses from the cochlea travel to the brain via the auditory nerve,” the tree domain rules would convert the sentence into the TextGraph shown in Figure 4.

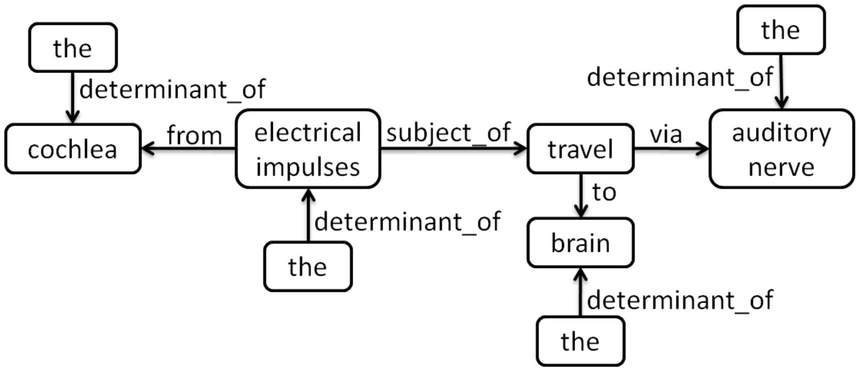

Figure 4. TextGraph for the example sentence.

Proposition Extraction in SemScape

Propositions are extracted from the TextGraphs using approximately 50 graph domain rules, which, like all other SemScape rules, are entirely based on grammar and are therefore domain-independent. These rules identify patterns in the TextGraph and translate them into <*node*, *link*, *node*> triples. For example, the rule in Figure 5 finds every subgraph in the TextGraph wherein a noun (?1) is linked to a verb (?3) with the relationship "subject_of" and a second noun (?2) is linked to the same verb (?3) with the relationship "to," provided that the word "not" does not modify the verb.

```
SELECT (?1, ?3 "to", ?2)
WHERE {
        ?1 "subject_of" ?3.
        ?2 "to" ?3.
        NOT("not" "property_of" ?3).}
```

Figure 5. An example of a graph domain rule.

For the TextGraph in Figure 5, this rule would select < *electrical impulses* > as the subject of < *travel* > (as indicated in the first condition in the WHERE clause of the rule) and < *brain* > as the "to" of < *travel* > (as indicated in the second WHERE clause of the rule) and extract the proposition < *electrical impulses*, *travel to, brain* > (as indicated in the SELECT cause of the rule). All propositions for the example sentence "The electrical impulses from the cochlea travel to the brain via the auditory nerve" are displayed in Figure 6.

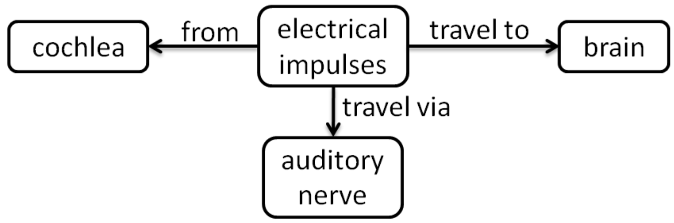

Figure 6. Proposition graph for the example sentence.

Matching Process for Scoring

Once the essays have been converted into proposition graphs consisting of connected <*node*, *link*, *node*> triples in which the link specifies the semantic connection between the nodes, the triples in the proposition graph for each student essay are matched to the triples in the proposition graph generated from the target essay based on four features.

First, the nodes (e.g., nouns) in each student's proposition graph are matched to the nodes in the target essay proposition graph. The resulting Node Match Count indicates the number of nouns in each student essay that are also found in the target essay. Second, the subset of nodes that are identified as concepts (by being in the ontology) in each student's proposition graph are matched to the concepts in the target essay proposition graph. The resulting Concept Match Count indicates the number of task-specific concepts in each student essay that are also found in the target essay. Third, the links (e.g., verbs, conjunctions, or prepositions) in each student's proposition graph are matched to the links in the target essay proposition graph. The resulting Link Match Count indicates the number of connecting words or phrases in each student essay that are also found in the target essay. Finally, the <*node*, *link*, *node*> triples in each student's proposition graph are matched to the <*node*, *link*, *node*> triples in the target essay proposition graph. The resulting Triple Match Count indicates the number of propositions in each student essay that are also found in the target essay. These features are summarized in Table 1.

Table 1

Features Used to Compute Essay Scores

Feature	Description
Node Match Count	Number of nodes in the essay that match nodes in the target
Concept Match Count	Number of concepts in the essay that match concepts in the target
Link Match Count	Number of links in the essay that match links in the target
Triple Match Count	Number of triples in the essay that match triples in the target

Matches between the student essays and the target essay are determined by direct comparison (e.g., < *ear*, *catches*, *sound* > in the student essay would be matched to < *ear*, *catches*, *sound* > in the target essay). Direct matches are relatively infrequent, so SemScape considers some things to be matches that are not direct. SemScape matches synonyms, word tenses, and passive forms so that < *ear*, *gathers*, *sound* >, < *ears*, *caught*, *sound* >, and < *sound*, *is caught by*, *ear* > would all be matched to < *ear*, *catches*, *sound* >. However, SemScape is currently not capable of identifying matches spread over multiple triples, so the sentence "The fleshy part of your ear catches sound" would not be matched to < *ear*, *catches*, *sound* > because it produces the triples < *fleshy part*, *catches*, *sound* > and < *fleshy part*, *of*, *ear* > rather than linking "ear" directly to "sound."

Scoring Process

Student essays were scored on a scale of 1 to 5 based on comparisons to predefined anchor papers. Each anchor paper represented the minimum match to the target essay needed to achieve that score. The anchor papers for the hearing essays were Essays 22, 43, 41, and 34. The anchor papers for the vision essays were Essays 11, 4, 44, and 28. There was no anchor paper for a score of 1, because that score was limited to essays that were off-topic. Therefore, any essay with a Concept Match Count of 0 was given a score of 1.

To determine which of the remaining scores on the scale to assign to each essay with a Concept Match Count greater than 0, the features listed in Table 1 were compared to the four anchor papers. For each feature, essays with a feature count below the corresponding feature count for Anchor Paper 2 were given a score of 1 for that feature. Essays with a feature count equal to or higher than Anchor Paper 2 but lower than Anchor Paper 3 were given a score of 2 for that feature, and so on. If the cutoff values for two anchor papers were very similar and there was a large gap to the next anchor paper (e.g., the value for Anchor Paper 3 was a 7, the value for Anchor Paper 4 was a 9, and the value for Anchor Paper 5 was a 23), the cutoff for the score associated with the middle anchor paper was changed to halfway between the other two cutoff values (e.g., the value for Anchor Paper 4 was changed from 9 to 15) to provide a more accurate benchmark. This process resulted in four scores for each essay: the Node Match Score, Concept Match Score, Link Match Score, and Triple Match Score.

The mean of these four scores was rounded to the nearest whole number, with values of .5 rounding up, to determine the Final Essay Score. Our earlier scoring schemes (see Kerr, Mousavi, & Iseli, 2013) combined match scores with indicators of length to determine the Final Essay Score, but the scoring process now relies solely on the proposition extraction process and does not include any indicators of essay length.

Measuring the Accuracy of the SemScape Process

The automatic essay scoring process was first tested extensively on the hearing essays, and then was run unchanged on the vision essays. Therefore, the results of the proposition extraction performance are reported for the hearing essays only, while the results of the automatic essay scoring performance are reported for both the hearing and vision essays.

To create a gold standard for measuring the accuracy of the proposition extraction process, the propositions in each hearing essay were extracted manually by a human rater. The automatically extracted propositions were then compared to the manually extracted propositions and the results were reported in two different measures: Precision and Recall. Precision indicates the percentage of automatically extracted propositions that were correct (e.g., that matched propositions that had been manually extracted). Recall indicates the percentage of manually extracted propositions that were automatically extracted by SemScape.

Automatic essay scoring bridges two fields of study: computer science and education. In computer science, the standard for reporting the accuracy of automatic essay scores is the Root Mean Squared Error (RMSE) and the Pearson correlation (as recommended in Ziai, Ott, & Meurers, 2012). In education, the standard is the Pearson correlation and the quadratic weighted kappa (as recommended in Williamson, Xi, & Breyer, 2012). Therefore, we report all three of these values for the match between the Final Essay Scores and the human rater scores, as well as the match between the individual feature match scores and the human rater scores. We also report the linear weighted kappa because it is a more accurate measure of exact agreement than the quadratic weighted kappa, which may overstate the agreement in situations where no scores differ by more than one point (Warrens, 2012). Additionally, we provide the agreement tables that these statistics are derived from.

Results

Proposition Extraction Performance – Hearing Essays

As can be seen in the Precision column in Table 2, the average accuracy of the generated propositions is almost 80%, but ranged from 47% to 100% for individual essays. The Recall values are lower, with the percentage of existing propositions identified by SemScape averaging 65% and ranging from 25% to 100%. The percentage of existing propositions not identified by SemScape was broken into two subcategories: Wrong and Missing. Wrong indicates the percentage of unextracted propositions where the SemScape process identified one or more nodes incorrectly, usually due to incorrect pronoun resolution. Missing indicates the percentage of unextracted propositions where the SemScape process failed to extract a proposition from the corresponding text (indicating the lack of an applicable TextGraph rule). Approximately 57% of existing propositions not identified by SemScape were Wrong, while 43% were Missing.

Table 2

Comparison of Automatically Extracted Propositions to Manually Extracted Propositions

Essay	Precision	Recall	Wrong	Missing	Essay	Precision	Recall	Wrong	Missing
1	79%	70%	13%	17%	30	71%	31%	29%	40%
2	83%	63%	25%	12%	31	57%	64%	27%	9%
3	89%	58%	28%	14%	32	74%	55%	32%	14%
4	83%	69%	31%	0%	33	94%	83%	7%	10%
5	74%	59%	7%	33%	34	82%	76%	13%	11%
6	84%	58%	27%	15%	35	67%	59%	38%	3%
7	72%	69%	17%	14%	36	88%	90%	7%	3%
8	94%	68%	4%	29%	37	74%	43%	23%	34%
9	94%	86%	0%	14%	38	75%	48%	23%	30%
10	81%	69%	9%	23%	39	94%	92%	8%	0%
11	85%	74%	26%	0%	40	70%	75%	13%	12%
12	78%	71%	14%	14%	41	65%	57%	39%	4%
13	90%	65%	8%	27%	42	94%	92%	6%	3%
14	68%	45%	16%	32%	43	77%	68%	27%	5%
15	93%	82%	9%	9%	44	91%	63%	4%	33%
16	90%	88%	0%	12%	45	78%	90%	5%	5%
17	97%	81%	19%	0%	46	68%	47%	53%	0%
18	90%	80%	20%	0%	47	85%	51%	33%	16%
19	60%	69%	21%	10%	48	100%	100%	0%	0%
20	90%	70%	9%	22%	49	69%	47%	53%	0%
22	54%	25%	75%	0%	50	71%	63%	24%	13%
23	82%	47%	21%	32%	51	56%	68%	20%	13%
24	48%	46%	31%	23%	52	75%	57%	0%	43%
25	75%	68%	19%	13%	53	54%	40%	15%	45%
26	100%	31%	38%	31%	54	47%	59%	24%	18%
27	94%	82%	5%	14%	55	79%	58%	42%	0%
28	76%	57%	20%	23%	56	84%	76%	21%	3%
29	76%	61%	15%	24%	Overall	79%	65%	20%	15%

High Wrong values generally occurred because of incorrect pronoun resolution. This is an area of concern with student writing because incorrect pronoun usage is very common. For example, Essay 22 has the highest Wrong value in the study. It consists of the following three sentences: “First someone says something. Then it goes to the eardrum and makes it twice as loud. Then it goes to the bones, and then it goes to the cochlea.” The “it” in these sentences is intended to refer to “sound,” but the word “sound” never actually occurs in the essay. The pronoun resolution system in SemScape determines that “it” most likely refers to “someone,” and a number of incorrect propositions such as < *someone, goes to, cochlea* > are then generated.

While a number of improvements could be made to the pronoun resolution system, SemScape will never be able to resolve a pronoun to a word that is not mentioned in the text. Similarly, regardless of the number of improvements made to the system, SemScape will likely be unable to resolve plural pronouns that refer to singular words, and vice versa. For example, the pronoun in the sentence “The sound waves enter the ear, then it goes down the ear canal” will be more likely to resolve to the singular noun “ear” than the plural noun “sound waves.”

Essays with high Missing values contain either a number of relatively uncommon sentence structures (such as split infinitives) or erroneous sentence structures (such as run-on sentences). Essay 53 (see Appendix B), which has the highest Missing value, has examples of both. The sentence “The sound waves go into the ear canal and make the eardrum to vibrate” contains an uncommon sentence structure. Without a rule to capture this structure, SemScape cannot extract the proposition < *sound waves*, *make to vibrate*, *eardrum* >. While at first glance this might seem like an erroneous sentence construction that should not have a rule made to capture it, the construction is actually valid, as can be demonstrated by sentences like “Yanking on the steering wheel forces the car to turn” which should result in the proposition < *yanking*, *forces to turn*, *car* >.

Essay 53 also contains a number of erroneous sentence structures. The sentence “Then the three bones start to vibrate, the anvil, stirrup, and the hammer” has a comma after the word “vibrate” that confuses the parser, making SemScape unable to extract a TextGraph from the sentence. Additionally, the final sentence of the essay, “Then it goes through the oval window and the fluid in the cochlea keeps changing and it goes to the brain and the brain finds out what it is,” is a run-on sentence that combines four separate steps into a single statement. The parser has difficulty dealing with such sentences and they often result in missing or incorrect propositions because the parser cannot figure out where the breaks should be. While uncommon sentence structures can be fixed by creating additional rules in the SemScape system, poorly constructed sentences will continue to produce Missing or Wrong propositions.

However, it is important to note that low Recall or Precision values do not necessarily indicate a higher probability of scoring an essay incorrectly, because SemScape scores essays based on their content rather than their grammar. In this study, Recall was not correlated with the essay scores given by human raters (r = -.004, p = .978), the Final Essay Scores assigned by SemScape (r = .141, p = .329), or the difference between those scores (r = -.229, p = .110). Precision was also not correlated with the essay scores given by human raters (r = .068, p = .641), the Final Essay Scores assigned by SemScape (r = .115, p = .425), or the difference between those scores (r = -.073, p = .616).

Additionally, there were no significant differences based on available demographic data. Recall (p = .065) and Precision did not differ based on gender (p = .157); nor did the difference between Final Essay Scores assigned by SemScape and the scores assigned by human raters (p = .555). Recall (p = .073) and Precision also did not differ based on ethnicity (p = .298); nor did the difference between Final Essay Scores assigned by SemScape and the scores assigned by human raters (p = .055). Furthermore, recall (p = .932) and Precision did not differ based on whether or not students had English as a primary language (p = .544); nor did the difference between Final Essay Scores assigned by SemScape and the scores assigned by human raters (p = .722). However, sample sizes were very small for some of the subgroups (e.g., only four students did not speak English as a primary language) so results may differ in a larger sample.

Automatic Essay Scoring Performance – Hearing Essays

The RMSE between the Final Essay Scores assigned by SemScape and the scores given by the human raters was .632 and the Pearson correlation was .798 (see Table 3). The Pearson correlation is much higher than those reported in other similar studies by Mohler et al. (2011) and Ziai et al. (2012). The RMSE is better than Ziai et al. (2012) and equivalent to Mohler et al. (2011). Additionally, the Pearson correlation (at .798) and the quadratic weighted kappa (at .792) were both above the .70 cutoff suggested by Williamson et al. (2012). However, the linear weighted kappa was only .625, putting it just below the suggested cutoff.

Table 3

Score Alignment Performance for Hearing Essays

Feature	RMSE	Pearson correlation	Quadratic weighted kappa	Linear weighted kappa
Node Match Score	.813	.680	.567	.415
Concept Match Score	.932	.588	.559	.435
Link Match Score	.813	.724	.703	.554
Triple Match Score	.809	.690	.679	.492
Final Essay Score	.632	.798	.792	.625

Table 4 shows the comparison of computer rater scores to human rater scores. There were no scores where SemScape was off by more than one point. However, SemScape performed worst on identifying essays rated as 5's by human raters, correctly identifying only half of those essays. SemScape was also not very good at differentiating 3's and 4's, categorizing 27% of 3's as 4's and 32% of 4's as 3's.

Table 4

Comparison of SemScape to Human Raters for Hearing Essays

	SemScape score					
Human score	1	2	3	4	5	Percent matched
1	**1**	-	-	-	-	100%
2	-	**7**	3	-	-	70%
3	-	2	**6**	3	-	55%
4	-	-	8	**15**	2	60%
5	-	-	-	4	**4**	50%

Automatic Essay Scoring Performance – Vision Essays

The RMSE between the SemScape Final Essay Scores and the scores given by the human raters was .866 and the Pearson correlation was .682 (see Table 5). The Pearson correlation is much higher than those reported in other similar studies by Mohler et al. (2011) and Ziai et al. (2012), who did not report correlations higher than .6. The RMSE is better than Ziai et al. (2012) but not as good as Mohler et al. (2011), possibly due to differences in scale. However, the Pearson correlation and the quadratic weighted kappa (at .600) and linear weighted kappa (at .493) were both below the .70 cutoff suggested by Williamson et al. (2012).

Table 5

Score Alignment Performance for Vision Essays

Feature	RMSE	Pearson correlation	Quadratic weighted kappa	Linear weighted kappa
Node Match Score	.886	.697	.588	.464
Concept Match Score	.856	.642	.599	.501
Link Match Score	.945	.596	.576	.457
Triple Match Score	.935	.574	.519	.395
Final Essay Score	.866	.682	.600	.493

Table 6 compares computer rater scores to human rater scores. There were four essays where SemScape was off by more than one point, scoring one student as a 5 instead of a 2, one student as a 4 instead of a 2, and two students as 5's instead of 3's. SemScape had the most difficulty correctly identifying essays with a score of 3 or 4, identifying more than half of the 3's as 4's and a third of the 4's as 5's. Additionally, SemScape had a tendency to overestimate vision scores, with only two essays given lower scores than the human rater and 23 essays given higher scores.

Table 6

Comparison of SemScape to Human Raters for Vision Essays

	SemScape score					
Human score	1	2	3	4	5	Percent matched
1	-	-	-	-	-	100%
2	-	**6**	4	1	1	50%
3	-	-	**8**	9	2	42%
4	-	-	1	**11**	6	61%
5	-	-	-	1	**4**	80%

Conclusions and Future Work

This report examined the performance of SemScape, a rule-based Natural Language Processing (NLP) system for automatically grading student essays for content. As opposed to most other text mining systems, SemScape's scoring process is entirely semantic and does not include any indicators of length or writing style.

SemScape was able to accurately extract propositions from student writing, with a mean precision of 79% and a mean recall of 65%. The 35% of propositions that were not successfully extracted were split between Wrong (20%) and Missing (15%) propositions. Wrong propositions were largely due to incorrect pronoun resolution and Missing propositions were largely due to uncommon or inaccurate sentence structures for which there were no applicable TextGraph rules. We plan to add more TextGraph rules to address uncommon sentence structures and reduce the percentage of Missing propositions. Rules will also be added to the pronoun resolution process to reduce the percentage of Wrong propositions by, for example, not allowing the pronoun "it" to resolve to a person. While increasing the proposition extraction performance of SemScape should increase scoring accuracy, neither recall (p = .110) nor precision (p = .616) was correlated with how accurately essays were scored. This indicates that poor proposition extraction performance creates random noise rather than systematic error and demonstrates that SemScape is not more likely to incorrectly score an essay with low recall and/or low precision in the proposition extraction phase.

SemScape was able to fairly accurately score the hearing essays. The correlation between SemScape scoring of the hearing essays and human scoring of the hearing essays was .798, well above the recommended cutoff of .7. The quadratic weighted kappa was also well above the recommended cutoff of .7, at .792, and the RMSE was just over half of a point on the scale, at .632. Additionally, the lone off-topic essay was easily identified by SemScape and not a single essay was off by more than one point on the scale.

SemScape's performance on the vision essays was not as good as its performance on the hearing essays. The correlation was .682 and the quadratic weighted kappa was .600, just below the recommended cutoff. The RMSE was much higher, at .866, and there were four vision essays that were off by more than one point on the scale. While this performance is good enough to indicate that SemScape does not need major reconfiguration when applied in new domains, it does point out a flaw in the current system.

This flaw arises because the current scoring system provides equal weight to the Node Match Score, Concept Match Score, Link Match Score, and Triple Match Score. This means that using all the right words (i.e., high Node Match Score, Concept Match Score, and Link Match Score) but not putting them together as anticipated (i.e., low Triple Match Score) will result in a fairly high scoring essay. Currently SemScape cannot differentiate between triples that do not match because the triple matching process is too direct and triples that do not match because the wrong nodes are linked together (indicating a misconception on the student's part). Given that nearly all incorrectly scored vision essays were given scores that were higher than the human rater, this seems to be a particular problem in these essays. Significant reworking of the triple matching process, such that it is possible to match a triple that is written as one proposition in the target essay but split across two propositions in the student essay, is necessary if the scoring process is to be improved.

Overall, SemScape's performance is encouraging. These results indicate that using a rule-based NLP technique to extract propositions from student essays is a promising method for scoring short essay constructed response items for content. Additional refinement of the rules and matching process should improve the performance of the system, and could potentially result in an acceptably accurate method of automatically scoring short essay constructed response items for content that would allow such items to be used on large-scale assessments wherein using human raters is prohibitively time consuming.

References

Bailey, S., & Meurers, D. (2008). Diagnosing meaning errors in short answers to reading comprehension questions. In J. Tetreault, J. Burstein, & R. De Felice (Eds.), *Proceedings of the Third ACL Workshop on Innovative Use of NLP for Building Educational Applications* (pp. 107-115). Stroudsburg, PA: The Association for Computational Linguistics.

Baker, E. L., Aschbacher, P. R., Niemi, D., & Sato, E. (1992). *CRESST performance assessment models: Assessing content area explanations* (CSE Report 652). Los Angeles, CA: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Cañas, A. J., Carff, R., Hill, G., Carvalho, M., Arguedas, M., Eskridge, T. C., Lott, J., & Carvajal, R. (2005). Concept maps: Integrating knowledge and information visualization. *Lecture Notes in Computer Science*, *3426*, 181-184.

Chen, N.-S., Kinshuk, Wei, C.-W., & Chen, H.-J. (2008). Mining e-learning domain concept map from academic articles. *Computers & Education*, *50*(3), 1009-1021.

Focus on Life Science, California, Grade 7 (Student Edition). (2007). Columbus, OH: Glencoe/McGraw-Hill.

Gaines, B. R., & Shaw, M. L. G. (1994). Using knowledge acquisition and representation tools to support scientific communities. In *Proceedings of the Twelfth National Conference on Artificial Intelligence (AAAI '94)* (pp.707-714). Menlo Park, CA: American Association for Artificial Intelligence.

Graesser, A. C., McNamara, D. S., & Louwerse, M. M. (2009). 2 Methods of automated text analysis. In M. L. Kamil, P. D. Pearson, E. B. Moje, & P. P. Afflerbach (Eds.), *Handbook of Reading Research* (pp. 34-53). New York, NY: Routledge.

Huang, C.-J., Tsai, P.-H., Hsu, C.-L., & Pan, R.-C. (2006). Exploring cognitive differences in instructional outcomes using text mining technology. In *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics (SMC 2006)* (pp. 2116-2120). Taipai, Taiwan: IEEE Computer Society.

Jacobs-Lawson, J. M., & Hershey, D. A. (2002). Concept maps as an assessment tool in psychology courses. *Teaching of Psychology*, *29*, 25-29.

Kerr, D., Mousavi, H., & Iseli, M. R. (2013). *Automatic short essay scoring using natural language processing to extract semantic information in the form of propositions* (CRESST Report 831). Los Angeles, CA: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Kintsch, W. (1974). *The representation of meaning in memory*. Hillsdale, NJ: Erlbaum.

Klein, D. C. D., Chung, G. K. W. K., Osmundson, E., & Herl, H. E. (2002). *Examining the validity of knowledge mapping as a measure of elementary students' scientific understanding* (CSE Report 557). Los Angeles, CA: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Kowata, J. H., Cury, D., & Boeres, M. C. S. (2010). Concept maps core elements candidates recognition from text. In J. Sanchez, A. J. Canas, & J. D. Novak (Eds.), *Proceedings of the Fourth International Conference on Concept Mapping* (pp. 120-127). Santiago, Chile: Universidad de Chile.

Landauer, T. K., Laham, D., & Foltz, P. W. (2003). Automated scoring and annotation of essays with the Intelligent Essay Assessor. In M. D. Shermis & J. Burstein (Eds.), *Automated essay scoring: A cross-disciplinary perspective* (pp. 87–112). Mahwah, NJ: Erlbaum.

Lau, R. Y. K., Song, D., Li, Y., Cheung, T. C. H., & Hao, J.-X. (2009). Toward a fuzzy domain ontology extraction method for adaptive e-learning. *IEEE Transactions on Knowledge and Data Engineering*, *21*(6), 800-813.

Magliano, J. P., & Graesser, A. C. (2012). Computer-based assessment of student-constructed response. *Behavioral Research*, *44*, 608-621.

Mohler, M. A. G., Bunescu, R., & Mihalcea, R. (2011). Learning to grade short answer questions using semantic similarity measures and dependency graph alignments. In *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies* (pp.752-762). Association for Computational Linguistics.

Mohler, M. A. G., & Mihalcea, R. (2009). Text-to-text semantic similarity for automatic short answer grading. In *Proceedings of the European Association for Computational Linguistics (EACL 2009)*. Athens, Greece.

Mousavi, H., Kerr, D., & Iseli, M. R. (2011). *A new framework for textual information mining over parse trees* (CRESST Report 805). Los Angeles, CA: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Mousavi, H., Kerr, D., Iseli, M., & Zaniolo, C. (2013). *OntoHarvester: An Unsupervised Ontology Generator from Free Text* (CSD Technical Report 130003). Los Angeles, CA: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

O'Neil, H. F. Jr., & Klein, D. C. D. (1997). *Feasibility of machine scoring of concept maps* (CSE Technical Report 460). Los Angeles, CA: University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST).

Richardson, W. R., Srinivasan, V., & Fox, E. A. (2008). Knowledge discovery in digital libraries of electronic theses and dissertations: An NDLTD case study. *International Journal on Digital Libraries, 9*, 163-171.

Rozali, D. S., Hassan, M. F., & Zamin, N. (2011). Development of preprocessing modules for an adaptive qualitative assessment using with dynamic question generation: A concept map approach. In A. Patil & C. S. Nair (Eds.), *Proceedings of the International Engineering and Technology Education Conference (IETEC '11)*. Kuala Lumpur, Malaysia: IETEC. Retrieved from http://ietec-conference.com/ietec11/Conference%20Proceedings/ietec/papers/Conference%20Papers%20Refereed/Wendesday/WP2/WP2.4_52.pdf

Shermis, M. D., Burstein, J., Higgins, D., & Zechner, K. (2010). Automated essay scoring: Writing assessment and instruction. In P. Peterson, E. Baker, & B. McGaw (Eds.), *International encyclopedia of education* (3rd ed., pp. 20–26). Oxford, UK: Elsevier.

Smith, A. E., & Humphreys, M. S. (2006). Evaluation of unsupervised semantic mapping of natural languages with Leximancer concept mapping. *Behavior Research Methods*, *38*(2), 262-279.

Stanford NLP Group. (2013). The Stanford parser: A statistical parser [Computer software]. Retrieved from http://nlp.standford.edu/software/lex-parser.shtml

Tseng, Y.-H., Chang, C.-Y., Rundgren, S.-N. C., & Rundgren, C.-J. (2010). Mining concept maps from news stories for measuring civic scientific literacy in media. *Computers & Education*, *55*(1), 165-177.

Valerio, A., & Leake, D. (2006). Jump-starting concept map construction with knowledge extracted from documents. In A. J. Canas & J. D. Novak (Eds.), *Proceedings of the Second International Conference on Concept Mapping (CMC '06)* (pp. 296-303). Santiago, Chile: Universidad de Chile.

Vargas-Vera, M., & Moreale, E. (2005). Automatic extraction of knowledge from student essays. *International Journal of Knowledge and Learning*, *1*(4), 318-331.

Villalon, J. J., & Calvo R. A. (2009). Concept extraction from student essays, toward concept map mining. In I. Aedo, N.-S. Chen, Kinshuk, D. Sampson, & L. Zaitseva (Eds.), *Proceedings of the Ninth IEEE International Conference on Advanced Learning Technologies (ICALT 2009)* (pp. 221-225). Washington, DC: IEEE Computer Society.

Wang, W. M., Cheung, C. F., Lee, W. B., & Knok, S. K. (2008). Mining knowledge from natural language texts using fuzzy associated concept mapping. *Information Processing & Management*, *44*(5), 1707-1719.

Warrens, M. J. (2012). Some paradoxical results for the quadratic weighted kappa. *Psychometrika*, *77*(2), 315-323.

Williamson, D. M., Xi, X., & Breyer, F. J. (2012). A framework for evaluation and use of automated scoring. *Educational Measurement: Issues and Practice*, *31*(1), 2-13.

Wu, H.-S. (2012). Assessment for the Common Core mathematics standards. *Journal of Mathematics Education at Teachers College*, *3*, 6-18.

Ziai, R., Ott, N., & Meurers, D. (2012). Short answer assessment: Establishing links between research strands. In *Proceedings of the 7th Workshop on the Innovative Use of NLP for Building Educational Applications* (pp.190-200). Association for Computational Linguistics.

Zouaq, A., & Nkambou, R. (2008). Building domain ontologies from text for educational purposes. *IEEE Transactions on Learning Technologies*, *1*(1), 49-62.

Appendix A: Concepts in Hearing and Vision Ontologies

Hearing Ontology	Vision Ontology
Auditory Canal	Blood
Body	Blood Vessels
Bone	Camera
Buildup of Fluid	Cells
Canal	Choroid
Cartilage	Ciliary Muscles
Cells	Cone Cells
Ear Canal	Convex Lens
Ear Drum	Cornea
Ear Infection	Eyeball
Ear Wax	Focus
Electrical Impulses	Image
External Ear	Impulses
Fibers	Iris
Fluid	Lens
Folds	Light Sensor
Hairs	Light-Sensitive Cells
High-Frequency Sound Waves	Monochrome Vision
Human Ear	Muscle
Impulses	Nerve
Infection	Nerve Cells
Inner Ear	Nerve Impulses
Inner Ear Bones	Nerve Signal
Liquid	Nutrients
Low-Frequency Sound Waves	Optic Nerve
Mechanical Impulses	Oxygen
Membrane	Pupil
Microscopic Hairs	Retina
Middle Ear	Rod Cells
Organ	Rods
Outer Ear	Sclera
Semi-Circular Canal	Screen
Sensory Cells	Sensor
Shock Waves	Sheet
Soft Tissue	Sheet of Cells
Stapes	Signal
Tissue	Structure
Tube	Tissue
Tunnel	Vessels
Tympanic Membrane	
Waves	
Wax	

Appendix B: Hearing Essays

\\01//

The telephone rings. The sound waves enter your ear canal. Then the sound waves make the eardrum vibrate. The vibrations of the eardrum move the three bones in the ear (hammer, anvil, and stirrup). Then the cochlea vibrates the semi-circular canal. Then the sound waves go through the auditory nerve, sending a message to the brain that the phone is ringing.

\\02//

No sound can be made without vibration. If no sound can be made without vibration, an object will have to vibrate. This will make a sound which is sent through the air, and your outer ear will catch it. After your outer ear catches it, the vibration travels down the ear canal. The ear canal is a tunnel or tube that runs down to the eardrum. When the eardrum picks up the vibration it vibrates, which makes the three inner ear bones vibrate. Those three bones are the hammer, anvil, and stirrup. When these vibrate, the stirrup vibrates in the oval window (the oval window is part of the cochlea), which then changes the vibration into electric impulses. The electric impulses travel through the auditory nerve, which sends it to the brain. The brain interprets this message, then it verifies what sound you've heard.

\\03//

Hearing is a complicated organ in the body. It is very interdependent. It starts off where you have the knock on a door (for example). Your auricle catches sound waves coming from the knock. It is sent through the ear canal where it vibrates the eardrum. The eardrum is connected to three of the smallest bones in the body, called the hammer, anvil and stirrup. These bones vibrate when they receive sound waves from the eardrum. It is passed through the oval window to the cochlea. The cochlea transfers the sound waves into electrical impulses. It is sent through the auditory nerve to the brain, which identifies it.

\\04//

When the phone rings, it goes to the outer ear. The outer ear catches the sound waves and puts them through the ear canal. Then the eardrum vibrates and makes the three bones to shake. Then the last bone of the three bones connects to the oval window and the cochlea makes waves like water that shakes in an earthquake and it sends it to a vein. Then it sends the message to the brain and you will hear it and you will pick it up.

\\05//

I will start with areas of the ear. The area that you can see on both sides of the head is called the auricle or the outer ear. It catches sound molecules collecting outside of it. Next is the ear canal, it carries the molecules from the auricle to the next part. I'm going to talk about the eardrum. The ear is a soft tissue that vibrates rapidly when sound molecules are collected. It vibrates against the next part, the three bones. The three bones (the hammer, the anvil, and the stirrup) receive vibrations from the eardrum and vibrate from that force.The last bone, called the stirrup, vibrates against the oval window. The oval window receives these vibrations, making the fluid inside the cochlea move. This occurrence sends an electrical impulse though the auditory nerve to the brain. There are three specific areas in the ear, these are the outer ear consisting of the auricle and the ear canal, the middle ear consisting of the eardrum and the three bones, and the inner ear consisting of the oval window, the cochlea, and the semi-circular canals which give you balance.

\\06//

Here's how the ear works. Let's say the phone rings. First the sound wave has to travel through the air into the outer ear. Then it goes into the ear canal. Then the eardrum catches the sound wave and starts to vibrate. When it starts to vibrate, it makes the three bones vibrate. When they start to vibrate, it makes the fluid in the semi-circular canals start to move, which makes the fluid in the cochlea start to move. Then the vibrations go to the nerve that goes to the brain. It sends the vibration to the brain, and the brain will decide what the sound is.

\\07//

First the outer ear catches the sound wave. Then they travel through the ear canal. The sound waves make the eardrum vibrate, which causes the three bones to vibrate (anvil, hammer, stirrup). The sound waves located in middle ear go through the oval fluid. Then the sound waves travel inside to the cochlea, which is located in the inner ear. The cochlea turns the sound waves into an electrical message that gets sent to the brain. The reason you have the outer ear instead of the holes in your head is so you can catch sound waves. Also, your ears are what lets you balance.

\\08//

The phone rings. The sound travels into your ear, through the hairs in the ear, and through the ear canal. When the sound gets to the eardrum, it vibrates. Then it goes to the three bones in your ear. They are called the stirrup, the

anvil, and the hammer. The sound then goes in through the semi-circular canal, and then goes into the tube that leads to the brain. It lets the brain know that the phone is ringing.
\\09//
For example, the phone rings. Before it gets to your brain there are many things that happen. The sound goes in your ear through the eardrum and vibrates and then goes through your tubes.
\\10//
This is how the ear works. For example, if the telephone rings the sound turns into sound waves. Then the outer ear catches the sound waves. The sound waves go through the ear canal. The ear canal leads to the eardrum. The vibrations make the eardrum vibrate. Then the vibrations go through the semi-circular canals. After that, the vibrations vibrate three small bones in your middle ear, called the hammer, anvil, and stirrup. After that, sound waves go through the cochlea, which turns the sound waves into an electric impulse. The electric impulse goes through the auditory nerve, which sends the message to the brain which tells you what you heard, which was the telephone.
\\11//
When somebody may be having a conversation, you hear and understand by waves. A vibration hits the surface of your ear and it goes in your ear. Messages are traveling in your ear. There is something in your ear. When it hits it, it turns into an electrode and sends messages to your brain.
\\12//
Your ear has a big job. It helps you hear. This is what happens. Say the phone rings, the vibrations get caught in the outer ear (the part you see). Then the vibrations go through the ear canal (a long tube leading to the eardrum). Then the vibrations hit the eardrum (like a drum) and then hit the three bones (the stirrup, anvil, and hammer). Right now we are in the middle ear. After the three bones vibrate, they go in the oval window to the cochlea. The cochlea makes the sound into electric impulses. Then the cochlea sends the electric impulses to the nerve that leads to the brain, which makes it ring. All of this happens in a split millisecond so you can hear. The ear has another job. It helps you keep in balance. There is something in your ear called a semi-circular canal, which keeps your body in balance. So without your ear, you would be in big trouble.
\\13//
First your outer ear catches the sound waves from the noise. Then the sound travels through your ear canal and causes the eardrum to vibrate. That makes the three bones (hammer, anvil and stirrup) to vibrate. The waves then get transferred into electrical impulses in the cochlea and then the impulses enter the middle ear and go through the semi-circular canals. They then go through the auditory canal, which is located in the inner ear and eventually goes to the brain.
\\14//
Let’s say the phone rings. Your ear or outer ear collects sound waves. The sound waves go past to wax glands and the little hairs that protect your ear. From there the vibration goes through the eardrum and vibrates the three bones, the hammer, anvil, and stirrup. Then it goes through the oval window and to the cochlea, where it gets turned into electric impulses and goes to the brain and you hear a sound.
\\15//
The ear first needs a sound, so let’s say it is a telephone. The sound goes in the ear canal, which goes to the eardrum. The eardrum vibrates and moves the adjacent bones which are the hammer, anvil, and stirrup. The stirrup vibrates in and out of the oval window. That pushes the fluid to the cochlea. The fluid goes through the semi-circular canals and then travels to the hairs, which change the fluid to electrical impulses which travel through a nerve to the brain. There it is identified as a telephone ringing.
\\16//
When you hear something, the reason why you hear is because of sound waves. Sound waves travel in your ear. The ear is made up of many things. There is wax and hair to protect bacteria from getting inside your ear. Also there are three bones that work together to help you hear, and there is an eardrum and ear canal. The sound waves go through the eardrum and into the three bones. The three bones work together to help you hear. After that the sound waves go through the ear canal and into your brain. The brain sends a message back to the ear to tell you what you hear. That is how you hear.
\\17//
When you hear a sound, this is what happens. First the sound waves travel through the outer ear and into the middle ear. The sound waves make the three bones vibrate against the eardrum, and the fluid in the cochlea starts to move. It sends a message to the brain and you can hear.
\\18//

The phone rings. The outer ear catches the sound and it goes through the ear canal and hits the eardrum. That makes the three bones vibrate and makes a loud vibration in the cochlea. Then the vibration turns to electricity and sends the electric impulse to the brain.
\\19//
Sound comes in sound waves. The process of hearing is: first let's say the phone rings. The outer ear collects the sound waves and passes them on to the ear canal. Then the sound waves hit the eardrum, which is vibrating. The eardrum makes the three bones in your middle ear vibrate. These bones are the anvil, stirrup, and hammer. Then the sound waves go to the oval window and to the cochlea. The cochlea then turns the sound waves into electrical impulses. Then the electrical impulses go through the semi-circular canals. Then the go to the nerve and the nerve sends the message to your brain. Then when it gets to the brain, you hear the phone ring.
\\20//
The way your ears pick up sound is by sound waves. Sound waves are vibrations that travel. The sound waves travel to your ear. Your ear sends the message through your ear canal, through the middle ear, the inner ear, the stirrup, and finally to your eardrum. Then your eardrum sends the message to your brain. This whole task takes less than 1/100 of a second. Your ear is always picking up sound waves, but sometimes you don't notice. The smallest bone is in your ear. It is called the stirrup. Near the eardrum there are microscopic hairs, these hairs also allow you to hear. The hairs can be easily damaged by loud noises, so it's important to take care of your ears.
\\22//
First someone says something. Then it goes to the eardrum and makes it twice as loud. Then it goes to the bones, and then it goes to the cochlea.
\\23//
Imagine the doorbell rings. First, in order to hear it, the following has to happen. You hear a sound. It goes to your outer ear, into the ear canal. In the ear canal is some wax and hair to protect it from letting dust in. The sound waves travel until they hit the eardrum. It begins to vibrate. Then it hits the three bones; hammer, anvil, and stirrup. They begin to vibrate (the eardrum makes it vibrate, they're attached to each other and the eardrum) and the stirrup hits against the oval window. There is the semi-circular canal which helps you balance. After that, the sound waves turn into electrical fluid and go through the cochlea. They go to the canal which goes to the brain and says that the doorbell rang.
\\24//
The phone rings. The sound waves go through the ear canal and hit the eardrum and it vibrates. The hammer vibrates and sends it to your brain and you hear the phone ringing.
\\25//
First sound waves travel to your outer ear and into your ear canal. The sound waves continue down the ear canal through the middle ear, making the eardrum vibrate and then making the three bones vibrate (anvil, stirrup, and hammer). Then the vibrating sound waves go into a nerve and into the brain, which tells the brain what sound you are hearing. The important things you need to hear are oxygen, and ear, and sound waves.
\\26//
The phone rings. It goes down the ear canal through the eardrum to the hammer. It vibrates to the brain, back through the hammer, through your eardrum, and right through the ear canal.
\\27//
The outer ear (the part you can see) catches sound waves. The sound waves travel through the ear canal to the eardrum. That then vibrates and makes the three bones vibrate too, over the oval window to the cochlea. The fluid in the cochlea moves. There is also hair on the cochlea that sends a message to your brain. The brain understands.
\\28//
The ear has many parts that work together to make your ear work. The outer ear is where the ear canal starts. The wax glands and hairs protecting your ears are by the ear canal. Your eardrum vibrates, which makes the three bones vibrate, because of the sound waves. The sound waves travel through the oval window and come through the semi-circular ear canal. To travel up to the brain, it goes by the auditory nerve. When it gets to the brain, you'll know it's the doorbell.
\\29//
This is what we learned about the ear. The way the ear works is when a sound vibration is going it starts like this. The vibration starts at the outer ear, called sound waves. Then the sound goes to the eardrum, then to the ear canal, then to the hammer. Then it goes to the cochlea that sends electrical impulses to the brain. Here's what all the parts that help your ear hear are called. First we will start with the outer ear, that is called sound waves. Then the inside parts of the ear start with the eardrum. It is a small part and important part too.
\\30//

Let’s say the phone rings. The sound waves travel through the air into the outer ear through the ear canal. They go to the eardrum, through the middle ear, through the anvil and stirrup. Then they go it the auditory nerve, which sends a signal to the brain that says the phone is ringing. That is how you hear something.
Here are some parts of the ear: eardrum, anvil, stirrup, oval window, and the auditory nerve.
Really the oval window has nothing to do with hearing. It helps you balance yourself when you walk, but all the other parts have something to do with hearing.
\\31//
I’d say if the door rings the sound travels into your ear and goes up to the ear canal and sends messages to your brain.
\\32//
The phone rings. The sound wave goes to the outer ear. It goes through the ear canal. It hits the eardrum in the middle ear and moves three bones (hammer, anvil, and stirrup). It goes through a hole into the cochlea, where it turns to electrical impulses. Then it goes through the nerve. Sound waves are turned into mechanical impulses by the eardrum, hammer, anvil, and stirrup. They are turned into electrical impulses by the cochlea. Hairs and ear wax protect it from dirt, crud, etc. Semi-circular canals are for balance.
\\33//
When the phone rings, the vibrations travel to the ear. The outer ear catches more of the sound, like a net. The vibrations go through the ear canal and to the three bones; hammer, anvil, and stirrup. All three bones vibrate. The vibrations travel to the cochlea where there is a fluid that changes the vibrations into electrical impulses so the brain can understand. A nerve called the auditory nerve delivers the message to the brain, and you hear!
\\34//
The way that the ear hears sound is this. First the phone rings. The sound waves travel through the oxygen and air to your outer ear. Then the sound waves travel through your ear canal, which is full of tiny ear hairs and some wax. The sound waves vibrate your eardrum, which is an oval like shape made out of cartilage. When the waves vibrate the eardrum, that makes three bones vibrate (the anvil, hammer, and stirrup). Those bones then vibrate the oval window to the inner ear. A fluid in the cochlea starts to rotate and turns the sound vibrations into electrical impulses. The impulses go through the nerve to your brain, which indicates that the phone is ringing. All of this happens in less time than this.
The anvil is named that because it looks like an anvil, and the same with the other two bones. The three bones look like their names.
\\35//
The way you hear is when sound vibrations go into your outer ear. The vibrations make the eardrum vibrate. The eardrum makes the three bones vibrate. The bones are called anvil, hammer, and stirrup. This part of the ear is called the middle ear. After the middle ear it goes into the inner ear into the cochlea. The cochlea changes the vibrations to electric impulses, so the brain can recognize it. Then it goes to the brain. The ear also helps you keep your balance. You have an outer ear to help you catch sound vibrations.
\\36//
Say the phone rings. The sound passes through the outer ear, goes through the ear canal, and vibrates your eardrum. The eardrum vibrates three bones in your ear. Then the bones vibrate through the oval window and it is turned into something that is not vibrations so the brain can understand. Then the other things that aren’t vibrations go through a nerve and got to the brain. The brain picks up the message and tells you that the phone is ringing. The three bones are called the anvil, stirrup, and the hammer.
\\37//
To hear the phone ring, the sound comes from the phone through your ear canal. It hits the eardrum and vibrates the eardrum and the hammer, anvil, and stirrup. Those are three little bones in the ear. Then it goes through the oval window to the cochlea and that turns it into electrical impulses and sends it down a nerve to the brain and you hear the phone ring. But all the parts of the ear don’t help you hear. The semi-circular canal helps you balance. If one part of the ear was missing, you would not be able to hear. Your ear wax helps you not get an ear infection because it catches germs and bugs and stuff.
\\38//
Sound comes from vibration, which is a movement. Say the telephone was ringing, the vibrations would get caught in the outer ear and go in the ear canal. Then they would go to the eardrum, and vibrate down to the bones. From the bones, the sound goes through the oval window and into the cochlea. Then it goes up the auditory nerve into the brain. Then you realize it’s a phone and you go and pick it up. Sounds long, right? Nope, it happens in less than a second. There is also a part of your ear that helps you balance, called the semi-circular canal. Ear wax does sound

gross, but be thankful you have it. It keeps bugs and small objects from damaging your ear and hearing. Remember, never put anything smaller than your elbow in your ear.

\\39//

While you were gone, we learned about hearing. Say the phone had rung. The sound waves would travel into your ear canal. In your ear canal, the sound travels through ear wax and more ear wax. Then it travels to the auditory nerve. Then it hits your eardrum. Once it hits your eardrum, it travels to your brain. Then it sends messages so that your ear senses that the phone is ringing.

\\40//

The outer ear is kind of like a radar that can detect shock waves. The ear is an important thing to the body for protection and warnings. It is also important to the body because you need to hear stuff that is important. There are also little hairs for protection and ear wax for protection. The little hairs protect you by getting dirt particles and making them stick to the ear wax and the little hairs. There are tubes in the ear that look like vines but have nothing to do with the ear. The tubes or vines are used for the sense of balance.

The hearing process. First the shock waves from an object go into the ear. Then they go through the ear canal, which passes the ear wax and the hairs. Then after that, the vibration that went into the ear vibrates the eardrum that vibrates the three little bones. Then the last bone, the third bone, vibrates the oval window that goes into the cochlea. The cochlea then makes the shock waves of the object into electrical impulses. Then the electrical impulses go to the nerve, which sends the message to the brain. Then the object might be a phone and the brain will tell you what the object was.

\\41//

When the phone rings, the sound wave travels into the outer ear and goes into the ear canal. It travels into the middle ear and makes the eardrum vibrate. Then it goes into the inner ear. The sound waves make the three bones in the ear vibrate. It goes through the oval window where it’s changed into electrical impulses. Then the sound waves go into the brain and the brain tells you a phone is ringing.

\\42//

Sound waves travel through the air. The outer ear (the part you see) catches the waves and sends them through the ear canal. At the end of the canal is the eardrum. The waves vibrate the eardrum, which vibrates the three bones (the hammer, the stirrup, and the anvil). The vibrations vibrate through the oval window to the cochlea. The cochlea turns the vibrations into electrical impulses. The impulses travel out the cochlea and through the auditory nerve to the brain. All this happens in less than a second.

\\43//

The hearing process is: the outer ear receives vibrations, the sound goes down the ear canal and into the eardrum, and the eardrum sends it to the cochlea where it becomes sound. Then it went to the brain. The brain decides what it means and then you know what was the sound.

The eardrum vibrates when the vibration hits it. The cochlea is liquid. The cochlea is attached to the eardrum. The eardrum isn’t a drum.

The brain has a special part for determining sounds.

\\44//

If a phone rings the sound wave will be caught by your outer ear. The vibration will go through the ear canal to the eardrum. The eardrum sends the vibration to the hammer, then to the anvil, then to the stirrup. Then it goes to the oval window, then to the cochlea. The cochlea makes the vibrations into electrical impulses. The impulses are sent through the auditory nerve to the brain, which determines that the phone is ringing.

\\45//

First the outer ear catches the sound wave and the sound wave travels through the ear canal. The sound wave vibrates the eardrum. That causes the three bones of the middle ear to vibrate. The vibration causes the oval window to open and close. Then the sound waves are turned into electric impulses by the cochlea (connected to the oval window). The sound impulses travel up the auditory canal and to the brain, where it is made into a sound.

\\46//

The sound gets caught in the outer ear. Then it goes through the ear canal. Then it hits the eardrum. It sends it to the three bones. They vibrate and send it to the semi-circular canal. Then it sends it to the brain. The brain tells you what you hear.

\\47//

The first thing you should know is how the sound waves go through your ear. If the doorbell rings, the sound wave first goes through your outer ear. Then it goes through your ear canal. When it gets through the ear canal, it vibrates the eardrum, the anvil, and the stirrup. Then it vibrates the oval window. Then it goes through the cochlea, and then goes to the brain. That is how you know it’s the doorbell ringing, but it all goes much faster.

Also, one part of the ear has nothing to do with hearing, it just keeps balance. It is called the semi-circular canal. The outer ear is supposed to catch the sound wave in its cup-shaped figure.
Also, if you didn't have one of the three bones in your ear, you would not be able to hear. Also, if you pop your eardrum, you also would not be able to hear.
\\48//
When you hear something your eardrum must vibrate. Then the sound will travel inside the ear canal, where the stirrup and anvil are. There the sound will be turned into electrical impulses.
\\49//
In class we learned about the ear. First the outer ear catches the sound, then it goes into the ear. Then it goes in a tube, which I forgot the name of. It hits the eardrum, which makes it vibrate. Then three bones (anvil, stirrup, and hammer) vibrate and it goes into the oval window. Then it goes into the cochlea and it is made into electric impulses and goes to the brain by the auditory nerve. I also know that the outer ear is made out of cartilage. The ear makes ear wax from little glands. The ear wax is to catch dust and keep bugs out.
\\50//
First, I will tell you how you hear the telephone ring. First, your outer ear catches the sound waves. Then the sound travels through your ear canal. The sound vibrates your eardrum. The vibrations carry to the three bones in your ear, the anvil, hammer, and stirrup. A liquid fluid travels through your cochlea. Then it turns the vibration into electrical impulses. The auditory nerve takes the message to your brain, which says the telephone is ringing.
There are little hairs in your ear that help keep bugs and dirt out. Ear wax may seem disgusting, but it really helps you. If you listen to really loud noises, you could blow out the little hairs in your ear. If you blow out to many, your hearing could get bad.
Don't stick anything smaller than your elbow in your ear. It could get stuck and pop your eardrum.
\\51//
There are two parts of the ear, the outer and inner ear. The outer ear is the part of the ear you see. The inner ear is where your eardrum and wax are. I will tell you about the inner ear. It has many useful things in there. The most important is the eardrum, that is how you hear. I will tell you the steps of how you can hear your phone ring. First your ear gets a message from your brain saying it's the phone. Lots of it is from vibration that can go through your hearing canal and then you hear the phone ring.
\\52//
First the outer ear catches it. It goes through the ear canal, vibrates the eardrum. Then it causes the three bones to vibrate. It goes through the oval window, then goes in the cochlea and then goes through the nerve and sends a message to the brain. Everything is caused by air and everything happens so fast.
\\53//
When you hear something, the outer ear catches the sound waves. The sound waves go into the ear canal and make the eardrum to vibrate. Then the three bones start to vibrate, the anvil, stirrup, and the hammer. Then it goes through the oval window and the fluid in the cochlea keeps changing and it goes to the brain and the brain finds out what it is.
\\54//
I want my friends to understand when we go to the black top how we can settle the problem that we were having between two of my friends who were there. First you could shoot for it. Then whichever one wins the shootout would be the one who is playing. If you don't like it, play another game.
\\55//
Vibration of sound travels through the out ear, which is made of cartilage. It hits the eardrum, which hits the three bones (the hammer, anvil, and stirrup) which hit the oval window. Around here is something that doesn't have anything to do with hearing. It is the semi-circular canal. It has to do with balance. Back to hearing. The oval window hits the cochlea, which changes vibrations into electrical impulses. The nerve sends them to the brain.
\\56//
If a telephone rings, this is the way your ear can hear it and get the message to the brain so you can know that the telephone is ringing. First the sound waves are carried by air into the ear canal. Second, the sound wave hits the eardrum, which vibrates. Third, the vibration makes the bones in the middle ear hit each other and move. Fourth, the message is sent to the cochlea that makes the movement to electric impulses. Fifth, the message is sent to the brain by the auditory nerve. But there is one part of the ear that doesn't help you to hear. That part is the semi-circular canals. They help you to balance. If you didn't have them, you would not be able to stand.

Appendix C: Vision Essays

\\01//
The light hits the object. The light reflects off the object and into your eye. The light passes your cornea. The iris (colorful part) opens your pupil or closes it. The light has now passed you pupil. The light hits the back of your eye. Now the cones and rods start working. The eye sends the object to your optic nerve and the brain and turns right side up.
\\02//
The first part of vision is light. To see you need light to travel to a object and have it reflect back to your eyes. When the light reaches the eyes it passes through the cornea which is a clear substance that covers the eyes. After the light passes through the cornea the iris focuses the light, the iris is molecule tissue that focuses light by opening bigger or smaller. The iris opens bigger and smaller at certain time of day like when it's bright it's smaller and when it's darker it's bigger. After it passes through the iris it goes through the lens which focuses the image or you can say the lens refracts the light. After the lens refracts the light the light is focused near the retina of the eye. The retina is made up of cones and rods which pick up color, black, and white. So when a image hits the retina the cones and rods pick the image up and send the image to the brain by the optic nerve. Then the brain interprets the image and tells what you are seeing.
\\03//
The light bounces off an object and into your eye. First it goes through the cornea, a tough outside layer that protects the eye. It passes through the pupil and to the lens. The lens refracts the light on the retina. In the retina there are cells called cones and rods. Cones attract to color and rods attract to black and white. After the message is seen to color or black and white, it is sent to the brain by the optic nerve.
\\04//
When we were learning about the eye we started with the outer covering of the eye. The covering is made out of a special kind of cell that I do not know yet because we're going to finish tomorrow in the afternoon. When the telephone rings light bounces off the phone and goes through the white part. It sends it to the pupil and hits the lens. Then it hits the hollow part of your eye. Then it goes to the nerve and then goes to the brain and you see the phone.
\\05//
I will start with the process of vision. Vision starts when light bounces (or reflects) off of an object and it enters your eyes, this begins your vision of an object. It enters through the cornea and into the pupil. After moving through the pupil it is refracted and focused by the lens. After this occurrence there is an image projected on the cornea it is upside down. That image is sent from the blind spot on the retina through the optic nerve to the brain which flips the message right side up.
The white area on the outside of the iris is called the sclera (sc-LAR-a). The iris is a very strong muscle. It is the colored part of your eye. It is stationed on the outside of the pupil, and is the muscle that gives you the ability to make the pupil smaller or larger in change of light. The pupil is the black hole in the middle of your eye it allows the image to go into the lens. The lens refracts the light to make an upside down image on the back if the retina. The retina is the holder of the rods and cones. The rods help you to see black and white and the cones enable you to see color. The optic nerve send the image to the brain which flips it so you can see right side up.
\\06//
This is how the eye works. First you need light. The light will shine on the object you would like to see. Then the light bounces off the object and into your eye. Then the image will go through you cornea and into your pupil. Then it will go through you lens to the retina. The retina will have the image facing upside down, but after the message goes to your brain it will turn right side up and it will find out what it is.
\\07//
The steps of vision are very simple and not too long. To see an object what must happen is this. Light bounces off the object and into your eye. The light goes through the cornea and into your pupil. It passes your pupil then goes into your lens (lens is the color of your eye). Then the light passes through the lens and the light refracts. Then it bounces off the retina and into the optic nerve and into the brain. The brain makes the light right side up again.
\\08//
You look at something (for example a peach), the light wherever you are goes onto the object (the peach) and bounces off it and then goes into your pupil. The vision of the peach then goes through your eye and up to your brain. The brain then turns the object or peach right side up and tells you the object you are looking at is a peach.
\\09//

The first thing that happens when you see something is it goes to the cornea. Then it goes to the pupil, then the lens, then the retina upside down, and then the optic nerve. Then it goes to the brain and that makes you see it right side up.
\\10//
This is how the eye works. For example, if you see a dog this is how you would see it. First the sun will reflect light off the dog. Then the light will enter the cornea. After that the light will pass the pupil which helps focus it. Then the light will pass through the iris. After that the light will refract in the lens which focuses it on the retina. While on the retina, the image of the dog is upside down. The retina sends a message to the brain though the optic nerve. This message tells the brain that you saw a upside down dog. Then the brain turns the dog right side up. That is how the eye works.
\\11//
The eye has many stages of work. It has to go through the lens, pupil, iris, cornea, retina, and the inner eye to complete your visions. Your cornea cause color your rod in the back and helps you see in the dark.
\\12//
For your eye to see you need light like the sun or a light bulb. So the light hits an object and refracts to the retina (the retina is the part that protects the eye). After the retina the light passes through the pupil. Then hits the lens, which make the light turns over, and goes through the eye to the back of the eye. It then hits the optic nerve that sends the message to the brain. Then the brain sees the object and tells you what it is. That's how the eye works.
\\13//
First you need light to see the object. Then the image passes through your cornea. It then goes through the pupil to the middle of your eye. The image then gets turned upside down backwards as it goes through your lens. The image is then printed onto your retina and travels through the optic nerve to your brain where it gets transferred back to normal. After that your brain recognizes the image. That all happens in less than a split second.
\\14//
First the light bounces off of the object and goes past the iris and in the pupil. Then it goes through the lens to focus. Then it hits the retina upside down. Then your brain turns it around and you see. You need three things to see: light, eye, and brain.
\\15//
First you are going to need light to start the whole thing. Ok here we go. The light refracts off an object an goes through the cornea and into the pupil. Then it goes through the lens which turns the image that you see upside down. Then the light goes onto your retina. Then the image is sent to the brain. By the way it also depends if you are in the dark or light to know if you cones or rods are working. And the cones see color and the rods see black and white. Just to let you know, the retina is made out of cones and rods. These are important cells to your eye.
\\16//
The eye works by sending light to the cornea. Then it goes through the cornea and through the pupil into the retina. After that the picture shows upside down, but something, I forgot what it was called, switches the picture right side up so you can see the picture right. P.S. I wasn't here most of the day
\\17//
First light bounces off of the thing you are trying to see and into your eye. It travels through the cornea and into the pupil. It passes through the lens and onto the retina. The light refracts and turns upside down. It sends a message to the brain and the brain turns the image right side up. Then you can see.
\\18//
The eye works when light bounces off a object. The image goes into the cornea and into the pupil. From the pupil the image goes through the lens (the lens is like a camera lens). The lens is to focus the image on the retina (and turns it upside down). The retina is the back of the eye, then a nerve called the optic nerve takes it to the brain, which turns it right side up.
\\19//
To see things you need light. Your see things when light bounces of an object into your eye. The process it goes through is: first the light that bounced off the object goes through your cornea. Then it goes through your pupil and lens. The lens refracts it and then the object is upside down in the back of the eye by the retina. The vision goes through your optic nerve to the brain. The brain then turns the vision right side up so you can see.
At daytime your cones are on. At nighttime your rods are on. Some parts of the eye are the cornea, the pupil, iris, lens and retina. There is muscles connecting to your eyes which move them.
\\20//
The eye is a very delicate part of the body. It has different cells to process the image to give to your brain. It uses cone cells to see color, it uses rod cells to see black and white. The cells are located in the retina. Your eye sends

images to the brain by using the optic nerve. The optic nerve is in the back of your eye ball. If you in any way damage the optic nerve you will probably go blind or be almost blind. If you look at your eye in the mirror you will see a black dot. It is called the pupil. The pupil decides how much light should be let back into the retina. If it is very bright outside your pupil will be big. The pupil is a hole so when you see something it goes to the retina process the image and sends it back to the optic nerve. Then it is sent to your brain. The eye processes the image upside down. Then the eye corrects it. Your eye should always be treated with respect and never try to damage it.
\\21//
The eye to see first the light bounces off the object then into your cornea then into the pupil then the iris then it travels to the lens that puts it into focus then to the back of the eye at the optic nerve where it is turned right side up. Then the message is sent to the brain where it decides what it is. This all happens in a split second. The things in your eye that help you see in the dark are called rods. The things that help you see in color are called cones. In class we learned about eye protection that you should always wear eye protection. We also learned that your pupil is actually a big muscle. The sclera is the white part in your eye. The eye lashes and eye lid keep from getting dust in your eye.
\\22//
The first thing that happen is that the sun refracts from the object to your cornea. It goes to the pupil and then goes to the lens. Then it goes to the rod that turns it black or white or the other rod that turn it colorful.
\\23//
You need light in order to see. When you're looking at an object it reflects off that object and goes into your eye. First it goes through the cornea and into the pupil, through your lens, which makes it refract (turn upside down). The light goes to the back of your eye, called the retina, then it goes through the optic nerve and sends a message to your brain. The brain makes the object turn right side up and then you get to see the object.
Some people can't see so they have to have someone beside them. Instead of using their eye (which doesn't work) they use a stick that tells them where they're going. You should appreciate your eye because without it you couldn't see.
\\24//
Say you are looking at the telephone. The light hits the telephone. You may see it upside down. It bounces back into your eye and goes to the back of your eye and bounces off it. Then it hits your lens and bounces off it. It goes through your optical nerve to your brain and your brain turns it the right way.
\\25//
You always need light to see. First the light reflects of the object and passes though the cornea, then through the pupil. Then it goes on to the lens which focuses the picture. Then it goes on to the retina which turns the picture upside down. Then the image travels through the optic nerve and into the brain which then turns the image right side up and tells you what it is.
In class we learned about different parts of the eye, like the cornea. The cornea protects the eye from bad stuff like germs, dust or dust from getting into your eye. We also learned about the lens which focuses the image. And we learned about the retina which turns the image upside down. We also learned about the optic nerve ,which move the image.
\\26//
Pretend you are looking at a telephone. The light reflects off the telephone and hits your lends through your pupil. Then it goes through the iris, then the cochlea. Then it goes through the optic nerve and back.
\\27//
You need to have light to see something. The light bounces off what you're looking at and into your eyes. The reflection passes through the cornea into the pupil, and to the back of the eye to the retina. That sends a message to your brain that flips the picture right side up. The message goes back to your eyes, all very fast in split seconds. And you understand what you see. With your eyes you see color and black and white. There are things that help you to see color and black and white. They are called cones and rods. The cones help to see color and the rods black and white. The colored part of your eye is the iris.
\\28//
To see objects, light reflects onto the object and into your eye. It travels through the cornea, which protects your eye. It goes through the pupil (which lets in as much light that is needed). As it is going through the lens, the light refracts and goes into the retina where the image is turned upside down. On the retina there are cones and rods. The cones help you see color, and the rods help you see black and white. The light goes right to the optic nerve which then helps it travel to the brain. The brain turns it right side up. Then you can see the object.
\\29//

When the little hits the eye, it starts in the lens. It travel through the pupil into optic nerve, which would go through the cones. Then the light go to the retina and makes its way to the concave part which is in the way back of the eye. When the light hits, it bounces off so it refracts the light upside down and goes back out.

\\31//

The eye can look in all kinds of directions. It can look up it can look down it can look sideways and straight. The eye is one important thing in the body besides the lines is something in the eye that helps it to see thing like a dog. In a dogs eye it is so different then ours. In a dog eye it has lines too but it is different than ours. The dog's inner eye is called something else.

\\32//

Light hits objects. light goes into pupil. lens focuses picture, hits retina. rods and cones color image, goes through optic nerve, goes to brain. The pupil lets light in the eye. The lens focuses the image. Rods let you see black and white. Cones let you see color. The retina collects image and sends it to the optic nerve which sends it to the brain.

\\33//

To see you need light. In the dark (unless you can't see anything) there is some light. If you look at a tree the light bounces of the tree first, then to your eye. The light then refracts when it first hits your cornea. Then it refracts again when the image hits the lens. The light goes through the pupil to the back of your eye (the image is upside down right now) and a nerve tells the brain to reverse the image. The brain does and you see!

\\34//

The way that you can see is this. The light bounces off the object onto your eye. It goes through the pupil to the lens. The light refracts. It goes into your cornea to the retina. Then the cones turn what you see into color, for the picture. Then the image goes to the optic nerve to your brain where the image is turned right side up and identified.

\\35//

The why your eyes work is when light hits the object and then the light reflects the light into your cornea. Then it goes through the pupil. The pupil controls how much light that goes into your eye. After the light goes through your pupil it hits the lens the lens refracts the light and hits the retina. The image is upside down in the process. The image is sent through the optic nerve to the brain. The brain turns it right side up.

\\36//

Say you want to look at a phone. The light hits the phone and passes through the cornea into the pupil. Then it goes to the lens and the light refracts and criss-crosses. Then the object is projected upside down onto the back of your eye called the retina. Then the object's light goes through a nerve in the back that sends the object to your brain. The brain turn it right side up and tells you it is a telephone.

Cones see color. Rods see light.

\\37//

If you want to see something there has to be light because the light comes from the light source. The light hits the object. The image is carried in the light and goes through the cornea the cornea, which covers the iris and pupil. Then it goes through the pupil. The pupil lets a certain amount of light go through the lens, refracting in the bending of light. Then it hits the retina that sends a message to the optic nerve. The optic nerve sends a message the brain that turns the picture right side up because it was upside down in the eye.

\\38//

To be able to see, you need light.Well, first the light hits the object then bounce off into your eye through the cornea and into the pupil. From there it goes to the lens which projects onto the retina. But the image is upside down so it has to go to the optic nerve and travel to the brain and gets turned right side up. The rods help you see light or dark and cones help you see color. The colored part of the eye is called the iris, believe it or not. It is made out of muscle. The process sounds long, right. Well, it takes less time than for you to hear, less than a second. It is amazing how vision works.

\\39//

Say the phone rang, and you turned to look at it. The light would refract off the phone and into your eye. First your pupil would get smaller, then it would go through your iris. Then it travels through your optic nerve and sends vibrations to your brain. Then the brain communicates to you that you are looking at the phone.

\\40//

They eye is an very important thing. Your eyes are there for a reason. The reason is that it can protect when a tree might fall and kill and that's why it's there to protect and for warnings. The eye is a muscle, that's why is can move in different positions. The iris is the part of your eye that is colored. The lens is to help focus the eye to see. There's a lot more important things like the retina and the sclera. The sclera is the white part of your eye. The eye lashes are there so dirt particles won't get into your eye. That goes for the eyebrows too. There are also tear ducts. The tear duct is a very tiny hole where the tears come out. In the eye in the back past the lens and the blind spot there's the

optic nerve which sends the message to the brain. Then the brain figures out what the object is. There's also another thing. When you first look at something it's upside down. After it goes through the process of seeing, the brain turns it right side up.
\\41//
Say you're reading a book. Do you know how you see the letters? It all begins with light. The light rays go through your lens and into the eye. Then it goes to your cones which gives it color. Then the light focuses on your pupil which turns the image upside down. The optic nerve sends the image to the brain which turns it right side up and tells you it's a word.
\\42//
Light bounces off the object you're looking at and reflects through your cornea. The image travels through the pupil, then refracts through your lens. The retina (in the back of your eye) changes the image into electrical impulses. The impulses travel through the optic nerve to the brain where it flips the image (it was upside down the whole time) right side up. Now you see the object.
\\43 //
The pupil and the outer eye see something. The vision is bent by the rods and cones. The bent vision goes into the retina. The vision then goes to the brain. The brain decides what it is and sets the vision in a understandable picture, and then you see.
Light bounces off objects and your eye picks up the vision. The pupil controls the light in your eye. In darkness the pupil grows big to gather as much light possible. In light it shrinks.
\\44//
The light hits the object. The light bounces to your eye. Then the pupil gets smaller or larger depending on how bright it is. The lens refracts the light upside down to the retina. The retina focuses the image. The nerve sends it to the brain.
\\45//
First light travels through the cornea, then through the pupil. The pupil is connected to the iris, which is made up of muscle. The iris controls how much light comes into the eye. The light is refracted by the lens. The light is refracted two more times before hitting the retina. Before the light hits the retina it passes through the vitrois, which shapes the eye. Back to the point, the light then travels through the optic nerve and then to the brain.
\\46//
Your eye sees in upside down. It hits your lens to make it clear. Then it goes to the blind spot to make it right side up. Then the blind spot sends it to the brain. The brain tells you what you see.
\\47//
When you see something, for example a piece of chalk. First the light bounces off the object and then it goes into your eye. It reflects into the cornea then through the pupil. It reflects in the lens, and appears upside down in your eye. Then the optic nerve turns it right side up in the brain. Then you know it is a piece of chalk. The rods help you see in the dark and the cones help you see color. The pupil is just a hole in your eye, not a black ball. The iris is just muscle. The color of the iris is made by melanin, and muscles move the eye to help you see in all directions.
\\48//
What parts of the eye do. The optic nerve sends messages from the eye to the brain. The brain controls sight, hearing, smelling, taste and memory, and other things you might do. The pupil focuses on what you want to see.
\\49//
First light reflects off the object. Then light goes into your pupil. It goes into your lens and bends into the eye. Then it hits the retina and goes into the nerve up to your brain, which turns the sight right side up and allows you to see it.
\\50//
Pretend you are looking at a tree. I will explain how you see the tree. The light bounces off the tree and into your pupil. The light travels through your iris and refracts into your cornea. It sends the message upside down. It travels through the optic nerve. The brain turns the message right side up.
\\51//
Let say you wanted to see a tree and the sun was shining just fine. You open your eye. The light hits the object and refracts into your eye so you can see.
\\53//
You look at something. The vision goes to the back of your eye upside down. It goes to the optic nerve. The optic nerve sends it to the brain and the brain decides what it is.
\\54//
Vision is all about different parts of the eye. All of the different parts have to work together to make you be able to see. Did you know that the eye is one of the important parts of your body. If you didn't have your eye you would

have to go around everywhere by feel. These are the kinds of things in the eye that you need to be able to see. You need your four muscles to be able to move your eye where ever you want. You need your pupil to absorb the light. You need all of these things to be able to see.

\\55//

Light bounces off an object. It hits your iris, which hit the lens. The lens focuses on retina, sending message to optic nerve. The optic nerve sends message to brain. The iris focuses by opening and closing. The vitreous humor fills in eye ball so it doesn’t lose its shape.

\\56//

This is the process of how the eye sees. Light reflects off object. Pupil allows how much light can go in. The light passes the lens. The lens focus the object. Light refracts to the retina. Nerve sends message to brain.

Appendix D: Human and Computer Scores for Hearing Essays

Essay	Human score	SemScape score	Essay	Human score	SemScape score
1	3	4	30	3	3
2	5	5	31	2	2
3	5	4	32	4	4
4	4	3	33	4	4
5	4	4	34	5*	5
6	4	4	35	5	4
7	4	4	36	4	4
8	3	3	37	5	4
9	2	2	38	4	3
10	4	5	39	2	2
11	2	2	40	5	5
12	4	4	41	4*	4
13	3	4	42	4	5
14	4	3	43	3*	3
15	4	4	44	4	3
16	3	3	45	4	4
17	4	3	46	3	3
18	4	3	47	4	4
19	5	5	48	2	2
20	2	3	49	4	3
22	2*	2	50	5	4
23	4	4	51	2	3
24	3	2	52	3	2
25	3	4	53	4	4
26	2	2	54	1	1
27	4	4	55	4	3
28	3	3	56	4	4
29	2	3			

Anchor papers are indicated with an *

Appendix E: Human and Computer Scores for Vision Essays

Essay	Human score	SemScape score	Essay	Human score	SemScape score
1	4	4	28	5*	5
2	4	5	29	2	4
3	3	5	31	2	2
4	3	3	32	4	4
5	5	5	33	3	3
6	3	4	34	4	4
7	4	5	35	4	4
8	3	3	36	4	4
9	3*	3	37	4	5
10	4	4	38	5	5
11	2*	2	39	3	3
12	4	4	40	3	5
13	4	4	41	3	3
14	4	4	42	4	4
15	3	4	43	3	4
16	2	3	44	4*	4
17	3	3	45	3	4
18	4	3	46	2	2
19	5	5	47	3	5
20	2	5	48	2	3
21	4	4	49	4	3
22	2	2	50	3	3
23	4	4	51	2	2
24	3	4	53	2	3
25	5	5	54	2	3
26	2	3	55	3	4
27	3	4	56	3	3

Anchor papers are indicated with an *