2009

May 4th, 2009

IPRO 343
Improving Communication Quality in Noisy and Distracting Environments

Instructor: Dr. Matthew Bauer
Additional Assistance Provided by:
Prof. Halcyon Lawrence and Dr. Kathryn Riley

Table of Contents

1. Abstract

This IPRO sought to identify and provide speech intelligibility benchmarks in noisy and distracting environments. Being able to comprehend speech can be difficult depending on location and noise level of its surroundings. With that in mind, IPRO 343 conducted an experiment on those comprehensive speech factors, mainly speaking rate and duration, which can affect intelligibility. Based on the results, it is recommended that longer announcements be broken up into shorter messages and messages in general should be played at a normal to slow speaking rate. Pitch was also tested and it was found to have a negligible effect on speech intelligibility.

2. Background

a. Problem Addressed in the IPRO

A number of noisy and distracting environments involve communicating information to users through audio-based menus, prompts, and instructions, either from live speakers or speech synthesis. These situations include order taking in fast food drive-thrus, automatic subway and bus-stop identification systems, public address and warning systems, menu navigation in cell phones, voting machines, ATMs, and fare machines for municipal transportation services. Intelligibility of speech signals differs depending on the interaction between quality of the speech signal and the context within which it is heard. For example, noisy environments make fast speech less intelligible (Venkatagiri 2003; Jones et al 2007), whereas in the absence of environmental noise, both fast and slow speech signals are equally intelligible for natural but not synthetic speech (Nelson 1948, Harwood 1955, Jones et al. 2007).

The goal of IPRO 343 was to develop an overarching set of recommendations about improving intelligibility of speech in noisy and distracting environments. Initially, the following factors were considered that affect speech intelligibility:

Speaker Related Factors

- Intonation
- Gender
- Accent
- Speaking Rate
- Pitch

Recording Related Factors

- Loudness – varying volume
- Repetition
- Length/Duration
- Attention Cues

The team collected and analyzed public address announcements from a variety of noisy environments such as at O'Hare International Airport, various train stations (i.e. Union Station, Metra Stations), and on CTA "L" platforms, buses, and trains. Based on the most salient of the parameters from the samples collected the team narrowed their focus to examining the effects on intelligibility by altering speaking rate and duration.

b. Previous Semester's Work

In fall 2008, the work of IPRO 343 focused on factors that may improve accuracy of taking customer orders in a simulated fast food drive-thru environment. The attention was concentrated on an industry specific problem of speech intelligibility. The IPRO this semester broadened the scope of the investigation to study speech intelligibility in more public noisy and distracting environments. The results this semester are more universally beneficial for a wider number of applications, which could lead to finding multiple potential sponsors.

Representatives from a major fast food company met with the IPRO 343 F08 team and reported that their employees often have difficulty understanding orders in the drive-thru environment, a situation the representatives attribute to interference from other employees talking (Poonja, Karim 2008, personal communication). The team investigated whether the apparent negative effect of employee chatter can be masked to improve speech intelligibility of drive-thru orders. The hypothesis was tested that the employee chatter masked by white noise will improve understanding. The results showed that the addition of white noise to background chatter improves intelligibility, as indicated by order accuracy for both native and non-native speakers of English. Therefore the team

recommended that some form of white noise generation can be adopted by the fast food industry to address this problem.

c. Ethical Issues

The Institution Review Board (IRB) reviews research proposals that involve human participants. Our instructor, Dr. Matthew Bauer, submitted the application from the previous semester, fall 2008, to the IRB which was approved [Refer to Appendix 1 for IRB and Consent Forms]. Under last semester's application we were required to indicate the purpose and scope of the experiment, the type of testing that would be involved and importantly, indicate the ethical implications of the study. The ethical issues which were indicated were:

1. There may be a slight discomfort from wearing headphones for an extended period of time, as well as possible discomfort from sitting in a chair for an extended period of time.
2. There was also a possibility that participants could experience increased stress from being asked to make decisions quickly.

In addition, this semester every member of IPRO 343 completed the National Institutes of Health (NIH) Ethics Training Course with a combined total of over twenty hours of training.

3. Objectives

The goal of this IPRO was to propose a set of recommendations which could be used to improve speech intelligibility in public announcement systems. To achieve this, the team needed to:

a. record various public announcements from around the city
b. evaluate the recordings and provide salient speech characteristics on which to test
c. design and conduct an experiment to test the effects of altering these characteristics to provide the optimum standard
d. analyze the results and make recommendations based on the data

4. Methodology

a. Work Breakdown Structure

Presented below in **Table 1** is the IPRO 343 schedule.

Table 1. IPRO Schedule

	Goals/Activities	Time Spent (in Days)	Start Date	Actual Completion Date	Planned Completion Date
Preparation Phase	Project Plan/ IRB Form	3	2/3/09	2/6/09	2/6/09
	Budget Proposal	3	2/3/09	2/6/09	2/6/09
	Ethics (NIH) Training	5	2/5/09	2/10/09	2/10/09
	Record	5	2/5/09	2/10/09	2/17/09[i.]
	Analyze	7	2/10/09	2/17/09	2/24/09[ii.]
	Midterm Presentation	13	2/19/09	3/4/09	3/02/09
Experimental Phase	Devise Experiment Materials	32 (Spring Break included)	2/19/09	3/23/09	3/27/09[iii.]
	Recruitment	21 (Spring Break included)	3/10/09	3/31/09	4/20/09[iv.]
	Administer the Experiment	8	3/23/09	3/31/09	4/20/09[v.]
Culmination Phase	Exhibit	28	4/2/09	4/30/09	4/30/09
	Final Report	28	4/2/09	4/30/09	5/4/09
	Final Presentation	15	4/14/09	4/29/09	4/30/09

b. Changes made to the Work Breakdown Structure

In some cases, actual completion dates differed from the planned dates, these changes are justified below.

i. During the preparation phase, the recording team had completed all of their required recording tasks sooner than the proposed deadline.
ii. Since recording finished early, it was possible for the analysis team to start immediately.
iii. Even though the proposed deadline was later than the completion date, extension was still necessary during this period due to Spring Break. The materials of the experiment were developed and ready for use after the week of Spring Break. However, before the week of Spring Break, a trial run of the experiment procedure was tested by the entire IPRO team and came to a conclusion that the materials needed to be refined due to the difficulty and length of the entire experiment. Therefore, one day after the week of Spring Break was spent on the redevelopment. Refer to Obstacles for more details.
iv. Recruitment was extended until the end of the experiment due to the possibility or recruiting insufficient participants. The start date of recruitment was during the week of March 9th, 2009.
v. Administering and grading the experiment finished sooner than expected date.

c. Experiment Methodology

For a detailed overview of the experiment refer to Appendix 2. This report presents the step-by-step process of the conducted experiment. It details the development, procedures, result, and conclusion of the experiment.

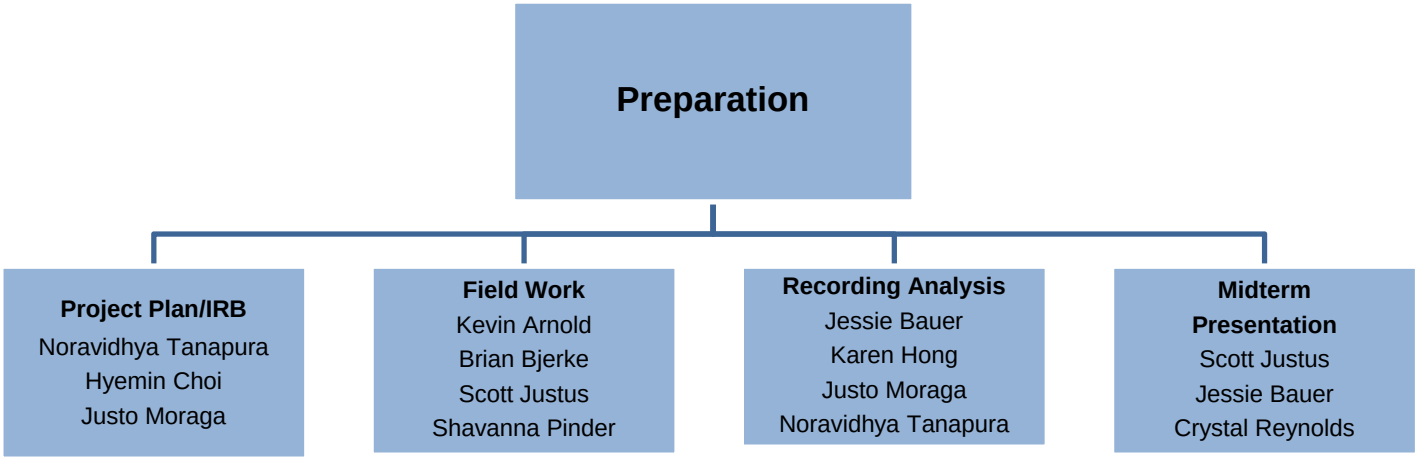
5. Team Structure and Assignments

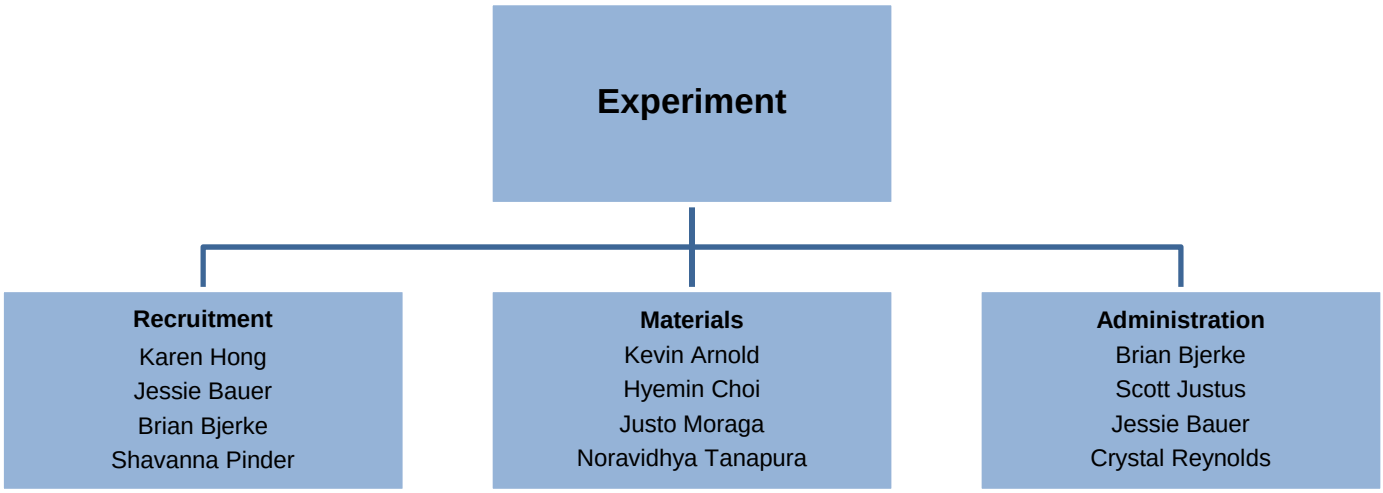
a. Updated Team Structure

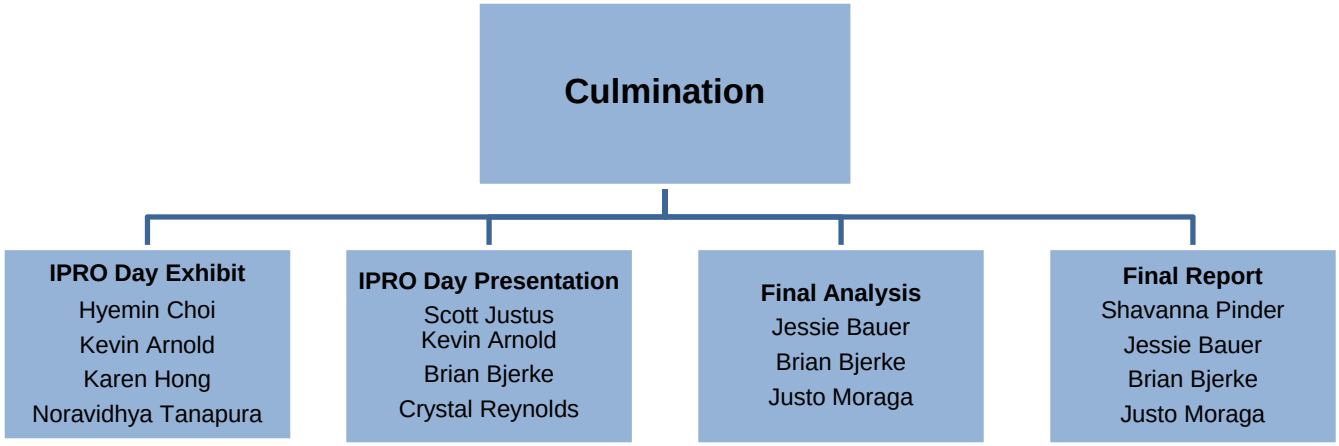
The IPRO 343 members were given team leader and team member roles. Individual

responsibilities changed during the course of the project. The project was divided into three phases; the preparation phase, the experiment phase, and the culmination phase. The breakdown of these is shown below under **Figure 1**.

Figure 1. Team Structure







Certain changes were made to the team structure during the course of the semester due to overlapping of members of different teams running at the same time. Changes were made to reorganize the members so that each person was working only on one team in the same time period.

b. Teams and Team Member Contributions

IPRO 343 was lead by Dr. Matthew Bauer in consultation with Dr. Kathryn Riley. Ten student members played a role during this semester's IPRO. Each member joined several groups based on their individual skills and interests, and every member also participated in running the experiment. Below **Table 2** shows the team contributions and individual phases of this IPRO.

Table 2. Team Member Contributions

Preparation

Groups	Description	Members	Sub-Tasks
Project Plan/IRB	This group handled the submission of the project plan, budget and the Institutional Review Board form (IRB).	Noravidhya Tanapura (Leader)	Organized topics for project plan

		Hyemin Choi	Wrote project plan/IRB form draft
		Justo Moraga	Proof read final project plan
Field Work:	This group recorded various speech syntheses for the analytical group.	Kevin Arnold (Leader)	Compiled sound data from recordings
		Brian Bjerke	Took Metra recordings
		Scott Justus	Took "L" recordings
		Shavanna Pinder	Took O'Hare recordings
Recording Analysis	Using the program PRAAT, this group analyzed the recordings for pitch, voice onset time, etc.	Jessie Bauer (Leader)	Analyzed sound data using PRAAT
		Karen Hong	Analyzed sound data using PRAAT

		Justo Moraga	Compiled sound data
		Noravidhya Tanapura	Analyzed sound data using PRAAT
Midterm Presentation	This group compiled the data into PowerPoint and presented for the midterm.	Crystal Reynolds (Leader)	Made PowerPoint slides and presented
		Scott Justus	Made PowerPoint slides and presented
		Jessie Bauer	Made PowerPoint slides and presented

Experiment

Groups	Description	Members	Sub-Tasks
Experiment-Recruiting	Members of this group were in charge of recruiting IIT students to come to the established experiment dates.	Karen Hong (Leader)	Recruited at the MTCC Bridge

		Shavanna Pinder	Recruited at the MTCC Bridge
		Jessie Bauer	Followed up on the participants.
		Brian Bjerke	Designed recruitment posters
		Justo Moraga	Scheduled the participants.
Experiment-Devise Material	This group generated the experimental methods and devices used to test the participants.	Justo Moraga (Leader)	Made experiment materials
		Hyemin Choi	Made experiment materials
		Kevin Arnold	Acquired data from recruitment group
		Noravidhya Tanapura	Compiled the experiment materials

Experiment-Administering	This group oversaw the experiments on the experiment days and collected the data acquired.	Brian Bjerke (Leader)	Set up the Experiment
		Jessie Bauer	Set up the Experiment
		Scott Justus	Secured consent forms
		Crystal Reynolds	Secured participant incentives
		All Team Members	Ran experiment/ Graded experiment results

Culmination

Groups	Description	Members	Sub-Tasks
Final Analysis	Members of this group analyzed the final data and determined any trends or relationships within the data.	Jessie Bauer (Leader)	Compiled experiment data
		Brian Bjerke	Analyzed experiment data

		Justo Moraga	Recommended standards using data
IPRO DAY-Exhibit	Members of this group designed the posters, brochure, and the exhibition table.	Hyemin Choi (Leader)	Designed IPRO day poster, set up exhibit table for IPRO Day
		Karen Hong	Designed IPRO day poster, set up exhibit table for IPRO Day
		Kevin Arnold	Designed IPRO day brochure, set up exhibit table for IPRO Day
		Noravidhya Tanapura	Designed exhibit table and brochure for IPRO Day, set up exhibit table for IPRO Day

Final Report	This group wrote the final report that has been submitted.	Shavanna Pinder (Leader)	Wrote abstract, background, and objectives for final report
		Jessie Bauer	Wrote team structure and assignments, budget, and results, for final report
		Justo Moraga	Wrote methodology, obstacles, resources, and results for final report
		Brian Bjerke	Wrote code of ethics, references, and acknowledge-ments, for final report
IPRO Day	This group was in charge of creating the	Scott Justus	Designed IPRO

Presentation	power point presentation and presenting on IPRO Day.	(Leader)	day presentation, presented on IPRO day
		Brian Bjerke	Presented on IPRO day
		Crystal Reynolds	Designed IPRO day presentation, presented on IPRO day
		Kevin Arnold	Presented on IPRO day

c. Team Profiles

Additional team information is available in Appendix 3.

6. Budget

a. Initial/Final Budget

The initial budget for this semester's IPRO is given under **Table 3** below.

Table 3. Initial Budget

	Days	**Price per Day**	**Total**
Participant Incentive/Support – Sodexo Catering	4	$125.00	$500.00
IPRO Day	**Amount**	**Price per Unit**	**Total**

Expenses			
Team Polo Shirts	8	$24.25	$194.00
Exhibit Materials	-	$90.00	$90.00
Other Expenses	**Amount**	**Price per Unit**	**Total**
Travel Expenses	-	$20.00	$20.00
Total Expenses			$804.00

The final income and expense account for IPRO 343 is given under **Table 4** below.

Table 4. Final Budget

Category	**Requested**	**Approved**	**Explanation**
Travel	$5	$5	Metra Ticket
Participant Support	$500	$500	Sodexho Catering
IPRO DAY Expenses	$299	$299	Experiment materials, etc.
Total	$804	$804	

b. Expense Details

A detailed listing of expenses based on date is given under **Table 5** below.

Table 5. Expense Details

Date	**Item**	**Cost**	**Amount**	**Total**
3-02-2009	Metra Ticket	$5	x1	$5
03-24-2009 to 03-27-2009	Sodexho Catering	$125 / day	x4	$500

04-14-2009	Experiment Materials	$90	x1	$90
04-14-2009	Team Shirts	$19.00 + shipping	x10	$194
Total				$804

c. iGroups

All other spending and budget concerns for IPRO 343 have been updated on iGROUPS.

7. IPRO 343 Code Of Ethics

Ethical considerations are the main priority for IPRO 343. With this in mind, IPRO 343 has an obligation to articulate its basic values, ethical principles, and ethical standards. The IPRO 343 sets forth these values, principles, and standards to guide members conduct. The *Code* is relevant to all student and faculty members, regardless of their professional functions, the settings in which they work, or the populations they serve.

All, personal and professional, conduct taken by IPRO 343 members shall adhere to state and legislative laws. Toleration of law-breaking will not occur, regardless of any progress breaking or bending the rules will bring. Should any of the laws be broken, then consequences none other than arrest shall be made.

No member shall reveal facts, data, or information without prior consent of students participating in experiment or data conveyed to him or her by advising faculty members. Discussion of results and or the progress IPRO 343 makes through experimentation that involves revealing results of specific individuals with non-IPRO 343 members shall not occur as all data should be kept confidential.

All personal conduct taken by members of IPRO 343 that either directly or indirectly relates to coursework for the progress of IPRO 343 shall remain professional. At any time a member is publicly representing IPRO 343 they shall behave with the utmost professional manner. Any misconduct will reflect poorly against IPRO 343 and could compromise its continuation.

Any progress to be achieved by IPRO 343 shall be innovative and any challenges will be taken

constructively. Actions taken that can influence the goals of IPRO 343 are to only be for improvement. Any detrimental effects could compromise its continuation.

The services provided by IPRO 343 members requires honesty, impartiality, fairness and equity. These services also must be dedicated to the betterment of public health, safety, and welfare of the group and community. If it is found and proven that a member of IPRO 343 has said or was responsible for acting against any of these qualities, it is up to the advisor to determine his or her future with IPRO 343.

IPRO 343 members adhere to abilities of utmost honesty and integrity in all relations. At no time shall any data or analysis be revealed that contain sensitive information without being discussed with all members and advisor. Severity of the consequences can only be determined by the type and seriousness of the released information.

Student members of IPRO 343 shall not attempt to obtain recognition or attempt to increase their status within the group by untruthfully criticizing or creating deception among other members. Rewards of completing a task shall be given to all members involved, not disregarding any member so as to take full credit. If partial credit is found and not directed towards a specific individual because the leader evidentially chose not to disclose this fact shall face consequences determined by the advisor of IPRO 343.

8. Results

a. Research Findings and Resources

Through the analysis of our experiment data, we have found that speaking rate and duration have a profound effect on the intelligibility of a spoken statement. We have found that both are inversely proportional to intelligibility. **Figure 2** that follows, illustrates this point.

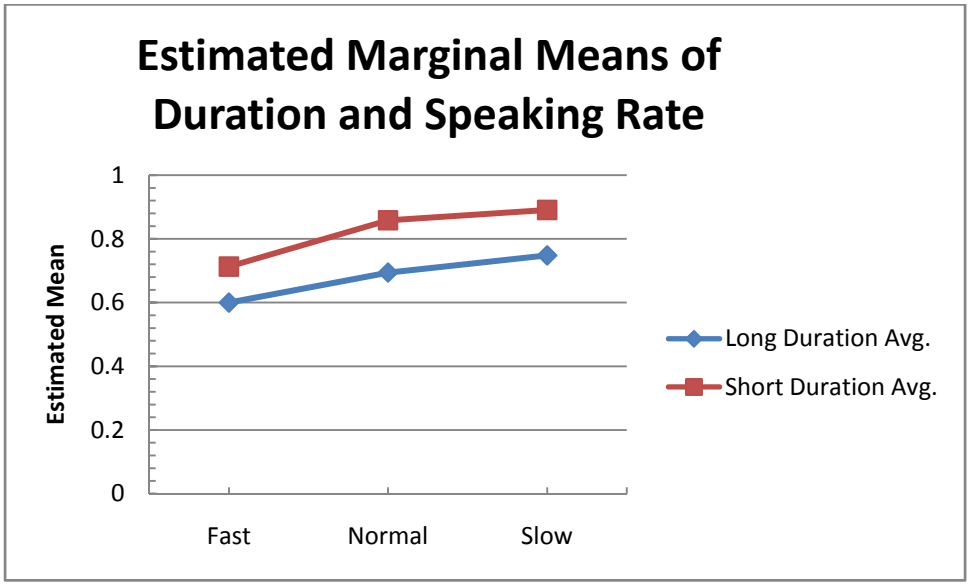


Figure 2. Estimated Marginal Means of Duration and Speaking Rate

As we can see from the above figure, as speaking rate decreases, intelligibility increases and short duration messages have a higher intelligibility over long duration messages. For a detailed analysis and an explanation of our experiment, interface, and stimuli please see the attached experiment report in Appendix 2.

b. Major Accomplishments

In addition to our own research findings, the team reflected on the process and indicated the following as being some of our major accomplishments:

i. Very few of the members of IPRO 343 had previously conducted a scientific experiment; this project allowed all members to be involved in the research, design, and experiment processes.

ii. Team members learned to use highly sophisticated recording devices to record dozens of announcements in public areas.

iii. None of the team members had significant experience using the sound recording software; this project allowed some members to learn how to use PRAAT to edit

sound files.

iv. The process of recruiting more than 60 participants also provided critical experience and employed a number of methods which included emails, and posters.

c. Assessment of Objective

All objectives listed in this report were successfully met, within budget and the time constraints of the semester.

d. Ethical, Moral, Cultural, or Scientific Issues

The team did not encounter any ethical, moral, cultural, or scientific issues in the conduct of the experiment. All participants signed the consent forms and no complaints have been directed to the team or the IPRO office regarding the conduct of the experiments. The confidentiality of all participants has been maintained.

9. Obstacles

Many obstacles were encountered during the experiment phase. Resolving these obstacles was crucial in order to complete the experiment. The following are brief descriptions of these obstacles and their resolutions.

1. The first procedure required our stimulus to be accompanied by sixty colored pages of shapes, direction, and color that the subject needed to identify and mark. Since each page printed was going to cost $.40, the total of printing 3600 pages (60 pages per 60 participants) was going to cost $1,440.00. By implementing a computer application, “Starquiz”, no paper printing was required and it allowed the team to grade and collect results sufficiently.
2. The first procedure went too fast and was too lengthy. Therefore, the experiment was cut down to 40 questions instead of 60 and the speed of the stimulus reduced. Also, a tutorial was developed so that any participant could become accustomed to the interface of the experiment.
3. The grading procedure required that each IPRO member type out the results letter by letter to each individual cell to a grading spreadsheet from the results of each

participant, which was very time consuming. By using the MID() function in the spreadsheet, the entire keyed response could be copied and pasted to a cell consisting of the function. It automatically parsed the response and pasted it individually to its corresponding cell, which saved us a lot of time.

Even though many obstacles were present, many solutions to overcome these obstacles were eventually figured out. With these obstacles resolved, in the end it was possible to retrieve valid results from the experiment. The document in Appendix 2 (The Experiment Methodology Report), presents a more detailed report on the experiment results and methodology for any present and/or future students who may conduct the same type of experiment.

10. Recommendations

In order to improve speech intelligibility under any noisy environments, the team recommends that:

1. Longer messages should be broken into shorter messages.
    - When not feasible, longer messages should be spoken at slow speaking rates.
2. For shorter messages, slower or neutral speaking rates improved intelligibility.
3. Since alteration in pitch had no significant effect on speech intelligibility, message frequency should be kept within the range of human voice.

Although, these recommendations not only can improve intelligibility in public noisy environments, they can be implemented in applications such as toys, intercoms at home or small buildings, or other places where any type of announcements or audio playback can be heard.

11. References

Refer to Appendix 2 – Experiment Methodology Report.

12. Resources

Table 6. Detailed Team Member Hours and Associated Cost

	Kevin Arnold	Jessie Bauer	Brian Bjerke	Hyemin Choi	Karen Hong	Scott Justus	Justo Moraga	Shavanna Pinder	Crystal Reynolds	Noravidhya Tanapura	Total
Project Plan/ IRB Form		1.0		1.0			3.0	1.5		11.0	**17.5**
Ethics (NIH) Training	2.0	2.0	3.5	1.0	2.0	2.0	1.0	1.5	2.0	3.5	**20.5**
Research	4.0	1.0	4.0	4.0			1.5	4.5	3.0	0.5	**22.5**
Fieldwork - Recording	5.5		5.0 $5.00			1.5		4.0			**16.0**
Recording Analysis	1.0	2.0			1.5		2.5		2.0		**9.0**
Midterm Presentation	0.5	5.5				9.0		2.0	7.0		**24.0**
Devise Experiment Materials	23.0			7.0			7.0			11.5	**48.5**
Recruitment		5.0	7.5	2.5	4.5		2.8	10.0		2.0	**34.3**
Experiment Administration , Grading, & Analysis	17.5	10.5	14.0	5.5	4.5	5.0 $500.00	3.0	13.0	12.5	6.5	**92.0**
Exhibit	5.0 $194.00+			6.0 $90.00	11.5					17.0	**39.5**
Final Report		5.5	5.0				20.0	22.5			**53.0**
Final Presentation	7.0		3.0			12.0			7.0		**29.0**
OTHER	5.0					1.0		7.5			**13.5**

13. Acknowledgements

We here at IPRO 343 would like to extend our appreciation to Dr. Kathryn Riley for being readily available to evaluate our midterm and final presentations and we thank the staff of the Humanities Department for providing the printing needs for our IPRO. We would also like to thank Galvin Library for letting us use their facilities to administer our experiment and Sodexo for providing the delicious refreshments!

Appendices

Appendix 1 – IRB Application Form and Participant Consent Form

APPLICATION FOR THE REVIEW OF RESEARCH INVOLVING HUMAN SUBJECTS

This application incorporates requirements from the Code of Federal Regulations, Title 45, Part 46, Protection of Human Subjects (rev. 3/83). Complete copies of 45 CFR 46 are available on the IIT IRB website at http://www.grad.iit.edu/research/irbhome.html.

ESSENTIAL DATA

1. **Responsible Project Investigator (qualified faculty/staff supervisor): Matt Bauer**

   Dept: _____HUM_____ Phone: __77967_____ Email: __matt.bauer@iit.edu_____

2. **Name of Investigator (if different from Responsible Project Investigator):**

   Dept: _____ Phone: _____ Email: _____

3. **Project Title:**

   IPRO 343: Improving communication quality in the drive thru environment

4. **Project Dates: From: _Oct 2008_ To: _Oct 2009_____**

5. **Type of Investigator(s):** __x_**Faculty**
   (check all that apply) _____**Staff**
   __x_**Graduate Student**
   __x_**Undergraduate Student**

6. **Status of Project:** __x_**New Project**
   _____**Periodic Review**
   _____**Change in Protocol**

7. **Site of Work:**
   Siegel Hall 236

8. **Type(s) of Subject:** _____**Adult, non-student**
   _x__**IIT student**
   _____**Non-IIT student**
   _____**Minor (under 18)**

9. **Characteristics**
   of Subject: _x__**Normal Volunteer**
   _____**In-patient**
   _____**Out-patient**

   _____**Mentally disabled individual**
   _____**Pregnant woman, fetus**

_____Individual with limited civil freedom

_____Individual with a court-appointed guardian

Note: The IRB encourages you to make double-sided copies in order to conserve resources.

10. Number of subjects, including "controls": 100

11. Sponsor, if externally funded:

_____
_____

12. If you have previously used human subjects in this research program, provide the information below for all subjects of the last twelve months:

_____Number of subjects screened

_____Number admitted to project

_____Number of withdrawals

_____Number who completed participation

_____Number still active

On a separate sheet, describe any problems encountered by participants. See Certifications for ongoing reporting requirements.

13. Is this research exempt from federal regulation? ( )YES (x)NO See Appendix I for conditions. If you believe that your research falls into categories listed, and therefore qualifies for expedited IRB review, CIRCLE the identifying numbers of those conditions below:

1 2 3 4 5

B. OBJECTIVES OF RESEARCH. Describe the objectives and significance of the proposed research involving human subjects:

1. Overview

This project will examine acoustic and cognitive factors that contribute to understanding speech in noisy environments. The goal of the project is to determine which of these aspects facilitate speech intelligibility among both native and non-native listeners. In particular, the project will focus on factors that may improve accuracy of taking customer orders in a simulated fast food drive-thru environment.

2. Objective

Representatives from a major fast food company claim many of their employees have difficulty understanding orders in the drive-thru environment, a situation the representatives attribute to interference from other employees talking (Poonja, Karim 2008, personal communication). At issue is whether the apparent negative effect of employee chatter can be masked to improve speech intelligibility of drive-thru orders.

The problem of understanding speech in noisy environments is not unique to drive-thru environments. A number of studies have shown that noisy environments reduce a person's ability to understand speech, particularly when the noise is due to background talk of a few people, compared to when the noise is due to environmental sources (e.g. "white noise") (Koul & Allen 1993; Payton et al 1994; Hoen et al. 2007; Barker 2007). Thus, environmental noise has less of a negative effect on speech intelligibility for listeners than noise due to background talk. Moreover, non-native listeners are especially prone to misunderstanding speech in noisy environments compared to native listeners (Van Wingaarden et al. 2002; Van Engeb & Bradlow 2007).

The current project tests the hypothesis that background talk masked by white noise will improve understanding of speech delivered in a drive-thru environment.

C. PROTOCOLS. Give details of the procedures that relate to the subjects' participation. What will the subjects do or what will be done to them? Append copies of all questionnaires or test instruments. If a research proposal has been or will be submitted to an external sponsor, append a copy of the technical portion of the proposal.

In the study, native English-speaking participants will be asked to play the part of an employee of a fast food restaurant in a simulated drive-thru situation. Participants will listen to a series of drive-thru orders from customers and mark what food items they ordered. All participants will listen to the same order, but the recording quality of the order will depend on two factors (2x2 design), which include hearing the order (1) with background talk at a low signal-to-noise ratio (SNR) or high SNR, and (2) the presence or absence of white noise (broadband noise between 100Hz and 10,000Hz). The participant pool will be divided into groups of 20 in each experimental condition. In addition, 20 non-native English speaking participants will listen to the drive-thru orders in the high SNR condition with white noise.

Participants will listen to recordings of orders through headphones. The headphones will play the individual orders on one side while the background talk and white noise play on the other side (following industry practice of drive-thru employees generally using head sets with speakers covering only one ear,

Poonja, Karim 2008, personal communication). Participants will then be asked to mark the order on a worksheet as quickly as possible. Each participant will hear approximately 10 to 20 orders.

The study will take place in Siegel Hall 236, a computer lab. Participants will be seated in front of a computer and wear over-the-ear headphones (Sennheisser HD 280 headphones, or equivalent). Before the start of the experiment, participants will hear a test signal and be told to adjust the volume to a level of their own comfort.

Sentence stimuli will consist of natural speech and exhibit a duration of approximately 10 - 15 seconds, e.g. “I would like 2 cheeseburgers, a diet Coke, 3 fries, and a chicken sandwich with pickles but no mayo.”

In addition, participants will be asked a set of demographic questions, including (1) age, (2) familiarity with English (Native, Native-like, or Non-native), and (3) frequency of using drive-thru environments.

The study will take about 20 minutes.

Participants will be volunteers, but will be offered a free lunch for participating, regardless of whether they complete the experiment or not (i.e. participants who withdraw will also be offered lunch). The lunch will be offered in Siegel Hall 218.

D. SELECTION OF SUBJECTS. Please check the appropriate responses and describe the methods you used to select your subjects. If you are using IIT students and offering credit for their participation, you must comply with IIT-IRB policy on this practice; the policy is attached as Appendix I.

1. Subjects will receive payment or course credit compensation for participation. If yes, state amount, form, and conditions in the case of monetary compensation; or attach a list of credit alternatives in the case of credit compensation (see Appendix II).

__x_yes ____no

Participants will not be given cash payment but will be offered a lunch of some kind (e.g. pizza).

2. Access to subjects will be gained through cooperating institutions. If yes, attach letter of agreement, or, for sponsored projects, DHHS Form 596. If agreement is conditional upon IIT approval, explain here.

____yes __x_no

3. This project involves investigators at another institution. If yes, identify investigators and institution(s).

____yes __x_no

4. Describe method of selecting subjects:

Members of the IPRO 343 will send email flyers to their friends and acquaintances throughout campus (flyer attached).

E. DECEPTION. If subjects are deceived or misled, or if information is withheld, identify the information involved, justify the deception, and describe the debriefing plan if there is one.

The study does not involve deception.

F. CONFIDENTIALITY OF DATA: Confidentiality of data is required unless subjects give express permission that data may be identified. Indicate which of the following categories describes this research, and provide supporting information as needed.

X Responses will be anonymous. No one, including the researchers, will be able to identify participants, whether through names or identifiers linked to names.

_ Responses will be confidential. Identifying information will be accessible only by the project researchers.

Describe the methods to be used to ensure confidentiality, such as where identifying information will be stored, and when identifying records will be destroyed.

__ Responses will not be confidential. Explain.

__ Other. Explain.

G. INFORMED CONSENT. Informed consent is a legal requirement for research involving human subjects: "No investigator may involve a human being as a subject in research covered by these regulations unless the investigator has obtained the legally effective informed consent of the subject or the subject's legally authorized representative. An investigator shall seek such consent only under circumstances that provide the prospective subject or the representative sufficient opportunity to consider whether or not to participate and that minimize the possibility of coercion or undue influence. The information that is given to the subject or the representative shall be in language understandable to the subject or the representative" (45 CFR 46.116). If the subject is a minor, at least verbal assent should be obtained from the child in addition to the required written consent by the parent/guardian. EACH SUBJECT MUST BE GIVEN A COPY OF THE CONSENT FORM.

Yes x No Informed consent will be obtained from all research participants.

Yes x No Informed consent will be documented through a written form which will be signed by the research participant or a legal guardian.

If you answered no to either of the above questions, please explain.

H. RISKS. Will subjects in the proposed research be placed at more than minimal risk? (*Minimal risk* means that the risks of harm anticipated are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.)

_x Minimal risk
____More than minimal risk

1. **Describe the risks and the precautions that will be taken to minimize them, even if risk is minimal. The concept of risk goes beyond physical risk and includes risk to the subject's**

dignity and self-respect, as well as psychological, emotional, or behavioral risk. "*No risk" is not an acceptable answer.*

There may be a slight discomfort from wearing headphones for an extended period of time, as well as possible discomfort from sitting in a chair for an extended period of time. There is also a possibility that participants experience increased stress from being asked to make decisions quickly.

2. Will any part of this research allow the investigator to identify participants who are likely to cause harm to themselves or others? (e.g. suicidal thoughts, child abuse)

No __x___

Yes _____ If yes, what procedures will be implemented?

I. <u>BENEFITS</u>. Describe the benefits to the subject and society. The IRB must have sufficient information to make a determination that the benefits outweigh whatever risks are involved.

The study will not benefit participants in any way, beyond the possible psychological benefit of participating in ongoing research. In general, the goal of the project is to isolate factors that may facilitate understanding speech in noisy conditions. While the focus of the study is designed to improve communication quality in the drive-thru experience, results may be applicable to other practical domains (e.g., improving intelligibility of speech synthesis in devices intended to comply with requirements of effective communication under the Americans with Disability Act).

J. <u>CERTIFICATIONS</u>:

I am familiar with the ethical guidelines and application requirements provided by the IRB and will adhere to the policies and procedures explained.

Should any change in procedures involving human subjects become advisable, I will submit it for review prior to initiating the change.

I certify using the consent form approved and stamped by IIT IRB.

If any problems involving a human subject occur, I will immediately notify the Director of Research Compliance and Proposal Development, who is also the Executive Officer of the IRB.

Signature of Responsible Project Investigator: Date:

Signature of Investigator (if different from Responsible Project Investigator): Date:

ILLINOIS INSTITUTE OF TECHNOLOGY

Consent to Participate in Research

Project Title: Improving Communication Quality in Noisy Environments

Researcher:

Team IPRO 343 Dr. Matthew J. Bauer

Introduction

You are invited to participate in a study about taking customer orders in a simulated fast food drive-thru environment. You are requested to read this form and ask any questions that you might have before deciding to be in the study. The purpose of the study is to determine what factors might improve accuracy of taking drive-thru orders.

Total Number of Participants

About 100 people will participate in the study.

General Plan of the Study

If you decide to be in the study, you will be asked to listen to a series of sound recordings. During each recording, you will input on a keyboard the content of what you are hearing. In the study, you will be seated in front of a computer at a lab in the library and listen to the recordings on headphones alongside other participants.

Length of the Study

The study will take about 20 minutes.

Possible Risks or Benefits of Participating in This Study

The study involves the use of headphones. Before the beginning of the test, you will be given an opportunity to play a test sound, by which you can calibrate the volume on your headphones and set it to the volume at which you are most comfortable.

Data Security and Confidentiality

The records of this study will be kept in private. In any sort of report that might be published, no information will be included that would make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records.

My Rights as a Participant

My decision whether or not to participate in this study will not affect my current or future relations with IIT or the research staff. If I decide to participate, I am free to withdraw at any time without affecting those relationships.

I understand that the Illinois Institute of Technology is not responsible for any injuries or medical conditions I may suffer during the time I am a research subject unless those injuries or medical conditions are due to IIT's negligence. I may address questions and complaints to Glenn Krell MPA, CRA, Executive Officer of IIT Institutional Review Board at (312) 567-7141.

I have read the material above and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that I may withdraw without penalty at any time

Researcher's Statement

I have fully explained this study to the participant. I have discussed the procedures and have answered all of the questions that the participant has asked.

Signature of Investigator _____ Date _____

Participant's Consent

I have read the information provided in this Informed Consent Form. All my questions were answered to my satisfaction. I have received a copy of the consent form. I voluntarily agree to participate in this study.

Your Name _____

Your Signature _____ Date _____

Appendix 2 – Experiment Methodology Report

IPRO 343 EXPERIMENT METHODOLOGY REPORT

"Deciphering Factors that Improve Speech Intelligibility under Noisy Environments."

Kevin Arnold, Jessie Bauer, Brian Bjerke, Hyemin Choi, Karen Hong, Scott Justus, Justo Moraga, Shavanna Pinder, Crystal Reynolds, & Noravidhya Tanapura

I. Abstract

This experiment assessed the factors that affect speech intelligibility in noisy environments. These noisy environments, for example, could be in any train platforms, airports, or any places that public announcements could be heard. According to the results from the previous semester, white noise contributed to improving intelligibility. This semester, however, the IPRO team took other speech factors that could help identify a benchmark to improve speech intelligibility in public announcements. These factors were pitch, duration, and speaking rate and the experiment results showed that pitch was negligible and specific alterations to duration and speaking rate made significant improvements.

II. Introduction

According to the Americans with Disabilities Act of 1990, any public entity required the use of "effective communication" to members of the public, and text-to-speech synthesis is one suggested way to achieve this. The language pertaining to effective communications was clarified in ADA Regulation for Title II in 1992,the ruling of which sets forth "the general…requirements for making programs accessible to individuals with disabilities and for providing equally effective communications" (DOJ 1992).The relevant language is stated in Section 35.160(a) and requires that a "public entity take such steps as may be necessary to ensure that communications with applicants, participants, and members of the public with disabilities are as effective as communications with others. Under Title II of the ADA, all state and local governments are required to take steps to ensure that their communications with people with disabilities are as effective as communications with others.

To meet these requirements, any publication regarding communication must be serviced

effectively not just to anyone in the public but to anyone who is impaired or disabled. These services, for example, could be any of the following: speech synthesizers, communication boards, audio recordings, and/or hearing aid-compatible telephones. Unfortunately, the language of ADA, as well as the language of the accompanying Regulation for Title II and the DOJ tool-kit, does not state precisely what counts as effective communication, nor does it state what design features, or talker characteristics, auxiliary services must exhibit in order to achieve effective communication. To take just one example, "speech synthesizers" is listed as an auxiliary service but nowhere is it explained what standards such synthesizers must meet in order to be considered accessible to disabled users. The problem with "effective communication" is that it leaves open the question of what specifications must be in place in order to meet that goal. With this in mind, the IPRO team agreed on assessing speech intelligibility under the factors of duration, speaking rate, and pitch to help develop these certain standards that these auxiliary services do not hold.

It was established in the beginning of the class that there were no standards among these factors that would help with speech intelligibility in public venues. The IPRO recording team took recordings from CTA platforms, Metra, and O'Hare public announcements. From those recordings, the IPRO analysis team concluded that duration and rate had many variations. On the other, pitch was not determined due to the poor quality of the recordings. However, the IPRO team was able to use these recordings to calculate averages of duration and rate on which to base our experiment.
Even though pitch was not able to be determined in the recordings, the experiment still accounted for all three factors. The following is the basis of the team's hypothesis:

- Speech intelligibility will decrease if duration is longer
- If speaking rate is increased, speech intelligibility will decrease
- Pitch will have no significant effect on intelligibility

III. Method

Pitch, duration, and speaking rate were implemented in the IPRO's experiment. It involved forty exercises for our participants to listen to while they responded by typing in what they heard. These exercises were different combinations of: long and short durations, high and low pitches, and slow, neutral, and fast speaking rates. In addition, white noise was also included in the background of these listening exercises to replicate a noisy environment.

A. Participants

1. Listeners

All participants of the experiment were students from IIT's campus. The team recruited 77 participants, and among these participants, there was a mix of non-native and native speakers of English. All participants were compensated with pizza and refreshments after the experiment.

Out of 77 participants and their results, the team was only able to use 65 of them for analysis. The team was forced to omit some of the results of a few participants, seeing as it would skew the total averages of the entire experiment. Two of the 77 participants only completed half of the entire experiment, while 8 of the 77 had blank responses. Also, two more were omitted because the stickers placed on the keyboard were inaccurate, refer to Stimuli for details. Furthermore, given that the team initially planned to recruit 60 participants, having 5 more would have been more than sufficient for a valid experimental conclusion.

B. Stimuli

Synthesized recordings were used to act as the stimuli of the experiment. The recording was extracted using a text to speech application in Microsoft Excel. These synthesized recordings were composed of 8 shapes, 8 colors, and 4 directions. Table 1 shows a visual of the recording.

Table 1: Stimuli Visual

Heart	Triangle	Square	Circle	Yellow	Blue	Black	Red	Up	Down
Star	Oval	Diamond	Cross	Orange	White	Purple	Green	Left	Right

Each of these visuals was then printed on a sticker so that it would be placed on the keys of the keyboard, shown in Figure 1.

Figure 1: Keyboard Stimuli

A sample of a recording included the number of the question, a brief pause, and then a series of shape, direction, and color in random order. For instance, "1…red, circle, up, triangle, blue, down, right, square, purple, oval, left, blue, star, orange, up."
Each sample included background white noise. This white noise was made using a formula tool in PRAAT that created a sound with frequencies between 250 and 1000 Hz. According to Noise Pollution and Control by Singal, the frequencies of the white noise replicated the same measurement of train sounds in a subway.

C. Devising the Experimental Procedure

In order to complete the procedure of the experiment, the stimuli needed to be randomized and manipulated to the desired duration, pitch, and rate using Excel and PRAAT. Using the random function in Excel, the experiment team was able to randomize the order of shapes, direction, and color. Since, there were two types of duration, two types of pitch, and three types of speaking rate, the experiment team concluded with a 2 by 2 by 3 measuring group, which meant there were (2*2*3) 12 different ways to manipulate the stimuli. Table 2 shows all the different combination of the stimuli.

Table 2: Subject Factors

Duration	Pitch	Rate	
Long	High	Fast	LHF
		Neutral	LHN
		Slow	LHS
	Low	Fast	LLF
		Neutral	LLN
		Slow	LLS
Short	High	Fast	SHF
		Neutral	SHN
		Slow	SHS
	Low	Fast	SLF
		Neutral	SLN
		Slow	SLS

The Experiment Materials team agreed that in order to have a justified accumulated result, each of the subject factors should be asked five times, which results in (5*12) 60 questions total. However, 60 questions seemed too lengthy, so the stimulus was shortened to 40, refer to Obstacles for further details. Using PRAAT, all 40 stimuli were manipulated to its corresponding subject factor. The following table (Table 3) shows the specifications of each factor.

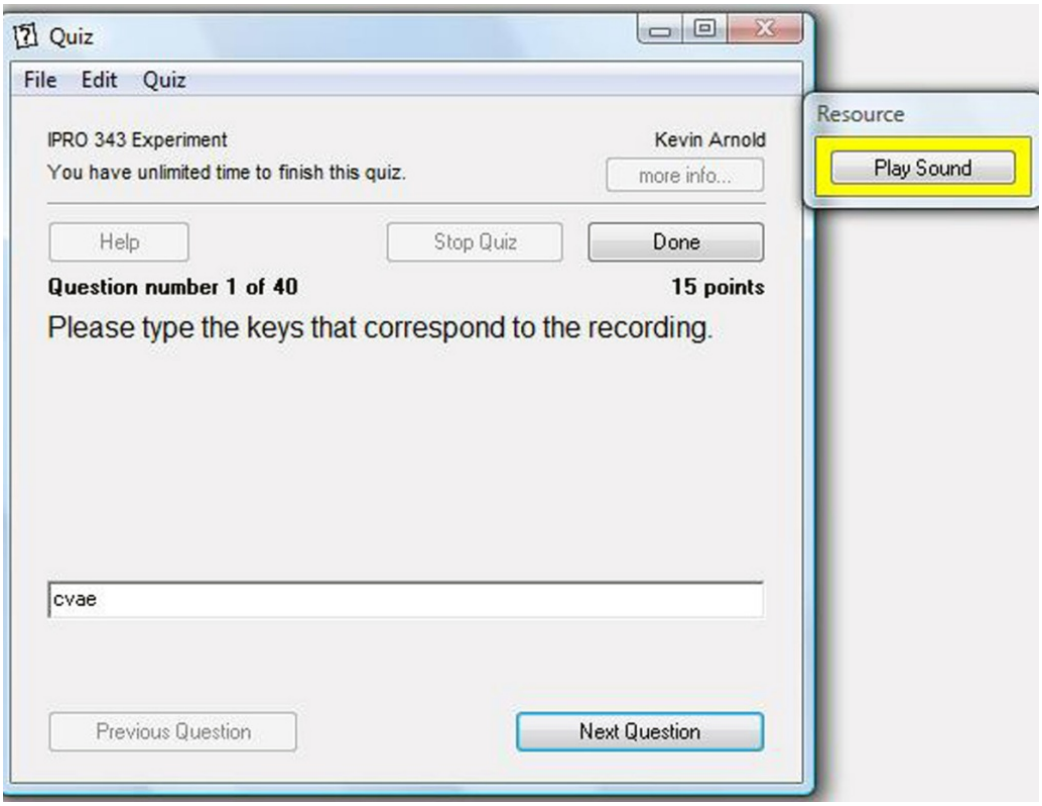
Table 3: Specifications of Subject Factors

Duration	**WPM**	**TIME (SEC)**	**# of WORDS**
Short	Slow	10.88	15
Short	Normal	9.09	15
Short	Fast	8.04	15
Short	Average	9.33666667	15
Long	Slow	22.22	30
Long	Normal	20.25	30
Long	Fast	16.14	30
Long	Average	19.5366667	30
Frequency	**Hz**		
High	209.02		
Low	113.76		
Words per Minute (WPM)	**W/SEC**	**WPM**	
Slow	1.3767	82.602	
Normal	1.4801	88.806	
Fast	1.8648	111.888	

For example, if the 1st listening stimulus was an LHN, it would consist of 10 shapes, 10 colors, and 10 directions being 30 words total in random order. It would also be at a higher pitch and a normal speaking rate.

Once all 40 stimuli were manipulated, they were integrated in a computer application called "Starquiz". This downloaded application was a 30-day free trial that lets you create a computer base quiz (http://www.cosmicsoft.net/starQuiz/). Each question in the quiz was accompanied with an audio application of each stimuli recording and a text box for the user to enter their responses, shown in Figure 2. In addition, the quiz was also accompanied with a tutorial which participants took. The tutorial was four questions taken from the actual quiz but the user input was not recorded. This was simply a practice run for the participant.

Figure 2: Starquiz Example



Ten computers in the computer lab had "Starquiz" installed, and these computers also had the stimuli stickers placed on each keyboard. With each computer, a Bose headphone was provided for each participant. A sample stimuli question would involve a participant to put on the headphones, hit play on the audio application of "Starquiz", and then type in the text box what he/she heard.

D. The Experiment

1. Conducting the Experiment

As the participants entered the computer lab they were asked to be seated by one of the ten computers with headphones. Each participant was then asked to read and sign the consent form, refer to Appendix 2. Before each began the experiment, they were asked the following questions:

-How old are you?
-Do you have any trouble discerning colors?
-Do you have any hearing problems that you are aware of?

Once they answered the given questions, they were given a number representing the number of participants. The participant was then asked to put on the headphones and start the tutorial. The quiz was then started after the tutorial.

2. Grading the Experiment

The grading script, shown in **Figure 3**, was composed of three sheets. Sheet 1 was the rating form that included rater one and rater two. There were two graders involved per one result of a participant to improve the accuracy of data input. Shown in **Figure 4**, is an example of the result in "Starquiz". All 40 answers were copied into the rating form twice, and Sheet 2, the answer sheet, then checks the answers from Sheet 1 and compares it with the correct answer. The Answer Sheet then sums up all the correct answers per individual question and transfers the entire total sum into Sheet 3, the Tally Sheet.

Figure 4: Result Example in Starquiz

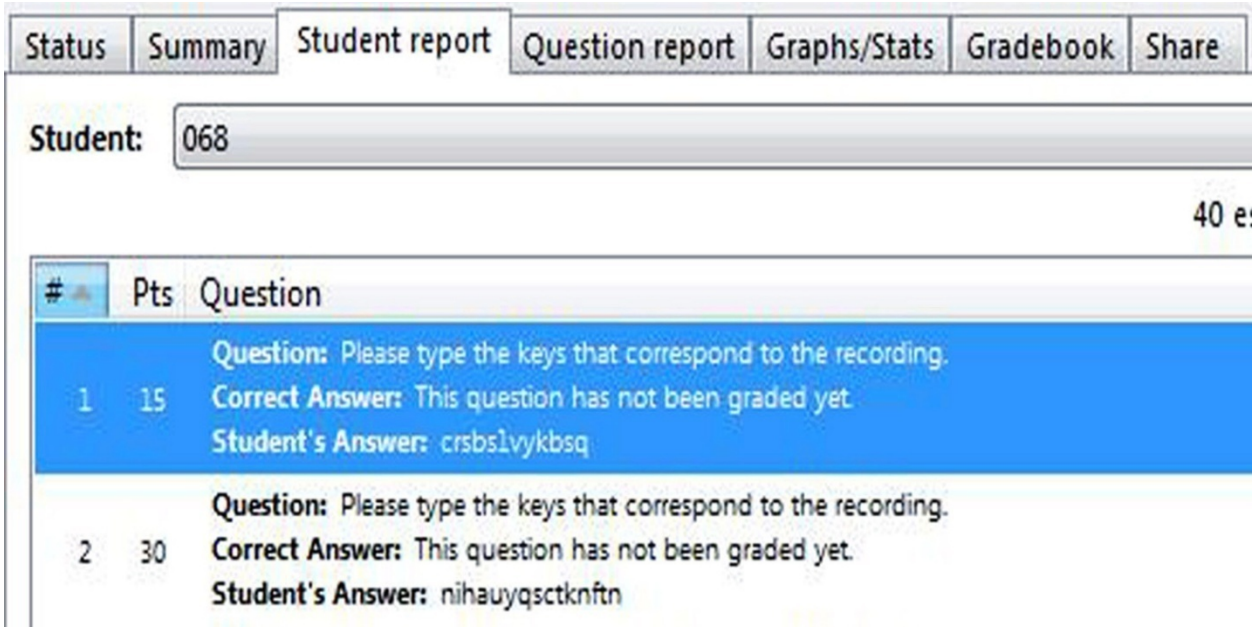
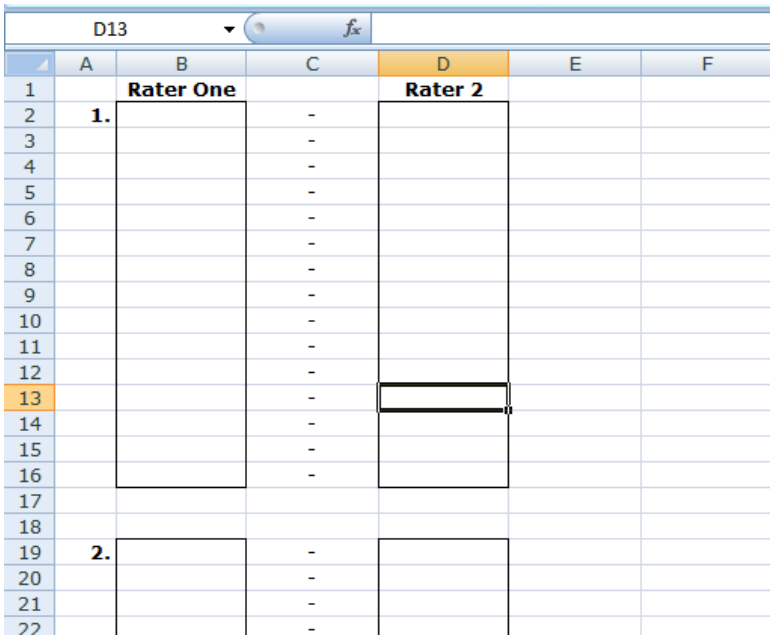


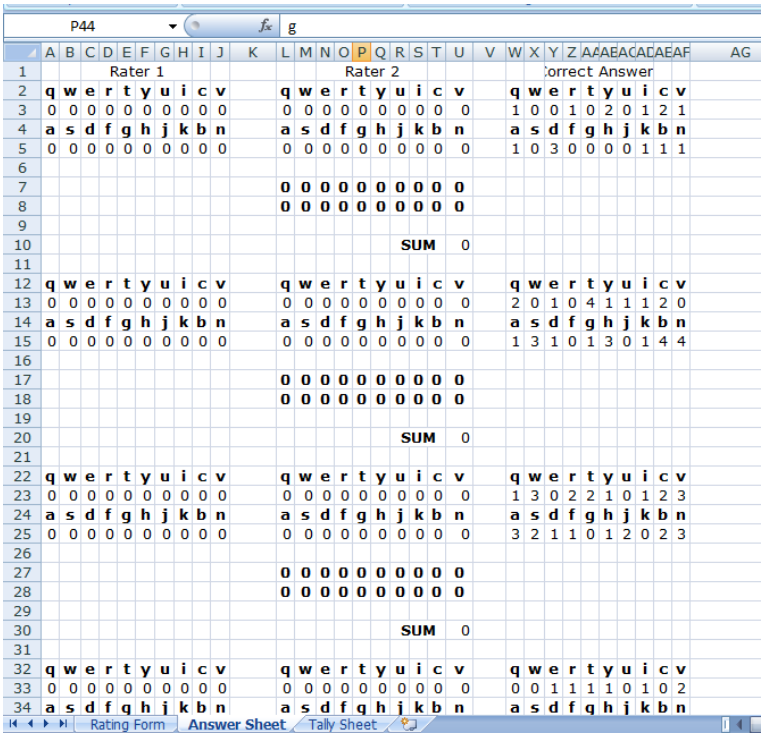
Figure 3: Grading Scripts

Sheet 1: Rating Form



	A	B	C	D	E	F
1		**Rater One**		**Rater 2**		
2	**1.**		-			
3			-			
4			-			
5			-			
6			-			
7			-			
8			-			
9			-			
10			-			
11			-			
12			-			
13			-			
14			-			
15			-			
16			-			
17						
18						
19	**2.**		-			
20			-			
21			-			
22			-			

Sheet 2: Answer Sheet



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1					Rater 1											Rater 2											Correct Answer							
2	**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**	
3	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		1	0	0	1	0	2	0	1	2	1	
4	**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**	
5	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		1	0	3	0	0	0	0	1	1	1	
6																																		
7												**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**													
8												**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**													
9																																		
10																			**SUM**		0												
11																																		
12	**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**	
13	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		2	0	1	0	4	1	1	1	2	0	
14	**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**	
15	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		1	3	1	0	1	3	0	1	4	4	
16																																		
17												**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**													
18												**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**													
19																																		
20																			**SUM**		0												
21																																		
22	**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**	
23	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		1	3	0	2	2	1	0	1	2	3	
24	**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**	
25	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		3	2	1	1	0	1	2	0	2	3	
26																																		
27												**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**													
28												**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**													
29																																		
30																			**SUM**		0												
31																																		
32	**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**		**q**	**w**	**e**	**r**	**t**	**y**	**u**	**i**	**c**	**v**	
33	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		0	0	1	1	1	1	0	1	0	2	
34	**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**		**a**	**s**	**d**	**f**	**g**	**h**	**j**	**k**	**b**	**n**	

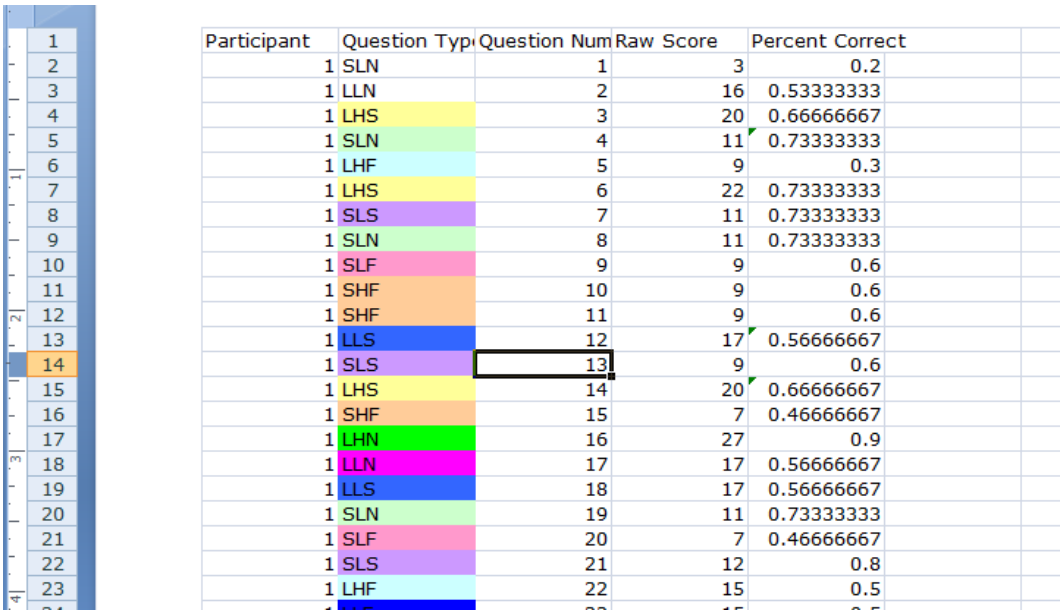
Rating Form | Answer Sheet | Tally Sheet

Sheet 3: Tally Sheet

	A	B	C	D
1	Question 1	0		
2	Question 2	0		
3	Question 3	0		
4	Question 4	0		
5	Question 5	0		
6	Question 6	0		
7	Question 7	0		
8	Question 8	0		
9	Question 9	0		
10	Question 10	0		
11	Question 11	0		
12	Question 12	0		
13	Question 13	0		
14	Question 14	0		
15	Question 15	0		
16	Question 16	0		
17	Question 17	0		
18	Question 18	0		
19	Question 19	0		
20	Question 20	0		
21	Question 21	0		
22	Question 22	0		
23	Question 23	0		
24	Question 24	0		
25	Question 25	0		
26	Question 26	0		

When all 65 participants' results were graded, it was all then allocated to another spreadsheet that analyzed the result, shown in Figure 4. The Grading Analysis Spreadsheet calculated the raw score and its percentage correct for each question. The spreadsheet also helps the grader identify the type of each question; refer to Table 2 for their representations.

Figure 4: Grading Analysis Spreadsheet



Participant	Question Typ	Question Num	Raw Score	Percent Correct
1	SLN	1	3	0.2
1	LLN	2	16	0.53333333
1	LHS	3	20	0.66666667
1	SLN	4	11	0.73333333
1	LHF	5	9	0.3
1	LHS	6	22	0.73333333
1	SLS	7	11	0.73333333
1	SLN	8	11	0.73333333
1	SLF	9	9	0.6
1	SHF	10	9	0.6
1	SHF	11	9	0.6
1	LLS	12	17	0.56666667
1	SLS	13	9	0.6
1	LHS	14	20	0.66666667
1	SHF	15	7	0.46666667
1	LHN	16	27	0.9
1	LLN	17	17	0.56666667
1	LLS	18	17	0.56666667
1	SLN	19	11	0.73333333
1	SLF	20	7	0.46666667
1	SLS	21	12	0.8
1	LHF	22	15	0.5

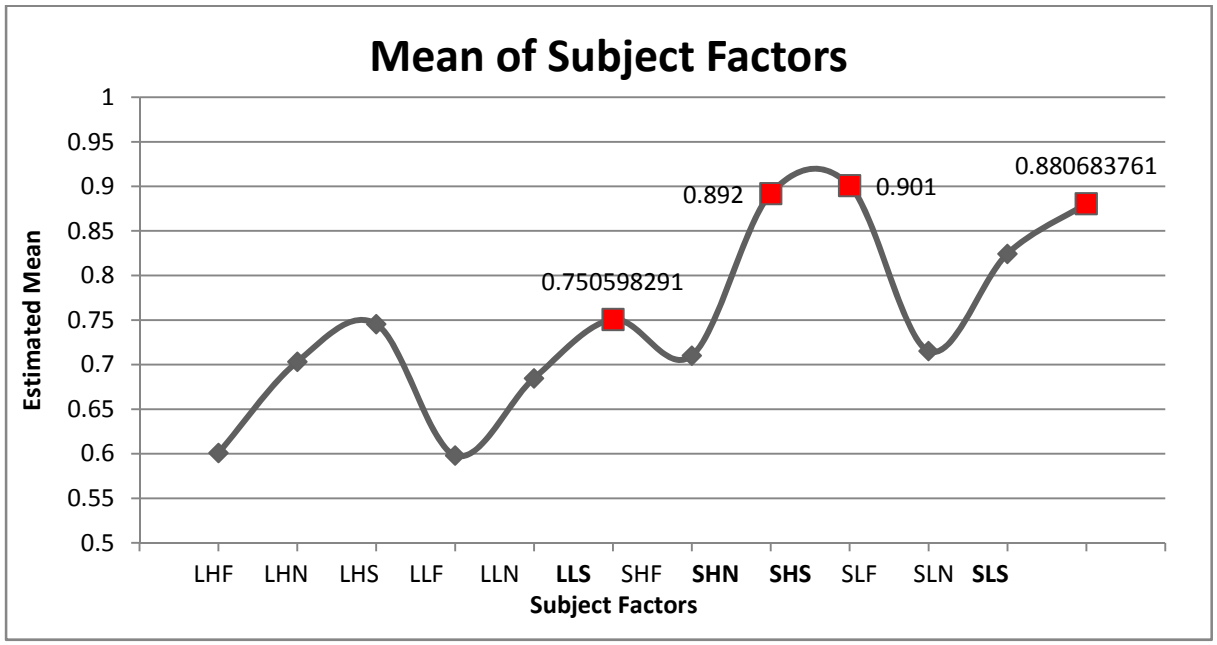
IV. Results

Judging by the averages shown in **Figure 5**, the factor of pitch had little effect on the experiment. Speaking rate, on the other hand, appeared to have more effect than pitch, while the effect of duration drastically made a difference. The three greatest mean all fell under the short duration factor, but the low pitch and slow rate ended up averaging the highest in the long duration. This justifies that duration had a significant effect, while pitch and rate either had a less or no significant effect. However, comparing rate and pitch, rate resulted at a higher average under slow and normal rate, while pitch, regardless of high or low, did not result in significantly changing the trend of the experiment. For example, under the short durations, the four highest averages had an even amount of high pitch and low pitch factors. It is clear to notice that the deviations responsible for these four subjects were duration and rate.

As mentioned earlier, to determine the best method of conducting an announcement we needed to set up specific scenarios that apply to situations where a public announcement is made. To obtain meaningful data, the following scenarios were used; LHF, LHN, LHS, LLF,

LLN, LLS, SHF, SHN, SHS, SLF, SLN, SLS. The first letter for duration (Long or Short), second for pitch (High or Low) and the last letter for speaking rate (Slow, Neutral, or Fast).

Figure 5: Overall graph detailing all aspects of testing



LEGEND:		
Duration	Pitch	Rate
L: Long	H: High	S: Slow
S: Short	L: Low	N: Neutral
		F: Fast

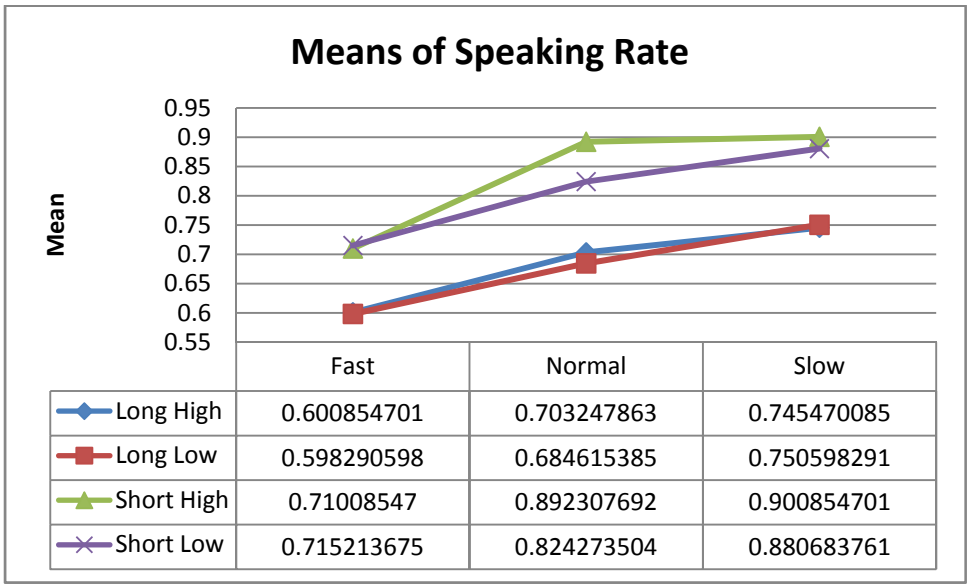
The higher points on the graph indicate higher speech intelligibility. As you can see from the graph, higher scores were from the following:

LHS, slower speaking rate, regardless of pitch, was the most intelligible for a longer message.

SHS/SHN/SLS, a high or low pitch at a neutral or slow pace are approximately equal to each other in terms of intelligibility for a shorter message.

Detailed graphs per sub type can be seen below.

Figure 1: Average Speaking Rate



	Fast	Normal	Slow
Long High	0.600854701	0.703247863	0.745470085
Long Low	0.598290598	0.684615385	0.750598291
Short High	0.71008547	0.892307692	0.900854701
Short Low	0.715213675	0.824273504	0.880683761

Figure 2: Longer duration messages at a high pitch with varying speaking rates

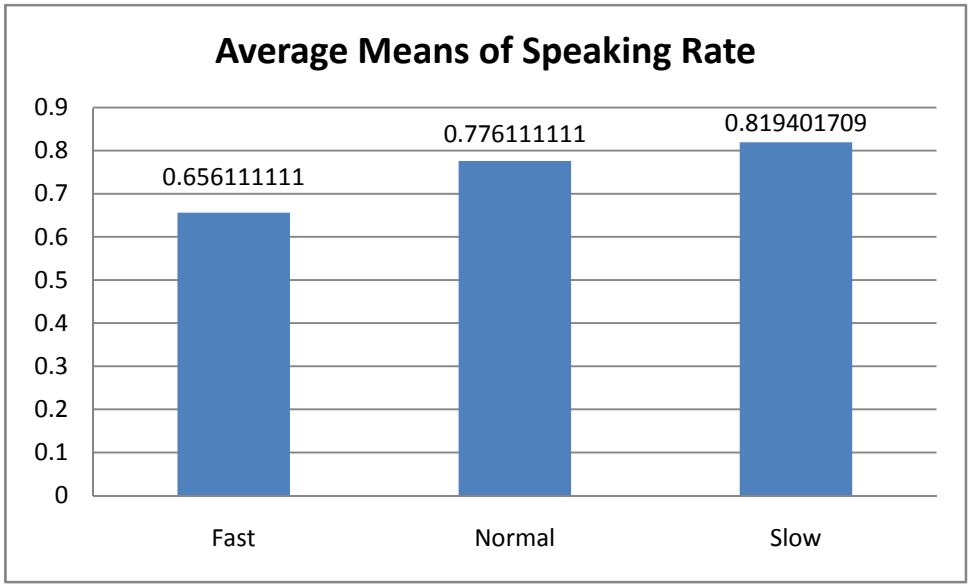


Figure 3: Average scores based on speaking rate

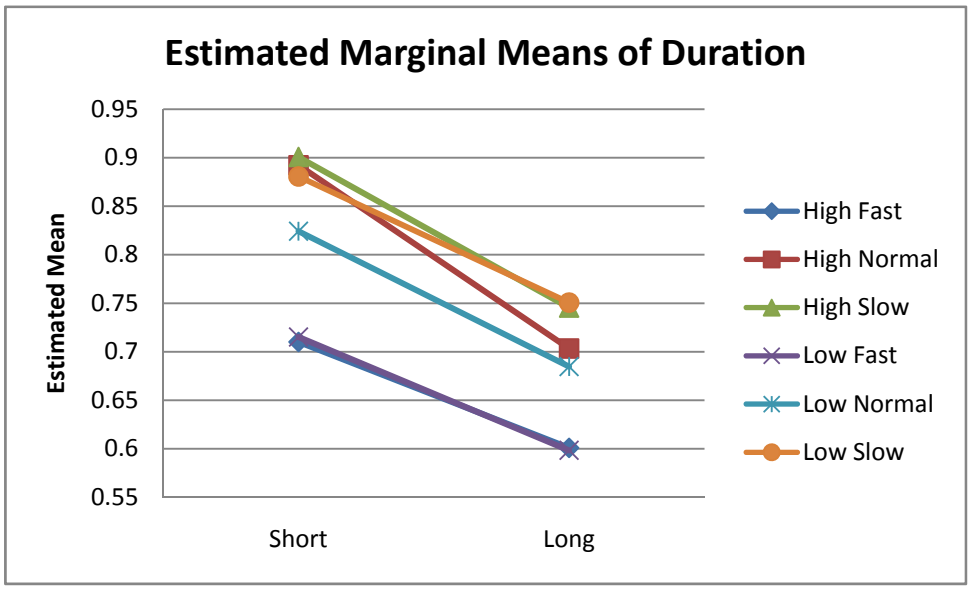


Figure 4: Messages with varying speaking rates

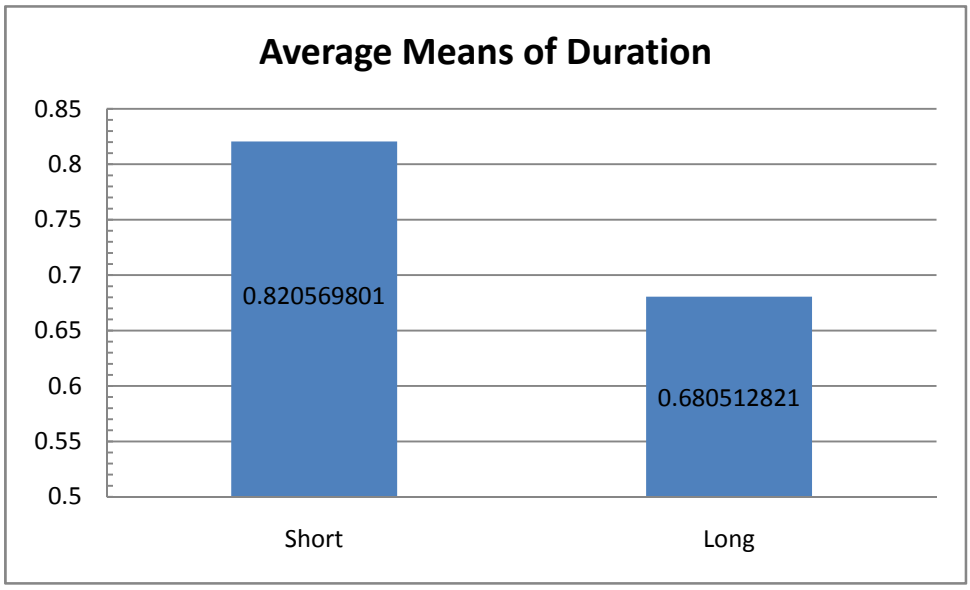


Figure 5: Average score based on duration

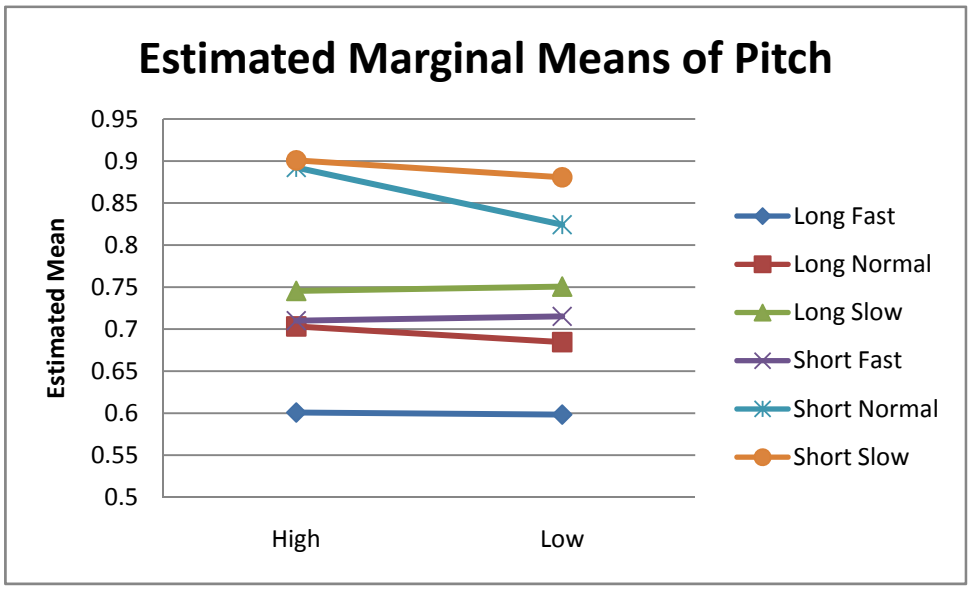


Figure 6: Estimated scores based on pitch

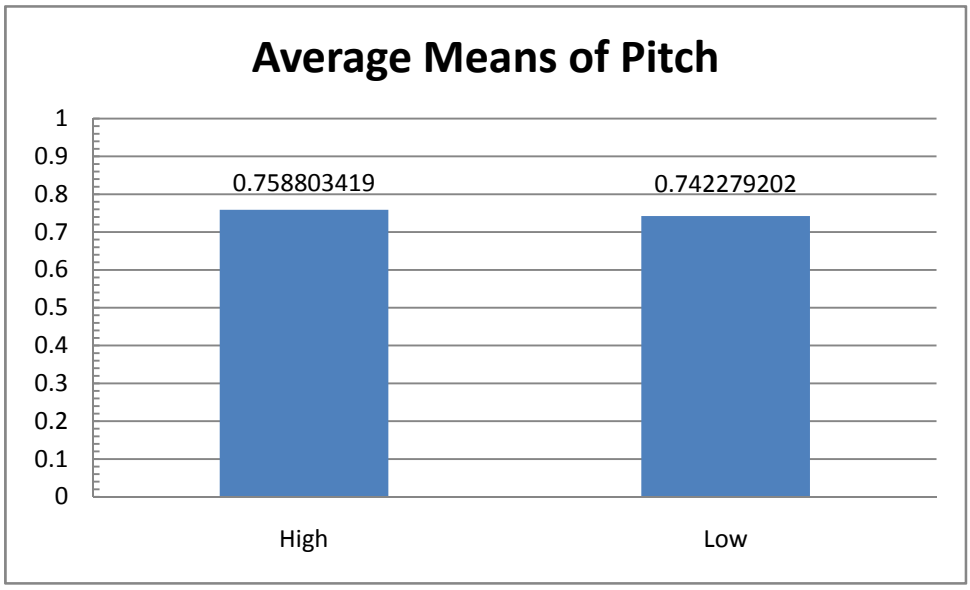


Table 1: Average scores based on factors of speech with message intelligibility

Effect	**Avg. Significance**
Duration	0.0004
Pitch	0.009
Speaking Rate	0.0004
Duration and Pitch	0.061
Duration and Speaking Rate	0.002
Pitch and Speaking Rate	0.019
Pitch, Duration, Speaking Rate	0.049

When determining the statistical significance of a research subject, the only appreciable information is any that scores an average significance of 0.01 and lower. The tests used to determine significance are as follows:

- Pillai's Trace
- Wilks' Lambda
- Hotelling's Trace
- Roy's Largest Root

According to the data collected from these tests, Duration, Pitch, Speaking Rate, and interactions between Duration and Speaking Rate showed statistical significance. This further exemplifies how these are the main factors to consider when determining speech intelligibility. Naturally, each factor on their own poses statistical significance when they are directly being tested on, so the more important factor to recognize in this data is the interaction between Duration and Speaking Rate.

The result for Pitch, individually, continues to prove statistically insignificant when compared to the individual scores for Duration and Speaking Rate. Also, when Pitch had interaction with either duration, speaking rate or both were clearly statistically

insignificant by having scores greater than 0.1.

V. Discussion

Based on the results of the experiment, it was concluded that out of the three assessed factors, altering duration and speaking rate improved speech intelligibility. Pitch, on the other hand, seemed to have negligible significant interactions with the other two factors. The analysis team later evaluated that longer messages tend to draw out its context, which may cause any listener to lose attention. Moreover, faster speaking rates are more difficult to comprehend and retain compared to slower speaking rates, especially if it is mentioned only once. However, alteration in pitch does not affect intelligibility compared to other factors, as long as its frequency is in the range of the human voice (female or male). Thus, our hypothesis was correct seeing that speech intelligibility can be improved by the alteration of speaking rate and duration.

VI. Recommendations

In order to improve speech intelligibility under any noisy environments, the team recommends that:

1. Longer messages should be broken into shorter messages.
    - When not feasible, longer messages should be spoken at slow speaking rates.
2. For shorter messages, slower or neutral speaking rates improved intelligibility.
3. Since alteration in pitch had no significant effect on speech intelligibility, message frequency should be kept within the range of human voice.

Although, these recommendations not only can improve intelligibility in public noisy environments, they can be implemented in applications such as toys, intercoms at home or small buildings, or other places where any type of announcements or audio playback can be heard.

VII. References

Bradlow, Ann, Gina Toretta, and David Pisoni. Speech Communication. Intelligibility of normal speech I: Global and fine-grained acoustic-phonetic talker characteristics. Speech Research Laboratory, Department of Psychology. 1996.

Dubbelboer F, Houtgast T. Department of Otolaryngology, VU Medical Center, Amsterdam, The Netherlands. 2007 Nov

Dubbelboer F, Houtgast T. Effects of Noise on Speech Intelligibility. Department of Otolaryngology, VU Medical Center, Amsterdam. 2007.

Jones, Caroline, Lynn Berry, and Catherine Stevens. Computer Speech and Language. Synthesized speech intelligibility and persuasion: Speech rate and non-native listeners. New South Wales. 2007. <www.ScienceDirect.com>

Lockyer, Norman. Nature. Vol. 214. Ann Harbor, Michigan: Nature Publishing Group, 1967.

Lockyer, Norman. Nature. Vol. 214. Ann Harbor, Michigan: Nature Publishing Group, 1967.

Lockyer, Norman. Nature. Vol. 226. Ann Harbor, Michigan: Nature Publishing Group, 1970.

Lockyer, Norman. Nature. Vol. 226. Ann Harbor, Michigan: Nature Publishing Group, 1970.

Palaz, Hasan, Yucel Bicil, Alper Kanak, and Dogan Mehmet. Speech Communication. New Turkish intelligibility test for assessing speech communication systems. Kocaeli, 2005. <www.elsevier.com/locate/specom>

Starquiz. Starquiz Reader 2.6.1 for Windows. March 12, 2009. <http://www.cosmicsoft.net>

Stevens, Catherine, Nicole Lees, Julie Vonwiller, and Denis Burnham. Computer Speech and Language. On-line experimental methods to evaluate text-to-speech (TTS) synthesis: effects of voice gender and signal quality on intelligibility, naturalness, and preference. Penrith South DC, 2004. <www.elsevier.com/locate/csl>

Van Wijngaarden, Sander and Jan Verhave. Applied Acoustics. Prediction of speech intelligibility for public address systems in traffic tunnels. Soesterberg. 2005. <www.elsevier.com/locate/apacoust>

Appendix 3 – Team Profiles

Below is a breakdown of each team member's individual background, and skills whose contributions led to the achievement of our team objectives and goals. For a breakdown of each member's achievements within each team role see Resources.

Kevin Arnold

Background: Fourth year political science major with a minor in technical communications; taking second IPRO

Skills: Experience with Microsoft Office, Praat, and Sound Editing

Team Roles: Co-Team Leader, Recording, Experiment Administering, Experiment Devise Materials, and IPRO Day Exhibit

Jessie Bauer

Background: Third year computer and electrical engineer; taking first IPRO

Skills: Experience with Microsoft Office, Java, and Visual Basic

Team Roles: Experiment Recruiting, Analysis, Midterm Presentation, Final Report

Brian Bjerke

Background: Third year computer engineer; taking first IPRO

Skills: Experience with Microsoft Office, Adobe Photoshop & Illustrator, InDesign, iMovie, and Sound Editing

Team Roles: Recording, Experiment Recruiting, Administering, Final Report, IPRO Day Presentation

Hyemin Choi

Background: Second year architecture major; taking first IPRO

Skills: Experience with Microsoft Office, Adobe Photoshop & Illustrator, AutoCAD, and Solidworks

Team Roles: IRB/Project Plan, Experiment Devise Materials, Experiment Administering, and IPRO Day Exhibit

Karen Hong

Background: Fifth year architecture major; taking second IPRO

Skills: Experience with Microsoft Office, Adobe Photoshop & Illustrator, AutoCAD, and 3D Max

Team Roles: Analysis, Experiment Recruiting, IPRO Day Exhibit

Scott Justus

Background: Fourth year biochemistry major; taking first IPRO

Skills: Experience with Microsoft Office

Team Roles: Recording, Midterm Presentation, Devise Materials, IPRO Day Presentation

Justo Moraga

Background: Third year computer engineer; taking first IPRO

Skills: Experience with Microsoft Office, C, Java, Adobe Photoshop, Sound Forge 7.0, and Acid 4.0

Team Roles: Minute Taker, IRB/Project Plan, Analysis, Experiment Recruiting, Experiment Devise Materials, Final Report

Shavanna Pinder

Background: Fifth year architecture major; taking second IPRO

Skills: Experience with Adobe Photoshop/ Illustrator/Flash, AutoCAD, 3D Studio Max, model making, hand drafting, freehand, typing and basic Spanish

Team Roles: Co-Team Leader, Recording, Experiment Recruiting, Experiment Devise Materials, Final Report

Crystal Reynolds

Background: Fourth year Psychology major with a minor in Biology; taking second IPRO

Skills: Experience with Microsoft Office, editing, researching literature, and some Spanish

Team Roles: Recording, Midterm Presentation, Experiment Administering, IPRO Day Presentation

Noravidhya Tanapura

Background: Fourth year Aerospace Engineer; taking second IPRO

Skills: Experience with Microsoft Office, Adobe Photoshop, iWork, AutoCAD, Matlab, Maple, Final Cut, Finite Element Analysis, and Praat

Team Roles: IRB/Project Plan, Analysis, Experiment Devise Materials, IPRO Day Exhibit