VISUAL INFORMATION PROCESSING
AND RESPONSE TIME
IN TRAFFIC-SIGNAL COGNITION

THESIS

DEMIRARSLAN, Hasan H.
Captain, TUAF

AFIT/GOR/ENS/92M-08

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GOR/ENS/92M-08

VISUAL INFORMATION PROCESSING AND RESPONSE TIME IN TRAFFIC-SIGNAL COGNITION

THESIS

DEMIRARSLAN, Hasan H.
Captain, TUAF

AFIT/GOR/ENS/92M-08

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1992	Master's Thesis

4. TITLE AND SUBTITLE
VISUAL INFORMATION PROCESSING AND RESPONSE TIME IN TRAFFIC-SIGNAL COGNITION

5. FUNDING NUMBERS

6. AUTHOR(S)
Hasan H. DEMIRARSLAN, Capt, TUAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology, WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GOR/ENS/92M-8

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release: distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

In man-machine design, it is important to quantify the reaction time components instead of simply determining the lump-sum reaction time to stimulus. The primary purpose of this thesis was to investigate the reaction time components, such as visual perception and muscle response time, and to quantify them by separating from their aggregated sum. The prime example, traffic-signal cognition simulation was used to examine human reaction time to signal change. With a modified computer program that simulates the driver's approach to the intersection, we measured the subject's reaction times and examined behavioral patterns. Twelve subjects were involved in the experiment. A logistic regression procedure was applied to the data to define subjects' choices at different distances. Decision process time and the conflicting decision area were examined. Logistic regression was used to reveal the distribution of the conflicting decision area and muscle response time. The results revealed the visual perception time distribution. The most important part of total reaction time was visual perception. Overall, the study showed the possibility of quantifying the reaction time components by using a simple computer simulation.

14. SUBJECT TERMS
Reaction Time, Visual Information Processing, Perception, Muscle Response, Logistic Regression

15. NUMBER OF PAGES
147

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

AFIT/GOR/ENS/92M-08

VISUAL INFORMATION PROCESSING AND RESPONSE TIME IN TRAFFIC-SIGNAL COGNITION

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

DEMIRARSLAN, Hasan H.

Captain, TUAF

March 1992

Approved for public release; distribution unlimited

THESIS APPROVAL

STUDENT: Hasan H. DEMIRARSLAN
Captain, TUAF

CLASS: GOR-92M

THESIS TITLE: VISUAL INFORMATION PROCESSING AND RESPONSE TIME IN TRAFFIC-SIGNAL COGNITION

DEFENSE DATE: 5 MARCH 1992

COMMITTEE:	NAME/DEPARTMENT	SIGNATURE
Advisor	Yupo CHAN Deputy Head and Professor Department of Operational Sciences School of Engineering	
Reader	Dr. Michael VIDULICH Research Psychologist AL/CFHP Workload and Ergonomics Branch	

Preface

This study was intended to provide insight into visual information processing. The results represent a step forward in measuring the human reaction time components by separating them from their aggregate sum.

I wish to thank my faculty advisor, Dr. Yupo Chan for his assistance and advice throughout this effort. In addition, I wish to thank my reader Dr. Michael Vidulich for his time and encouragement; and to my friends, for their time during the experiments. Special thanks are given to Dr. Moore for his support in statistical analysis of the data. I also thank to Dr. Kabrisky for his advice on the experiment and many thanks to Mark Nowack for his corrections to my writing.

Finally, I wish to thank to my wife, Mehtap, and my son, Goktug, for their loving support and patience through this study.

Hasan H. DEMIRARSLAN

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

AFIT/GOR/ENS/92M-08

Abstract

In man-machine design, it is important to quantify the reaction time components instead of simply determining the lump-sum reaction time to stimulus. The primary purpose of this thesis was to investigate the reaction time components, such as visual perception and muscle response time, and to quantify them by separating from their aggregated sum. The prime example, traffic-signal cognition simulation was used to examine human reaction time to signal change. With a modified computer program that simulates the driver's approach to the intersection, we measured the subject's reaction times and examined behavioral patterns.

Twelve subjects were involved in the experiment. A logistic regression procedure was applied to the data to define subjects' choices at different distances. Decision process time and the conflicting decision area were examined. Logistic regression was used to reveal the distribution of the conflicting decision area and muscle response time. The results revealed the visual perception time distribution. The most important part of total reaction time was visual perception. Overall, the study showed the possibility of quantifying the reaction time components by using a simple computer simulation.

I. INTRODUCTION

"In human-machine interface, ... , perception time and response time are among the key behavioral parameters for proper design" (Chan, 1991:6). Available information shows that today there is no direct and precise way to measure the perception and response time; however, most man-machine designs require the precise determination of perception and response time. According to research conducted by Dr. Yupo Chan, the process of perception, signal transmission and motor response is still in the hypothesis building stage (Chan, 1986:1).

Background

In traffic engineering and many other situations, such as the cockpit environment, it is important to understand and to come up with reliable perception and response times. In the cockpit environment, it can mean life or death to a fighter pilot because of the variability of the perception and muscle response time under different conditions.

A driver's reaction to traffic signals is a prime example. In the setting of a yellow light at an intersection, the separation of the visual perception component from the muscle-response component is very important. It is often desirable to reduce decision making times between man and machine where critical decisions are involved. Precise determination of visual perception and muscle response time is critical to the safety of millions of people who drive through the signalized intersections (Chan,1987:1). Determining the optimum change interval for a yellow warning light at intersections continues to be a problem. If a warning traffic light turns yellow at the signalized intersection when a driver approaches the intersection, there are two simple alternatives for the driver. He will either decelerate and bring his car to a stop before entering the intersection or go through the intersection, accelerating if necessary, and complete his crossing before the signal turns red. In the first case both visual perception of the signal and foot-muscle response are involved. If the driver decides to clear the intersection before the light turns red, the second case, only visual response time is involved if there is no acceleration. Therefore, there is a need to understand the visual-information processing component and the muscle response component separately to design intersections properly.

Total reaction time can be expressed as the sum of visual perception and muscle response time (Eq (1)). Visual

perception includes the time duration from the presentation of the stimulus until body reaction starts. The remainder of the reaction time is **muscle response time duration.** The expression of reaction time in terms of its components is:

$$t_r = t_v + t_m \tag{1}$$

where

t_r = reaction time

t_m = muscle response time

t_v = visual response time or perception time.

"Traffic engineering handbooks have never recognized the difference and have historically used an aggregated reaction time in the design of yellow lights" (Chan and Liao, 1987:47-48). Preliminary research by Dr. Yupo Chan proved that such a design in practice will always result in a "**dilemma zone**" in which a driver does not have enough time to either clear the intersection or stop for the light (Chan,1986:7). This creates risky situations that may result in accidents.

Objectives

The purpose of this research is to investigate human factors such as visual perception time and muscle response time and to find an indirect method to measure them. This will help to reduce the accident potential at signalized intersections by helping determine the optimum yellow light setting. Ultimately, the precise determination of the perception time, in the human-machine interface, will help produce proper designs.

A computer program has been written on a microcomputer (Chan 1985, Liao 1982) to simulate the behavioral process that a driver goes through at an intersection. This simple computer model will be used for empirical verifications of the results. The computer program basically can be used to measure the response time of drivers. It also allows the user to change the characteristics of intersections, including the width of the intersection, the prevailing speed, the change interval (yellow light), and the deceleration rate to evaluate the design under different conditions.

The major task of this research involves running the computer model on a number of subjects acting as drivers in the experiment and observing the subjects' behaviors. The variables in this experiment are the various conditions of pavement, approach speed and intersection geometries. Careful design of experiments has to be performed. For example, careful parametric analysis of the equations for stop and go zones is critical. "**Stop zone(S)** is a distance from the intersection long enough for a driver to stop when the yellow light turns on. **Go zone(G)** is defined as a distance from the intersection such that if the light turns yellow when the driver is within this distance, he should be able to run through the crossing safely" (Chan, 1986:6-7). The stop zone and go zone equation can be expressed in terms of approach speed(V), deceleration rate(a), reaction time(t_r), intersection width(W), yellow light change interval(Y) and car length(L). The clear mathematical expressions of the go and stop equations are helpful to see the effects of the variables.

Stop zone and go zone equations are:

$$S = (t_m + t_v) * V + \frac{V^2}{2 * a} \tag{2}$$

$$G = Y * V - (W + L) \tag{3}$$

The following steps must be accomplished to achieve the stated objectives.

1) Review simple kinematic equations describing the physics of such a simple behavioral process; the simple motion equations and drivers' behaviors are combined in these equations. The fundamental equations can help us to see the effect of human factors in man-machine design.

2) Collect data by running subjects through the simulation

program. From these data we can determine the reaction time distribution for each individual or sample. Reaction time distribution is important to find optimum design parameters in statistical base and also to show the effect of human decision delay in the man-machine design.

3) Design the intersections to create minimal dilemma zones, taking into account the response time and other variables in the experiment. So we can observe the driver behavior with minimum noise.

4) Collect statistics about driver decisions and behavioral patterns and evaluate the results in a statistical base.

5) Use the results to find indirect methods to measure the perception or muscle response time. Use statistical properties to separate the reaction time components.

II. LITERATURE SEARCH AND REVIEW

Introduction

The following chapter will review literature pertinent to this research proposal. Because this research is about investigating human factors in man-machine design, particularly visual perception time, by designing the yellow light duration at signalized intersections; the discussion covers the topics of yellow time setting at the signalized intersections, drivers' behavior, reaction time, and specifically, visual perception time. Another aspect of this literature review is examining the material dealing with the effects of visual perception time duration on the man-machine design.

Yellow Light Setting at Intersections

The signal change interval is an essential element of signal control at an intersection. "In traffic engineering, setting change intervals is a complex task. There is still not an agreement among traffic engineers from one jurisdiction to another regarding the correct way to set a change interval" (Chan and Liao, 1987:48).

To provide a systematic method of determining the change interval(Y), Gazis and others developed the following equation based on theoretical considerations.

$$Y = t_r * V + \frac{V^2}{2 * a} + \frac{W + L}{V} \tag{4}$$

where

Y = signal change interval (sec)

t_r = reaction time of driver (sec)

V = vehicle approach speed (ft/sec)

a = deceleration rate (ft/sec^2)

W = intersection width (ft)

L = vehicle length (ft)

They analytically calculated the stop zone and go zone distances by considering all possible parameters (Gazis and others, 1960:112-132). One traffic engineering book suggests that a reaction time of 1 sec, a deceleration rate of 10 ft/sec^2, and representative vehicle length of 20 ft be used in the above equation (U.S Department of Transportation, 1975). Stein reviewed the policies and procedures commonly used to determine the duration of traffic signal change interval. Stein mentioned some conservative assumptions, such as reaction time and deceleration rate, in the current design equations. He concluded that the current interval timing is not specific to the intersection characteristics, and many signals do not provide sufficient time for vehicles to safely cross the intersection (Stein, 1986:444). Frantzeskakis also mentioned the shortcoming of methods presently used in the United States for computing signal changing intervals. "These methods do not consider the actual routes followed by vehicles and corresponding critical points, as well as, the time that such conflicts may take place" (Frantzeskis, 1984:58)

Several suggestions were made to improve Eq (4), as well as the values of the parameters involved. The effect of grade on stopping distance is considered by Parsanson and Santiago" (Frantzeskakis, 1984:50). In spite of the constant speed limit, V, the 85th percentile speed, $V_{.85}$, has been proposed. Following this probabilistic design philosophy, some argue that the 15th percentile of slower traffic should also be computed (Parsonson and Santiago, 1980:68).

In 1986, Mahalel and Zaidel examined the stopping probability function. This function describes the stopping pattern of all drivers at the intersection approach (to prevent rear-end accidents). The range of the dilemma zone can be inferred from the stopping probability function without any assumption for constant approach speed. Zaidel and Mahalel also demonstrated how the concepts of the stopping probability function and dilemma zone might be used in practice to determine the change interval. By their use of probability function, they eliminated the need for estimating the reaction time and deceleration rate of individual drivers (Mahalel and Zaidel, 1986:39-43).

According to Lin, most researchers have attempted to provide a logical basis for timing the change interval. In this connection, most studies focused on measuring the behavior of individual drivers who are confronted by the signal change interval. Drivers' reaction time, deceleration rate, and the decision making process in response to change interval are the primary variables examined in these studies. "Driver's behavior can be affected by numerous factors and is difficult to measure. In contrast, direct measurement of drivers' aggregated needs for the change interval can be performed easily. Such needs relate to the time required for the intersection to clear after the yellow onset" (Lin,1986:46-49). Lin proposed the use of aggregated change interval requirements that can rely on a straightforward regression analysis to develop a model for signal timing. Consequently, it is doubtful that a single reaction time and single deceleration rate will provide a desirable change interval under all circumstances.

Reaction Time

Even though the yellow time duration is associated with several parameters, this research deals with the reaction time, specifically visual perception time, as a design parameter. Therefore the importance of the information about visual perception time leads the researcher to seek more information about reaction time and its components.

Olsen and Rothery observed motorists' responses to the yellow phase of traffic signals obtained at five intersections, representing three speed zones. They found that driver behavior does not seem to change as a function of different yellow light durations at intersections. (Olson and Rothery, 1961:650-663).

Stimpson and others investigated the response of drivers to onset of yellow at two signalized intersections. It was found that potential intersection conflicts could be virtually eliminated with small increases in the duration of the yellow phase (Stimpson at al., 1980:28). This conclusion also indirectly refers to the fact that visual response time duration should be considered at the design of intersections to shrink the dilemma zone.

Gazis and others conducted theoretical analyses and observed the behavior of motorists confronted by an amber signal light. They only separated the acceleration and deceleration time durations. In the examination of the dilemma zone, they treated these separately. During these observations in the field, the mean reaction time was found to be 1.14 seconds (Gazis and others, 1960:112-132).

Johansson and Rumar investigated the distribution of brake reaction times which can be expected from drivers who have to brake suddenly and completely unexpectedly in traffic situations. They mentioned an important methodological problem in studying brake reaction time. It was the measuring error of the reaction times. From the field experiment, the distribution of brake reaction times over the population of drivers was studied. "The picture that has emerged from the studies reviewed was that reaction time varies with the type of task involved, with level of attention over different sensory areas and from individual to individual" (Johansson and Rumar, 1971:23-27). The distribution of brake reaction times showed approximately normal distribution over a range. This study also mentioned Lister's (1950) investigations on brake reaction times; he split the total reaction time into perception time (time from the presentation of the stimulus until the foot starts to move) and movement time (time from the start of the movement until the foot reaches the brake pedal). He ascribed increased brake reaction time variation and increased variation in perception time in conditions of lower expectancy (Johansson and Rumar, 1971:23-27). Taoka studied the statistical distribution of brake reaction times, he examined brake reaction times data collected by

Gazis (1967), Worthman and Mathiasa, Chang at al., and found the lognormal distribution fits the data very well.

Recent studies on break reaction times showed that, older subjects were significantly slower than younger people. "Older drivers needed 50 percent more time than young drivers to observe and decide whether they could merge into traffic" (Kortelling, 1990:95-108). Physical and psychological changes in old age have a substantial impact on the ability of carry out the daily tasks (William, 1990:605). The researchers emphasized age related differences between young and older drivers.

The human operator requires time to detect and process signals, to select and initiate a course of action, and to bring the desired response to completion. The operator's response speed cannot be ignored because of its natural limits and variabilities. Wargo (1967) investigated human operator response speed and examined the delays that contribute to the reaction time in five steps: receptor delays, after-transmission delays, central process delays, efferent transmission delays, muscle latency-activation time delays. Also in his research, subjects' reaction times were measured according to simple choice or multiple choice. It appeared that the operator's fastest hand reaction to an expected visual stimulus was on the order of 113-328ms; however, in choice reaction time, the reaction time can be expected to range 113-528ms. In this total reaction time, muscle contraction time was 30-70ms in each case. The relation between reaction time and stimulus intensity was nonlinear and reaction time decreased as stimulus intensity increased to its limit. "The major cognitive factor in reaction time is probably decision time "(Wargo, 1967:221-227). So, the perception time that includes decision process delay time for the operator is the most important part of the total reaction time and has a most variability as a reaction time component.

Human Factors Design handbook (1981:793) gives definitions of simple and complex reaction times. **Simple reaction time** is the shortest time between the moment a sensory receptor is stimulated and the time some body element reacts. **Complex reaction time** includes human information processing time. The subject may be asked to recognize one stimulus from among several and to respond by selecting one of several response modes. We are more concerned with complex or choice reaction time. In the book, response time is defined a function of several factors, including the following:

1. The sensory channel through which the stimulus initiated
2. The signal or stimulus characteristics
3. The complexity of signal
4. Signal rate

5. Whether anticipatory provisions are present

6. The response mode (the body member used).

As previously mentioned, reaction time, as a design parameter for signal information processing, can be separated into muscle response and visual perception components. Significant information about one component will also help to quantify the other component. Chan and Liao wrote a computer program to analyze the driver response to a yellow light. They also considered the reaction time as a design parameter and separated visual response time and muscle response time analytically. Chan and Liao found the interesting fact that, by using the current design formula it is not possible to eliminate the dilemma zone. An interesting experiment can be conducted by using such a simulator to separate the lump-sum reaction time into visual perception and muscle response time components. The important result of this research is a way to measure visual perception time by observing drivers' behavior.

Driver's Behavior at Intersection

Sheffi and Mahmassani studied driver's behavior at high speed (over 35 mph) and modeled driver's behavior as a binary decision (stop and go). They developed a probit estimator of stopping probability, from which the dilemma zone can be determined. Dilemma zone curves (probability of stopping vs distance from stop bar) were used to develop the dilemma zone boundaries. They estimated probit model parameters by collecting data from the field (Sheffi and Mahmassani, 1981:51-55). Prashker and Mahalel studied option space and drivers' indecision zone. Drivers who are in the option zone when the signal turns yellow can either stop their vehicles or cross before the light turns red. In the indecision zone, drivers can make both decisions (stop or go) with associated probabilities. They used a microscopic desegregate behavioral model, similar to the model used by Sheffi and Mahmassani (1981). Based on this model, it was concluded that the simple probit behavioral model is adequate for analyzing drivers' behavior at intersection approach when continuous green ends. They found that drivers' decisions are based not only on their speed and distance from the intersection, but also on the relative speed and location of their vehicle compared to other vehicles (Prasker and Mahalel, 1989:401-403).

Summary

The literature review shows that reaction time has been considered mostly as a constant parameter in man-machine design, and its quantified value is changed depending upon adopted assumptions. The studies about brake reaction times revealed a probability distribution for reaction times of subjects. The components of reaction time, visual perception and muscle response time, are expected to have the same type of distribution. In man-machine design, this result has to be considered. The complex structure of reaction time makes efforts to directly measure the perception time difficult. The dimension of study about reaction time changes in terms of the area the researcher is dealing with. The reaction times vary according to the type of stimulus, environmental conditions and individual characteristics. As a parameter, either reaction time or its component visual perception time has to be treated in some kind of probabilistic base. The disagreement about defining constant reaction time instead of using its real distribution supports the idea of employing the reaction time or its component perception time, as a probabilistic design parameter. This can be used in optimal setting of yellow change intervals at signalized intersections.

Even though it is not easy to see an example of perception time used directly in man-machine design, reaction time includes the visual perception time. Therefore perception time is indirectly used as a parameter. "For the first time , Chan and Liao separated the visual perception time from the muscle response time by way of theoretical kinematic equations. They discovered an empirical procedure to measure the reaction time components individually" (Chan and Liao,1987:48). The researchers emphasized the point that an experimental procedure can be applied to measure these components.

The research presented in this thesis represents a step forward in measuring the visual information-processing mechanism by employing an indirect way of using a simple form of yellow-light cognition.

III. METHODOLOGY

Introduction

This chapter discusses the data collection procedure, the methods employed in data evaluation, experimental process, and separation of the perception and muscle response times following data collection. A complex behavioral process occurs when drivers approach the intersection. To gain better understanding of the behavioral process when a driver approaches an intersection, we will use a computer program that simulates a driver's approach to an intersection.

Visual Information Processing at Intersection

Sensing, information processing and decision, and response functions are depicted in Figure 1. Since the experiment is a simulation of a driver's approach to signalized intersection, the input variable is yellow light onset. Information receiving (sensing) will be done by eyes. The subjects will process the information and decide to stop or to go. Both decisions will be completed by hand reaction and the subject will stroke associated keys on the keyboard to show his choice. There are three possible outcomes. The car may stop before the intersection, cross the intersection, or cause an accident.

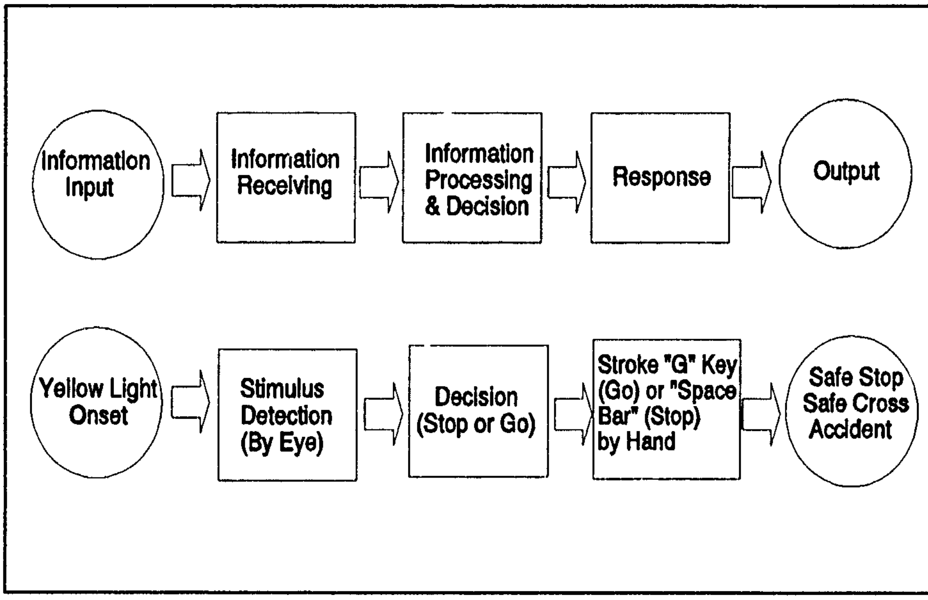


Figure 1. Representation of Basic Functions Performed by Human in Man-Machine System.

Conducting Experiment

Twelve students will serve as subjects on this experiment. Subjects will be voluntary students from AFIT and local universities. Before the experiment begin, each will practice to understand the experiment and to decrease wrong key strokes.

Apparatus. A microcomputer simulation program will be used to simulate driver's approach to a signalized intersection. The program represents a three dimensional graph of the intersection. Figure 2 shows the figures presented in the simulation program's display.

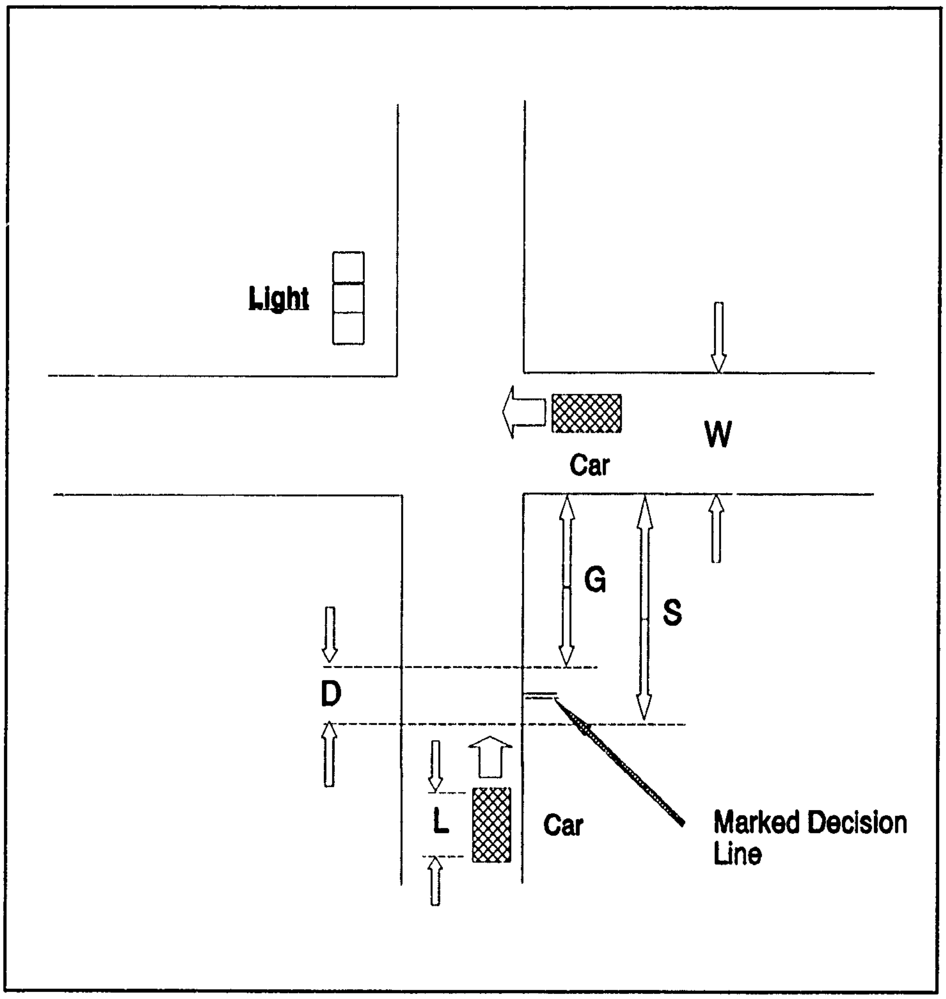


Figure 2. Graphical Representation of Simulation

A subject sits in front of the computer and runs the program. During the approach, a yellow light randomly comes on and subject reacts to the light by choosing one of two alternatives. He either decides to stop or to go. The decision is based on his perception of light and distance.

The subject makes a choice by pressing "space bar" or "G" key to stop or to go respectively.

The computer program is modified to complete the experiment. After modifications, it is possible to collect data about reaction time and relative distance from the intersection when yellow light turned on. The modified computer program used in the experiments is given in Appendix A.

Limitations. The microcomputer program used to collect the data, was written in Apple Basic on the Apple II microcomputer. The program simulates the driver's reaction time at a traffic light. The screen displays a three dimensional perspective of a signalized intersection as a car moves toward the intersection. It is calibrated at constant parameters. The reaction time data was truncated and the computer can only produce limited discrete reaction time values even though reaction time is a continuous variable. Another limitation is distance measurement, in this experiment only discrete distance values from the intersection were available. The results of the experiment will be based on this discrete data set. We will use these data to approximate the underlying continuous distributions. The program was modified to measure the distance from the intersection. Another program modification allowed the experiment to be run either with or without the marked decision line (Figure 2). The reference is a cue that can help subjects to make stop and go decisions during the approach.

Sampling Unit and Sampling Frame. Any discussion of sampling must necessarily begin with the definition of the population being studied. In the real world, the population of drivers can be treated as having infinite number of members. In our study, twelve students will constitute the sampling frame and in some sense represent the university student population. We intend to find this small population's parameters by a sample. Here, it is useful to treat each individual as a sampling unit. The sampling units must be defined to be mutually exclusive and must collectively exhaust the population (Ben-Akiva and Lerman, 1985:217-230). We will assume the twelve individuals are selected randomly from the population. This sampling method is called simple random sampling (Ben-Akiva and Lerman, 1985). In the real driver population, it is very reasonable to categorize the drivers in two groups, "young drivers" and "older drivers". Physical and psychological changes in old age have substantial impact on the ability of carry out the daily tasks. Recent studies on brake reaction times showed that, older subjects were significantly slower than younger people (Kortelling, 1990:95-108). The whole driver population can be divided into two groups, each called stratum. To represent the whole population, it would be necessary to choose Stratified Random Sampling. Because we are dealing with data from a computer simulation that is a representation of laboratory conditions and due to a relatively small sample size, we don't apply Stratified Random Sampling procedure. Therefore, the parameters derived from our sample may not be representative of the entire population.

Sample Size. We know from the literature review, individual or population reaction times are approximately normally distributed. If sample size, "n," is 30 or higher we can approximate the underlying distribution (D'Agistino and Stephens, 1986:281). In order to find the population's reaction distribution, we will combine the reaction time of subjects. Gazis (1967) collected 87 data points to find the reaction time distribution. Prashker and Mahalel (1989) observed drivers' behaviors at different intersections and used different sample sizes. They made 40 or more observations to get valid results. Sometimes they collected 200 observations. We will make more than 40 observations for each subject to get valid results.

Selection of the Factors

There are number of variables influencing a driver who is approaching an intersection. The computer program can control most of the variables except the reaction time of the driver. The control of the variables will allow us to focus on the subject reaction time and indirectly his or her muscle response and perception time. The variables which can be used as factors in the experimental design are shown in Table 1. The experiment will be conducted on the computer, with the exception of reaction time, all the other parameters will be under designer's control.

TABLE I

Model Variables

CONTROLLABLE VARIABLES	RANDOM VARIABLE(S)
Approach Speed Deceleration Rate Change Interval Intersection Width Car Length	Reaction Time - Muscle Response Time - Perception Time

Table 1 shows the controllable and random variables in intersection design. We should emphasize that another random variable, not in the table, is error in measurement. This error component is not considered in the experiment.

In this study, we assumed that the variables are independent random variables. The field experiments revealed the fact that the reaction time changes with the distance from the intersection (Taoka, 1989:19-21). But, this study especially deals with the reaction times around the indecision zone in which the driver may make conflicting decisions, and in this area we can get the proper values for reaction times that can be used in appropriate design.

Simple Versus Complex Reaction Time

The term "**reaction time**"generally is considered at two levels. The first is called "**simple reaction time,**" which is the shortest time between the moment a sensory receptor is stimulated and the time some body element reacts (Woodson, 1981:793). Practically speaking, in the experiment to measure simple reaction time, we will have a test subject respond to a stimulus (here yellow light), by pressing a certain key on keyboard.

The second level is called "**complex reaction time,**" in which the scientist attempts to include human information processing time (Woodson, 1981:793). In our experiment, the subject is asked to react yellow light by selecting one out of two response modes (stop or go). The computer program allows us to collect only stop decision related reaction times and the subjects will use their right hands to respond the yellow light in stop decisions.

Normality Assumption

"Although over repeated trials a single individual's reaction time tends to follow a positively skewed distribution, it has been known for many years that across individuals the distribution of individual's average reaction time conforms very closely to the normal distribution" (Maxwell and Delaney, 1990:52). Allowing the sample variability, the reaction time data can be presented as a theoretical normal distribution. More recently, there are many areas of psychology in which large-scale studies indicate that commonly used dependent variables follow a normal distribution quite closely (Maxewell and Dalaney, 1990:52). The reaction time distribution is one of the very common examples. Measures of aptitude, personality, memory, and motor skill performance are often approximately normally distributed (Maxewell and Dalaney, 1990:54). In this experiment, normal distribution was assumed for reaction time and its components.

Data Collection

Data collection will be conducted in three different ways. First, the choice reaction times of the subjects will be measured by the computer program. In this case, a subject sits in front of the simulation. He starts the program to simulate an approach to the intersection. When the yellow light comes on, he makes a decision to stop or to go through the intersection. If he stops, his reaction time will be measured by computer.

Secondly, the simple reaction times of the subjects will be measured. In the second case, a subject's only decision is to stop when the yellow light comes on, without considering whether he is in stop or go zone. In that case, the simple reaction times of the subject will be measured.

In the third experiment, the subject will run through the experiment and his behavior will be observed. The choices of subject at different distances are the main concern. Stopping and crossing decisions at different distances from the intersection will help to find the stopping probability and crossing probability curves. At certain distance, the number of stopping and crossing decisions can be helpful to see difference between theoretical and observed results. Data consist of choice reaction times, simple reaction times, numbers of stop and go decisions and associated distance values from the intersection. Each subject perform three one-hour computer sessions in the data collection phase during this experiment.

Data Evaluation

The simple and choice reaction time data frequency distribution will be found after these experiments by statistical means. The underlying distribution of the data will be examined to approach the data in more aggregate fashion. The statistical properties of the data will be explained. The results collected from the third experiment are very important to find the muscle response time component and its distribution by conflicting decision area. **Conflicting decision area** represents an area in which "stop" or "go" decisions can be given with associated probabilities. The data will reveal the stopping probability distribution that explains the possibility of drivers' stop at a distance during the intersection approach.

Reaction Time Components

After these runs, each subject's simple and choice reaction time distribution will be ready. The difference between simple and choice reaction time distribution gives an idea about the decision processing time. The stopping probability distribution in the third experiment with respect to the distance from the intersection can reveal the muscle response time component for a specific driver or sample. When we subtract the muscle response time components from the total reaction time, the remainder will be perception time of driver. When the underlying distribution of the reaction time and its components are found, the statistical properties of random variables will be used to find the sum of the independent random variables.

We made an assumption about reaction time and its components. Namely, that they are approximately normally distributed. The moment generating function of any normally distributed random variable is:

$$m(t) = \exp(\mu * t + \frac{\sigma^2 * t^2}{2}) \tag{5}$$

The moment generating function has a property that the sum of the two normally distributed random variables, t_m and t_v, is again normal with mean ($\mu_m + \mu_v$), sum of the means, and variance ($\sigma_m^2 + \sigma_v^2$), sum of the variances. Convolution theory is helpful to find the reaction time components' distribution (Ross and Sheldom, 1989:50-66).

From here if we know the reaction time and the muscle response time distribution, then the perception time distribution will be the difference between them in a statistical sense. Previously we mentioned reaction time consists of muscle response and perception time duration.

The moment generating function of the summed reaction time can be expressed by Eq (6):

$$m(t)_r = \exp((\mu_m + \mu_v)*t + \frac{(\sigma_m^2 + \sigma_v^2)*t^2}{2}) \qquad (6)$$

where $m(t)_r$ moment generating function of reaction time consists of the product of the perception and muscle response time moment generating functions.

Experiment to Separate Muscle Response Time

The variables in the in the "go zone" and "stop zone" equations (Eqs (2) and (3)) are examined. Theoretically, the difference between these two equations can only come from the muscle response time. If the muscle response time is assumed to be zero, the optimum change interval will be reduced by the amount of muscle response time. This idea is the basis for the experimental design and will allow us to separate reaction time components. The experimental procedure will have five steps. Before explaining the steps, it is helpful to express the reaction time components in terms of each other. Eqs (7) and (8) define these relationships.

$$t_{dec} = t_r - t_s \qquad (7)$$

$$t_r = t_m + t_v \qquad (8)$$

where, t_s, simple choice reaction time, t_r, reaction time or complex choice reaction time, t_v, visual perception time, t_{dec}, decision process time and t_m is muscle response time.

STEP 1: The reaction times of subjects has to be measured and underlying distribution will be defined. This will reveal complex or choice reaction time distribution. From the literature review, we found that reaction time distribution is approximately normal.

STEP 2: The second experiment will allow the designer to measure the simple reaction time. The subjects will respond to the yellow light by stroking the space bar. The stop ar go decision is not to be made at this moment. Only simple response values will be collected and the underlying distribution will be defined.

STEP 3: By using statistical properties of continuous random variables, the difference between simple reaction time and choice reaction will be found for sample. The result gives the decision process time or thought time.

STEP 4: The intersection will be designed according to each subject's reaction time (at some probabilistic base), and the designer will observe safe stops and go decisions. There is a marked line on the computer to help the subject make their decisions more comfortable. The observed crossing and stopping decisions may differ according to theoretical (deterministic) crossing and stopping decisions.

When we observe the subjects' decisions with distance from the intersection, stopping probability distribution at various distances can be obtained. The range of this curve represents the muscle response time with approach speed. The details are explained in application of the method.

STEP 5: After determining the distribution of muscle response time (we expect an approximate normal distribution), we can find the perception time distribution. The difference between reaction time and muscle response time gives the perception time distribution. The statistical properties of continuous distributions will be used to get this result. Convolution theory is a very reasonable approach to take and the moment generating function uniquely determines the distribution. By examining each experimental method, we can get more insight about the results and formulation.

Method

The go zone and stop zone line shows the possible alternatives to make dilemma zone zero. When reaction time is not constant, there is no deterministic way to explain the variability of dilemma zone under different response times to yellow light. On the graph we can show the different stop zone lines.

In Figure 3, at optimum design point the go zone line(G1) is tangent to stop zone curve(S1). If we relax the deterministic case the stop zone curve can be S2. When the stop curve is S2, only G2 can make the dilemma zone zero and allows an optimum design. Also it is possible to draw the go zone line(G3) without the muscle response time component. If we subtract the muscle response time from the yellow light, we can see the possible dilemma zone(D) on the graph.

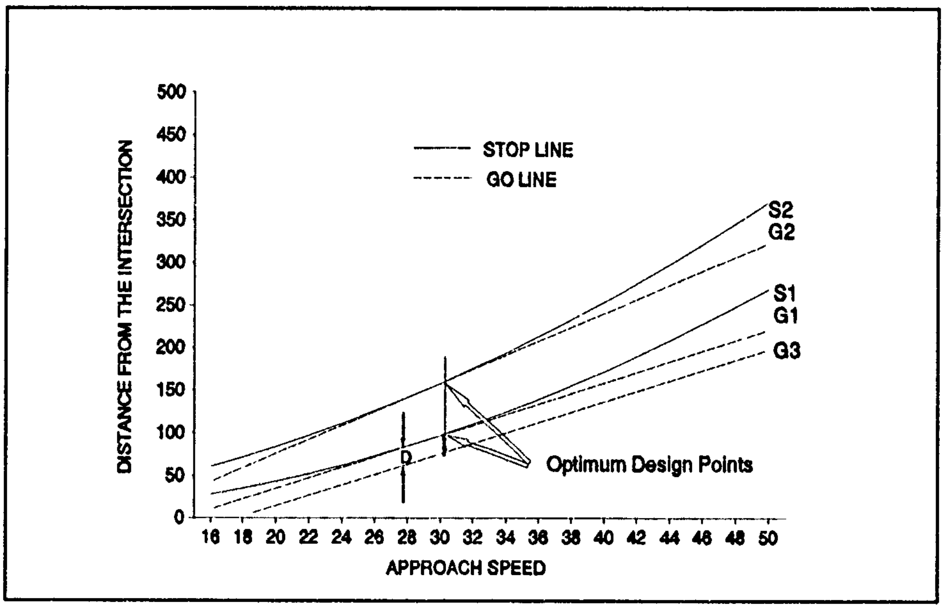


Figure 3. Stop and Go Zone Graphs at Various Speeds

Eq (9) shows the go zone equation without the muscle response time component (G3 line represents this). The difference between the tangent point of S1 and G1 curves with G3 curves depicts how the optimum design change when the muscle response time is subtracted. Dilemma zone will not be zero and "D" shows this difference between G1 and G3 lines.

$$G = (Y - t_m) * V - (W + L) \tag{9}$$

When we substitute the change interval equation (Eq (4)), Y, into the above equation, the go zone will be a function of perception time and by using the dilemma zone formulation, D = S - G, now dilemma zone is

$$D = t_m * V \tag{10}$$

The difference between stop and go decisions is a function of the muscle response time and approach speed.

The basic idea comes from the contention, that the yellow light might be considered by a driver either a recommendation to stop or a recommendation to cross the intersection at slightly different distances from the intersection. In more realistic way, go decisions do not include muscle response time and this creates a small gap between stop and go decisions as function of approach speed. This situation creates a conflict zone, in that a stopping probability distribution, PS, can be shown, as on Figure 4. Conflicting decision area represents the muscle response time area at that speed. We know that for go decisions and stop decisions, the perception time is the same, and the conflicting area is a representative of the muscle response time. Figure 4 shows a stopping probability curve as a function of distance.

When we run the experiment, we can observe that the probability of stopping is high at the distance which is relatively far from the intersection, and low when driver is relatively close.

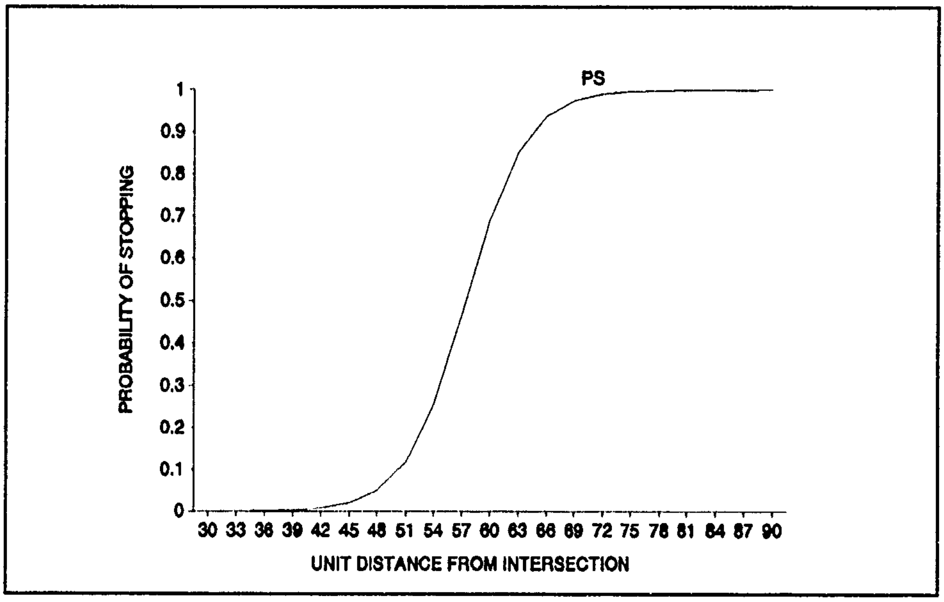


Figure 4. Stopping Probability Curve with Distance

Since drivers cannot instantaneously change their actions when yellow light comes on, the transition state from "go" to "stop", takes time. In this situation, the driver's physical process begins after a certain time duration, the driver's reaction time. If we consider hypothetically the transition state from "go state" to again "go state", we note that in this case the driver decision is to cross the intersection, and this transition does not include muscle response time.

Let P(x) be the stopping probability function and "x" the distance from the intersection at the onset of the yellow light. The probability of drivers' cross decisions will be 1 - P(x). This function represents a realization of independent Bernoulli trials carried out at various distances from the intersection. The existing stopping probability function refers to conflicting decisions at certain distances from the intersection. Figure 5 depicts this situation. Figure 5 also shows the theoretical step function for stop and go decisions, it is only valid for zero reaction time cases.

In the real world, the size of the conflicting decision zone can be affected by several variables. These variables are simply, approach speed, deceleration rate, intersection width, environment and the others. By using a computer simulation we control most of the variables. In the simulation the subjects will decide according to their reaction time or in some sense their intuitive feelings. After all, conflicting decision zone is a function of the subjects' muscle response time. Our basic assumption is that, in stopping decisions, subject total reaction time is involved but in go decisions only perception time is involved. This provides the difference between go and stop

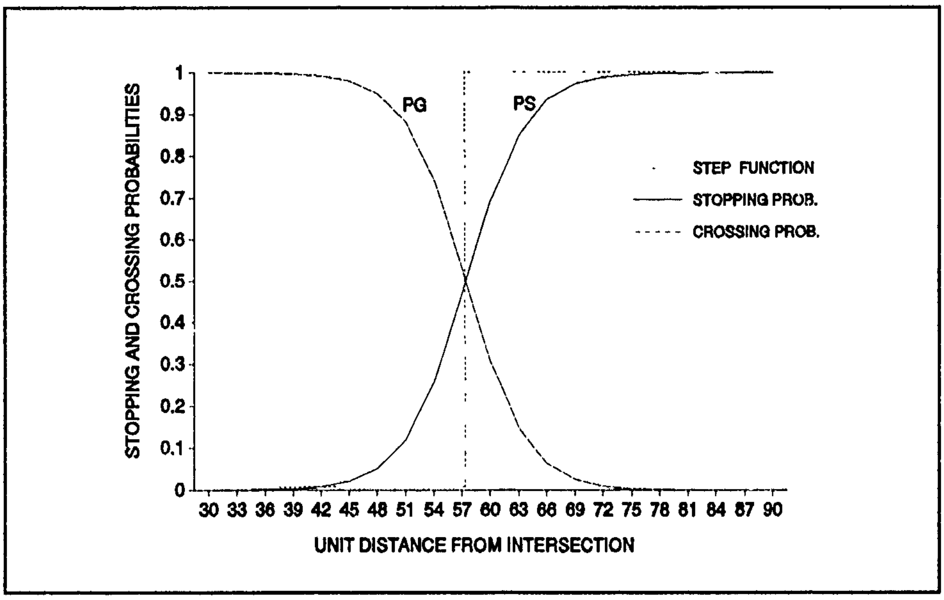


Figure 5. Sopping and Crossing Probability Curves and Theoretical Step Function

decisions, that is the muscle response time of subject.

Model Definition

Logistic procedure fits linear logistic regression models for binary response data by the method of maximum likelihood. Binary response variables (stop, go) are our response variables. Logistic regression analysis is often used to investigate the relationship between the response variability and explanatory variables (SAS manual,1990).

The response, R, of an individual can take on one of two possible values, denoted by 1 and 0. For example, R = 1, if the decision of subject is stopping, or R = 0, if the decision of subject is crossing the intersection. The curve is said to be S-shaped. It resembles a plot of a cumulative distribution of a random variable. Primary reasons for choosing the logistic distribution are: 1) from mathematical point of view, it is a extremely flexible and an easily used function, and 2) it has a meaningful interpretation (Hosmer and Lemeshow, 1989:6-10). In our experiment, the explanatory variable is distance from the intersection. Let's call it with (DIST) and DIST is any random distance from the intersection. $P = Pr(R = 1|(DIST))$ is the response probability to be modelled. The linear logistic model has the form

$$logit(p) = \log\left(\frac{p}{1-p} \right) = \alpha + \beta * DIST \qquad (11)$$

where α is the intercept parameter, and β is the coefficient of slope parameter.

We can fit the logistic regression model with one dependent and one independent variable. The Maximum Likelihood Estimates (MSLEs) of regression parameters are computed using the Iteratively Reweighted Least Squares (IRLSs) algorithm. The SAS package is suitable to find the parameter estimates. Using the estimates, we can calculate the estimated logit of the probability of an event as

$$logit(p) = \alpha + \beta * DIST \qquad (12)$$

Now we can calculate probability of stopping, PS, as follows

$$PS = \frac{1}{1 + \exp(\alpha + \beta * DIST)} \qquad (13)$$

This function is the stopping probability function. 1 - PS gives going probability function given by PG.

$$PG = \frac{\exp(\alpha + \beta * DIST)}{1 + \exp(\alpha + \beta * DIST)} \qquad (14)$$

<u>Summary</u>

The methodology is essentially based on the observation of subjects' behaviors and reaction times in a computer simulation and the statistical analysis of these results. Subjects' choices at different distances from the intersection are our main concern in the experiment. The logistic regression method will be used to approximate the reaction time components by evaluating binary type responses at different distances. The logistic regression procedure is evidently applicable to find the conflicting decision area and indirectly the muscle response time. The simple and choice reaction time results will help to quantify the visual perception and decision process time durations.

IV. EXPERIMENT

Subjects

The twelve subjects from AFIT and local university students were involved in the experiment. The data collection phase was completed in three one-hour sessions for each subject. Ages of the subjects ranged from 19 to 34 years. Three subjects were female. In our experiment each session refers to the different procedure. In first session, choice reaction time and choice behavior of the subjects (between stop and go decisions) were observed by a computer simulation that included a marked decision line to help the subjects make comfortable decisions. In a real-life experiment, the time perceived by drivers to intersection is variable and cannot be observed directly. In the first experiment, the marked decision line eliminates this problem. In the second session the same experiment was applied by running the simulation without a marked decision line. Thus, the subjects' distance perception times were involved in second experiment. In third session, simple reaction time of the subjects were measured.

Reaction Time Data

To find the choice reaction time distribution of the sample, cross reaction time data were collected (50 data points from each subject). A total 600 data points were collected. The simple reaction time data consists of 480 data points (40 data points from each subject). The reaction time data came from the laboratory conditions in which the subject was anticipating the stimulus. The choice and simple reaction time data are given in Appendix B and C.

Choice Reaction Time Distribution. In the experiment there were two possible responses. The subjects needed to make a choice of responses depending on the distance from intersection when the stimuli occurred. The choice reaction data come from the stop decision results. When the subject decision was to stop, the computer gave the reaction time of the subject. Also, the subjects used their right hands for stop decisions and left hands for go decisions.

Because the stimulus may occurred at any distance from the intersection, a test was performed to see if there is any effect of the distance on reaction time. The field experiment in literature review showed that yellow light response time increases as the distance to the intersection increases. The test revealed that there is no a statistically significant effect, at $\alpha = 0.10$, as a result of different distances on yellow light response time. This suggests the subjects do not appear to adjust their response particularly as a result of distance from the intersection in laboratory conditions. When we plotted each individual's reaction time data, in simple and choice cases, we did not see any pattern indicative of learning that may reduce the reaction time during the session. In the experiment, learning did not affect the reaction times significantly. So, we did not restrict reaction time data points with the distance.

The choice reaction time data statistics are summarized in the Table 2.

TABLE II

Observed Choice Reaction Time Data Statistics

MEAN	MEDIAN	STD. DEV.	MIN. VALUE	MAX. VALUE
0.49 sc	0.43 sc	0.161 sc	0.26 sc	1.02 sc

The statistical distribution of the reaction times is important in order to express and use the data in design. Figure 6 shows the frequency distribution of reaction times for 600 points.

The normality test was not directly appropriate to see whether the reaction time data conform to a normal distribution because the data consist of ten discrete values between 0.26 second to 1.02 second. Based on the histogram of the data, literature review and probability plotting on normal probability paper, reaction time data conform to the in laboratory conditions. When we plotted each individual's reaction time data, in simple and choice cases, we did not see any pattern indicative of learning that may reduce the reaction time during the session. In the experiment, learning did not affect the reaction times significantly. So, we did not restrict reaction time data points with the distance.

The choice reaction time data statistics are summarized in the Table 2.

TABLE II

Observed Choice Reaction Time Data Statistics

MEAN	MEDIAN	STD. DEV.	MIN. VALUE	MAX. VALUE
0.49 sc	0.43 sc	0.161 sc	0.26 sc	1.02 sc

The statistical distribution of the reaction times is important in order to express and use the data in design. Figure 6 shows the frequency distribution of reaction times for 600 points.

The normality test was not directly appropriate to see whether the reaction time data conform to a normal distribution because the data consist of ten discrete values between 0.26 second to 1.02 second. Based on the histogram of the data, literature review and probability plotting on normal probability paper, reaction time data conform to the normal distribution and normality assumption was accepted. The normal distribution with mean, $\mu_r = 0.49$, and variance, $\sigma_r^2 = 0.026$, can represent the choice reaction time data. The formulas to estimate the parameters and the plotted data on normal probability paper are given in Appendix J. The normal approximation appears to be sufficient in the plotting.

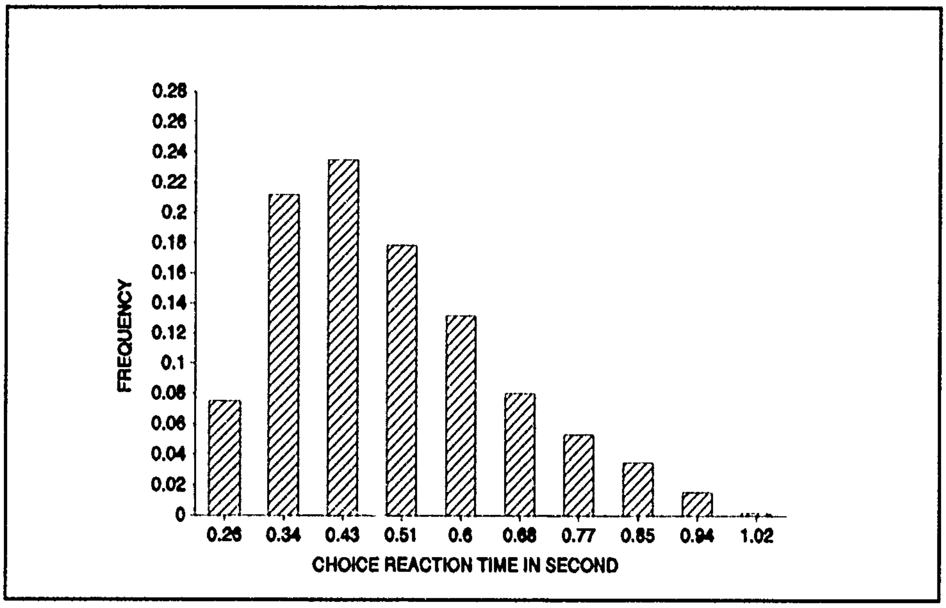


Figure 6. Frequency Distribution of Complex Reaction Times.

The reaction time, as a design parameter has to be considered with its distribution. The variance of the reaction time data dictates this. For safe design, such as yellow light setting, its percentile value (say 90th percentile) is more reasonable rather than mean value. Because the mean values do not account for the variance of the data, for safer design purposes, the distribution of the data should be used by considering its variance.

Simple Reaction Time Distribution. In our experiment we instructed to the subjects to make a certain response (pushing the space bar) when yellow light appeared during the intersection approach. From this experiment we collected 480 data points (40 data points from each subject) that represents simple reaction time of the sample. Table 3 shows the summary statistics of collected data.

TABLE III

Simple Reaction Time Statistics

MEAN	MEDIAN	STD. DEV.	MIN. VALUE	MAX. VALUE
0.35 sc	0.34 sc	0.0709 sc	0.17 sc	0.6 sc

In the experiment, as we can realize from the Table 3, the simple reaction data were restricted to six discrete values. As explained previously in limitations section, 480 data points are not distributed continuously, similar to the choice reaction time data. Figure 7 shows the frequency distribution of the 480 simple reaction time data.
Simple reaction time data, because of its simplicity, are restricted to a small range. This allows us to get few discrete data points from the computer (it is explained in limitations section). We did not apply the normality test

directly to the data because of its discrete structure.

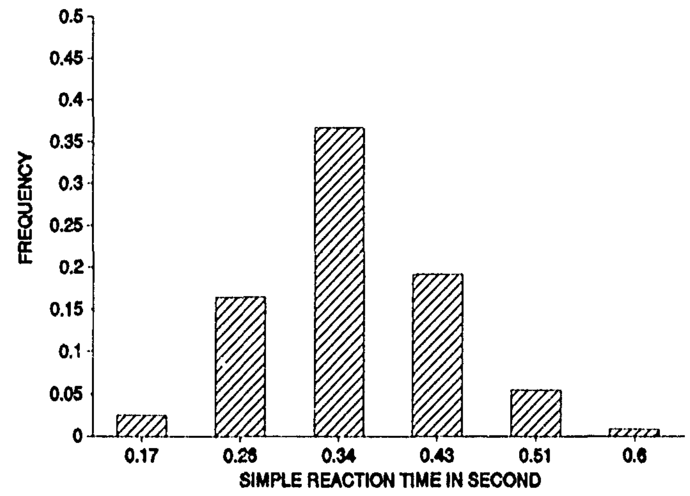


Figure 7. Frequency Distribution of Simple Reaction Times.

We can approximate to the normal distribution by examining the histogram of the simple reaction time data. For simple and choice reaction time distribution, the normality assumption is supported by literature review and by plotting on normal probability paper. The studies about driver reaction times under "anticipation" conditions shows an approximately normal distribution for the same kind of data. Thus, we can assume that the simple reaction time distribution is normally distributed with mean, $\mu_s = 0.35$, and variance, $\sigma_s^2 = 0.00503$. The normality assumption is also emphasized in methodology section. The formulas for parameter estimations and the plotted data on normal paper are given in Appendix J. The normal approximation seems to be sufficient.

Decision Process Time Delay. Because the decision process is involved in choice reaction time (the subject needs to choose either to stop or tc go), the response time increases when compared to the simple reaction time. The difference between simple and choice reaction times gives an approximation of the decision process time delay. With assumption; decision process time and simple reaction time are independent variables, we can use the moment generating function properties (for sum of the independent variables) to find decision process time distribution. Table 4 shows the mean and variance of the decision process time during visual information processing.

TABLE IV

Decision Process Time Statistics

	MEAN	VARIANCE
CHOICE REACTION TIME	0.49 sc	0.026 sc
SIMPLE REACTION TIME	0.35 sc	0.005 sc
DECISION PROCESS TIME	0.14 sc	0.021 sc

The difference between choice and simple reaction time distribution gives the decision process time which is approximately normally distributed with mean(μ_d) = 0.14 and variance(σ_d^2) = 0.021.

The mathematical calculations show that the decision process time drives most of its variability as a component of reaction time. Another observation from the simple reaction time is about muscle response time. In reality, muscle response time cannot have larger mean value and variance than the simple reaction time, because muscle response is a part of it. Under these circumstances, we do not expect muscle response time distribution with mean and variance that are far away from the simple reaction time distribution's. Simple reaction time values will be used for cross check of the later findings.

Stopping and Crossing Probability Distributions

The main object of this part of the study was to see how the subjects' decisions (stop and go) vary in response to a somewhat anticipated signal as a function of distance. Because there were only two response modes in the experiment, the stopping and crossing probability distributions can be represented by logistic curves. The distributions are complementary and one distribution explains the other.

Experimental Data. In this part, the twelve subjects' choice behaviors were observed in two slightly different experiments. The first eliminated the distance perception differences of the subjects. It is known that the perception of subjects can vary from individual to individual and this may cause a noise around the imaginary decision line. The computer graphical simulation included a marked decision line (Figure 2) that was at the optimum design point. This line helped the subjects to make stop and go decisions comfortably without any need to perceive the time to reach the intersection. In second experiment, we removed the marked decision line, and assumed that the subjects were very familiar with the experiment and their distance perceptions did not vary much. In each case 1200 data points (100 data points from each subject) were collected by running the experiments. The collected data are given in Appendix D and E. The wrong key strokes (pushing a different key than intended) were excluded. The number of wrong key strokes did not reach the five percent level during these sessions.

Model Calibration. We evaluated the results for the complete sample of twelve subjects. At this point, we did not discriminate them according to any other explanatory variables (such as age and sex) except distance from intersection. Model coefficients were found by evaluating each data point. The logistic regression model was applicable to this situation. In the model, the dependent variable was the binarv choice variable that took only the values, 0 and 1 (go and stop decisions respectively). The independent explanatory variable was the distance from intersection that is given as an unit distance. Probability of stopping and crossing equations are represented in the methodology section as Eq (13) and (14). The logistic regression procedure was found to be very good for this type of binary response data.

Results with Marked Decision Line. To find the model coefficients, SAS statistical software was used. The logistic regression coefficients are constant(α) and slope parameter(β). The scatter plot of distance(DIST) and choice and SAS output file are given in Appendix G. The logistic regression coefficients and findings are summarized in the Table 5.

TABLE V

Maximum Likelihood Estimates in Experiment 1

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	PR> CHI-SQUARE
INTERCEPT	17.9726	1.3018	0.0001
DIST	-0.3130	0.0225	0.0001

We can conclude that the effect of DISTANCE is significant with p-value of 0.0001. Maximum likelihood (-2logL) is 389.023.

With above parameters, the fitted logistic regression curves (stopping and crossing curves) are shown in Figure 8. Using the parameter estimates, we can calculate the estimated logit of the probability of event (stop) as

$$\text{logit}(\dot{PS}) = 17.9726 - 0.3130*\text{DIST}$$

Now, suppose DIST = 50, then logit(PS) = 2.3226. Using this estimate, we can calculate PS as follows:

$$PS = 1 \ / \ (1 + e^{2.3226})$$
$$= 0.08927$$

The value is the predicted probability that a subject will stop if the yellow light comes up at DISTANCE = 50. Probability of crossing can be calculated at the same manner as follows:

$$PG = e^{2.3226} \ / \ (1 + e^{2.3226})$$
$$= 0.91073$$

The value is predicted probability that a subject will cross the intersection when DISTANCE = 50 units.

The stopping and crossing probability curves define the range between stop and go decision lines. Stop and go decision lines are determined by the similar calculations given above. Next section explains this process in details for with and without line cases.

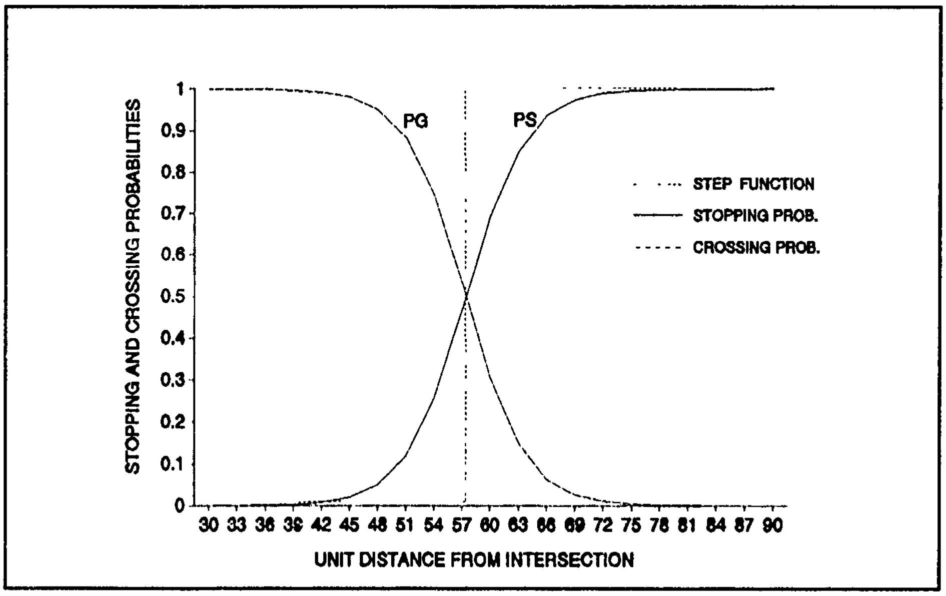


Figure 8. Probability of Stopping and Crossing Curves

Results without Marked Decision Line. We ran the experiment without the marked decision line and evaluated 1200 data points again. Different logistic regression parameters for this data set were obtained relative to the previous one. Summary statistics are given in Table 6. SAS output for these data is given in Appendix H.

TABLE VI

Maximum Likelihood Estimates of Data from Experiment 2

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	PR> CHI-SQUARE
INTERCEPT	13.6410	0.8780	0.0001
DIST	-0.2345	0.0150	0.0001

The coefficients and the results are different in each type of experiment. The Figure 9 shows the difference between two stopping probability curves.

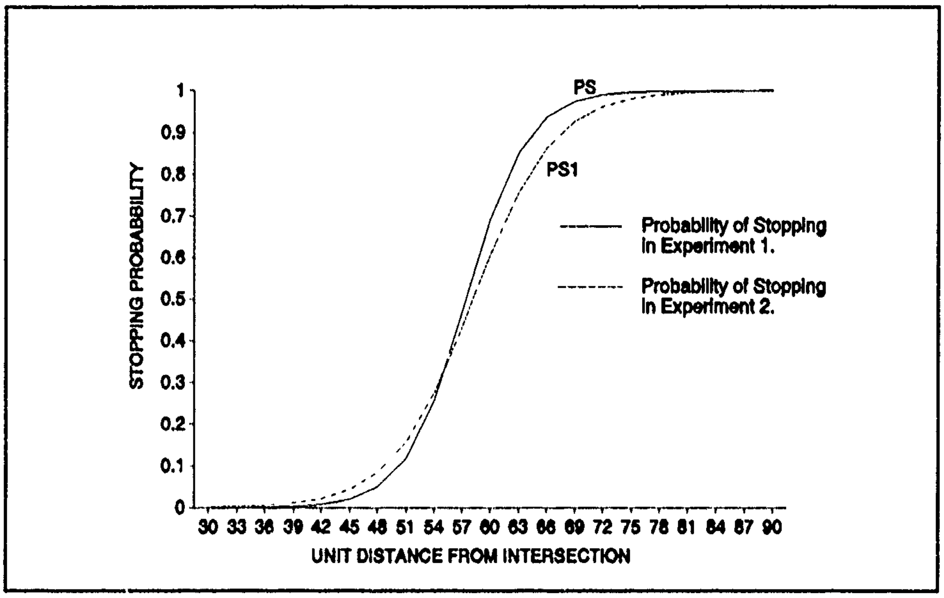


Figure 9. Probability of Stopping Curves with and Without Line Cases.

When we compare the predicted values for each case at a certain distance (say 50 units), the results as follows:

$$PS(1|DIST=50) = 0.08927$$

$$PS1(1|DIST=50) = 0.12831$$

Probability of stopping changed in the two type of experiments. When the conflicting decision area is defined as a distance between theoretical stop and go distances in which go and stop decisions can be given with associated probabilities, we can see that the second curve (from the experiment without a marked decision line) has a larger conflicting decision area than the first one in terms of size. In the experiment without a marked decision line, the logistic curve shows the larger conflicting decision area that refers to the effect of marked reference line in second experiment. This result is expected, because the subjects needed to estimate the distance for safe stop and go decisions. Individual differences in perception of distance from the intersection, can cause noise around the optimum imaginary decision line and conflicting decision area fluctuates depending on the accuracy in perceiving the distance. So the range between stop and go distances will be larger than the first experiment.

In order to find the conflicting decision area in both experiments, we have to define cut probability. Because the curves hypothetically never reach a probability of one or zero. A five percent cut will provide reasonable value to evaluate the stop and go distances. This percentage value also generates the lowest and highest observed distances at which conflicting decisions occurred. The Figure 10 shows the approximate range. In the figure, the letter "A" and "B" represent the conflicting decision areas for the two types of experiments, with or without the marked line respectively. In Figure 10, PS and PG curves represent the results of the first experiment. PS1 and PG1 curves come from the second experiment (without marked line). We can notice that, "B" is larger than "A" in size and the potential difference between "A" and "B" shows the effect of the marked decision line in design.

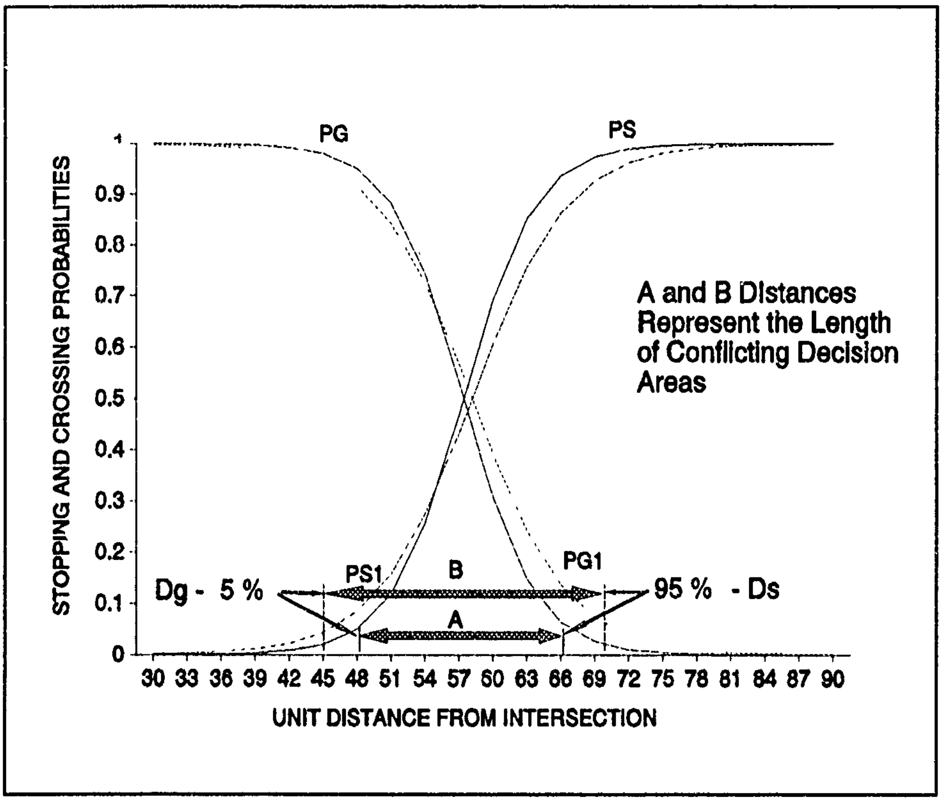


Figure 10. Conflicting Decision Area in two Experiments

The Table 7 summarizes the findings about conflicting decision areas. The distances are calculated by representing the 90 percent coverage. In the other words, for the stopping distance case, when the distance from the intersection is about 66.9 units or more, the subject will stop with probability of 0.95. For the crossing case, when the distance is 48 units, the subject will cross the intersection with a probability of 0.95.

TABLE VII

The Range Between Stop and Go Distances

DISTANCE FROM INTERSECTION	EXPERIMENT	
	WITH MARKED DECISION LINE	WITHOUT MARKED DECISION LINE
STOPPING DISTANCE(D_s)	66.9 units	70.7 units
CROSSING DISTANCE(D_g)	48.0 units	45.7 units
CONFLICTING ZONE(D_s-D_g)	19.0 units	25.0 units

The unit difference between the two logistic curves, approximately 6.0 units, refers to the range due to the perception variability of the distance. Because of incomplete information about the distance, the subject's decisions were influenced and the size of area 32 percent increased. This range can be converted to time duration by dividing the distance with constant approach speed. In this case 6.0 units stands for 0.23 second time durations. The distribution of distance perception time can be derived from the two logistic curves. We will emphasize the general mathematical procedure to drive the area distributions in the section on finding conflicting decision area distribution. The first step is find the distribution functions of the two conflicting decision areas (A and B in Figure 10) and take the difference between them. The moment generating functions of two distributions will help to find the effect of marked line in the experiment. In the two types of experiments, the distances associated with the 0.5

probabilities were slightly different. They are 57.42 units and 58.17 units respectively. Thus, 0.75 unit difference in expected values refers to 0.03 second and it is not very significant value. The difference as a time duration comes from the lack of information and may refer that the subjects had a tendency to over estimate the distance with incomplete information. The significance of this finding should be supported by more runs.

For safe design purposes, the time duration (0.23 second) has to be considered to set yellow light duration that is commonly calculated according to deterministic design formulas. Evidently, incomplete information about the distance changes the size of the conflicting decision area in the second experiment. The indication of the two different conflicting decision zones, from the two slightly different experiments, is to show the possibility of decreasing the size of the conflicting decision zone by some means. The smallest conflicting decision zone is the main concern for better design in human-machine interface.

Defining Muscle Response Time and its Distribution

By using the logistic regression curve, we can quantify the muscle response time. Before explaining the derivation of the muscle response time distribution, the simple kinematic equations has to be visited again. A deterministic formulas allow us to find the optimum design parameters in the intersection approach. By considering these deterministic formulas, we can derive the muscle response time. The idea comes from the parameters that are involved in stop and go zone equations. When we don't consider the acceleration possibility, "go" decisions will not include the muscle response time component ("stop decision does). As previously mentioned, the difference between stop and go zone equations is given as follows:

$$S - G = (t_m + t_v) * V + \frac{V^2}{2 * a}) - (Y - t_m) * V - (W + L) \qquad (15)$$

where Y is represents optimum setting according to design formulas (Eq (4)) and the difference between two zones will no longer be zero. $S - G = t_m * V$ represents the difference (Eqs (10) and (11)). The results of the logistic regression procedure will help to quantify this distance.

From Figure 10, the distance "A" represents the difference between stop and go decision lines. We can express the range as:

$$D_s - D_g = t_m * V$$

Now let's find the difference between stop and go distances. From the probability of stopping curve, the distance where the probability of stopping is 0.95 is called D_s, the distance where the probability of stopping is 0.05 is called

D_g. By substituting these results in the probability of stopping curve equation (the crossing probability curve gives the same results), following equations will be obtained:

$$0.95 = \frac{1}{1 + \exp\ (\ \alpha + \beta * D_g)} \tag{16}$$

$$0.05 = \frac{1}{1 + \exp\ (\ \alpha + \beta * D_g\ )} \tag{17}$$

We can solve these equations to get the distance $A = D_s - D_g$, and the following equations will be obtained:

$$\alpha + \beta * D_s = \ln(0.05)$$

$$\alpha + \beta * D_g = \ln(19.0)$$

By solving these two equations simultaneously, the "α" will be canceled. The difference is a function of the slope coefficient only as given by:

$$D_s - D_g = a/\beta$$

where -5.8888 is expressed with letter "a" as a constant parameter. The distribution and the parameters of the area that represents the muscle response time duration with approach speed will depend on the slope coefficient. In logistic regression, the inferences are usually based on the sampling distribution of coefficients (here α and β) which tend to follow a normal distribution for much smaller sample sizes (Hosmer and Lemeslow, 1989:44). The result is similar to the inverse of the normal distribution. The parameters of the slope coefficients are known. We can find the mean and variance of the muscle response time.

Under the assumption, the slope coefficient is normally distributed β~N(-.3130, 0.000507). We can approximate the muscle response time distribution by evaluating the mean and variance of the reciprocal of the independent normal variable. The derivation of D_s - D_g are given in Appendix F. "A" also conforms a normal distribution with certain parameters, mean (18.91 units) and variance (1.91). The approximation is done under the assumption that β will not take zero values. By revisiting D_s - D_g equation again, t_m can be derived by dividing the unit range by constant approach speed.

This procedure can be applied to an individual or a group to find the muscle response time. Thus, the results will depend on the sample. The expected value and variance of "-5.8888/β are calculated by straight forward statistical formulas (Eqs (18) and (19)).

$$E\left(\frac{a}{\beta}\right) = \int_{-\infty}^{\infty} \frac{a}{\beta} * f(\beta)\, d\beta \tag{18}$$

$$Var\left(\frac{a}{\beta}\right) = E\left(\left(\frac{a}{\beta}\right)^2\right) - E\left(\frac{a}{\beta}\right)^2 \tag{19}$$

where "a" refers to the constant value (-5.8888). From the above equations, we found the mean and variance of the muscle response time; $t_m \sim N(0.15, 0.003)$, the mean and variance were converted to the time. Appendix F explains the solution of the equations (Eqs (16) and (17)) and finding the probability distribution of muscle response time.

In Table 7, statistical stop and go distances were given previously. The range represents the conflicting decision area (tied to the muscle response time). The logistic regression of data that come from the experiment with the decision line gives us this area as a function of the approach speed.

Another important point to mention is that the experiment was conducted in laboratory conditions. The car has a considerable length. Because the car is not a point mass, the conflicting decision area will be affected by the car length. When the car length is subtracted from the conflicting decision area, the rest will be muscle response time as function of the approach speed.

Mathematical calculations are straight forward and, 18.9 - 15 = 3.9 units represents the muscle response time with approach speed. In simulation, the car length was 15 units and approach speed was 25.6 unit/second. So, 3.9 = t_m*V and $t_m = 3.9/25.6 = 0.15$ second. This is nothing more than the expected value of the muscle response time. The variance of the muscle response time is obtained by variance of the conflicting decision area by converting it to the time. Because the standard deviation was 1.382 units, in terms of time, it represents 0.0539 second standard deviation and the variance will be $\sigma_m^2 = 0.003$.

This value is the muscle response time component of the reaction time. By recalling the normality assumption again, the muscle response time will be normally distributed with mean, $\mu_m = 0.15$ second, and variance $\sigma_m^2 = 0.003$. We supported the normality assumption with work in Appendix F. We generated 8000 data points normally distributed with $\mu = -0.313$ and $\sigma^2 = 0.000507$ and we called the variable, β. We defined the new random variable $U = -5.8888/\beta$. We found the frequency distribution of "U" and tested for normality. Also we expressed the new data with Inverse Gaussian Distribution that is defined with mean(μ) and scale parameter(λ) for random variables larger than zero (Chhikara and Folks, 1989:7). At the same time we showed the similarity between normal and Inverse Gaussian Distribution. When the assumptions changes about coefficients, we will have an alternate way to express the skewed distributions with Inverse Gaussian Distribution.

Visual Perception Time Distribution

After these results, we have a reaction time distribution and a muscle response time distribution. By using the moment generating property, we can find the perception time duration (including decision process time). The methodology section described the derivation of this. Eq (6) shows the moment generating function of the sum of the muscle and visual perception times. By this expression, the visual perception time distribution parameter can be found. In Eq (20), the moment generating function of visual perception and muscle response time is given. As a solution of Eq (20), the moment generating function of visual perception time is shown in Eq (21).

$$\exp(.493*t+.0261*t^2) = \exp((.15+\mu_v)*t+\frac{(.003+\sigma_v^2)*t^2}{2}) \tag{20}$$

$$m(t)_v = \exp(0.343 * t + 0.0231 * t^2) \tag{21}$$

So, the visual perception time is the difference between reaction time and muscle response time. Also, the visual perception time is normally distributed with mean, $\mu_v = 0.343$, and variance, $\sigma_v^2 = 0.0231$. In summary, the expression of the reaction time, muscle response time and visual perception time expressions are:

$$t_r \sim N(0.493,\ 0.0261)$$

$$t_m \sim N(0.150,\ 0.0030)$$

$$t_v \sim N(0.343,\ 0.0231)$$

In the above representations, reaction time and its components are normally distributed random variables.

Other Explanatory Variables in the Model

Even though the sample age group has no large range, from 19-34, we entered the age and sex into the model as new explanatory variables. After the running the logistic regression procedure, at $\alpha = 0.10$ level, only distance and age were significant variables to explain the subjects' behaviors. SAS output is given in Appendix I for three variables. The summary statistics of the findings are given in the Table 8.

TABLE VIII

Maximum Likelihood Estimates of Model with New Explanatory Variables

VARIABLES	PARAMETER ESTIMATE	STANDARD ERROR	PR> CHI-SQUARE
INTERCEPT	15.5224	1.4721	0.0001
DISTANCE	-0.3180	0.0232	0.0001
AGE	0.1067	0.0351	0.0024
-2LOG L	389.260		

By evaluating the results with the age variable, we can see that, for older subjects, the probability of stopping at some distance, is less than the younger subjects. When we calculate the 95 percent and 5 percent stopping probabilities for 20 years old and 30 years old subjects, the associated distances are shown in Table 9. In this age group, the length of the conflicting decision zones were the same for the older and younger subjects. But the results shows that, at any distance the older subjects have less probability at stopping with respect to the younger ones.

TABLE IX

Age Group Classification

PROBABILITY OF STOPPING	20 YEARS OLD	30 YEARS OLD
0.05	46.26 Units	49.62 Units
0.95	64.78 Units	68.14 Units
CONFLICTING ZONE	18.52 Units	18.52 Units

It is possible to classify the older subject into a "go decision group" and the younger subjects into a "stop decision group" at the optimum design point. More subjects can calibrate the results with more sensitivity.

The logistic regression refers to the fact that, at the same distance, older subjects have a tendency to go at the optimum design point. This may reflect that the light perception time of older subjects (without decision process) may be longer than the young subjects. Because their decision will depend on the last situation of the car in the experiment, they may perceive that the car is in the go zone even though it was in the stop zone because of the delay in cognition. This finding should be supported by using a high speed approach simulation with careful design. The same idea can reveal the light perception time duration without decision process. The difference between the theoretical and observed logistic curves refers to the light perception time duration. But the experiment has to be conducted more carefully because of the small magnitude of light perception time. In the recommendation chapter this procedure will be explained in details.

Summary

Human behaviors were examined by computer simulation in laboratory conditions. The choice and simple reaction time distributions were approximated. The choice behavioral pattern of the people is explained by logistic regression. The dependent variable was choice and independent variable was distance from the intersection in the model.

The results from logistic curves revealed the conflicting decision area and its distribution. The conflicting area indirectly refers to the muscle response time. Thus, the muscle response time distribution is found by evaluating the coefficients involved in conflicting decision area. Finally, the visual perception time duration was quantified by using the results from choice reaction time and muscle response time distribution.

V. CONCLUSIONS AND RECOMMENDATIONS

Reaction Time

The results of the reaction times for traffic-signal cognition show that, under anticipation conditions, the response time distribution is approximately normal. Actually, total reaction time depends on a number of variables and its mean and variance change under different circumstances. Simple and choice reaction time distributions reveal the fact that visual information processing is the most important part in reaction time. Reaction time is shorter in the simple response case. Simple reaction time has very small variability when compared to choice reaction time. The evident reason is that the choice reaction time includes visual information processing (especially the decision process time).

As a design parameter, the reaction time distribution is important in order to find an appropriate probabilistic design parameter. Instead of using mean reaction time, the 90th percentile value (common significant value) is more reasonable for certain designs. The large reaction time variance dictates this requirement.

The study revealed reaction time components. We can define the reaction time in terms of its two components.

Thus, instead of using the lump-sum value, reaction time components should be used as design parameters.

Decision Process Time

In visual information processing, decision process time has the most variability as a reaction time component. The requirement to make a decision to stop or to go creates this variability. The difference between simple and choice reaction time shows the magnitude of the decision process time. This points out the most important part of the reaction time to deal with. It is often required to minimize the response time, especially when critical decisions are involved in a man-machine interface. For example, in a cockpit environment, a fighter pilot often needs to make quick decisions. Most of the decisions can be explained with complex reaction time distributions. To reduce fighter pilot reaction time, some means must be employed. This refers to the reduction in the total reaction time. Still, at that point, the biggest contributor will be decision process time. Therefore, the most effort should be placed on decision process time variability. Human psychological limits are more vulnerable than his/her physical limits.

In that concept, aircraft simulators should be used to examine the pilot's response to more complex visual signals.

Model Significance for Behavioral Pattern

The response variable is binary in an intersection approach task. These type of situations are often encountered. In daily traffic or in a cockpit environment, a driver or a pilot often makes decisions between " do or do not". In high speed flight, the small time duration represents very long distance. Sometimes late decisions may lead to unrecoverable results. As the human is needed in the cockpit, the perception and muscle response time will continue to play a role in the result of the missions.

With some explanatory variables (age, speed, distance) logistic regression can explain the human behavioral pattern for two choice cases. Most often designers try to decrease the range of conflicting decision area in the man-machine interface. By evaluating two different experimental results, we showed that the conflicting decision area is smaller in the experiment with the decision line. This result points to the possibility of some means to decrease the conflicting decision area. It refers to the fact that during intersection approach it is possible to decrease conflicting decision area by some means similar to the marked decision line.

In this framework, the model is applicable to the cockpit environment to evaluate pilots' behavioral pattern under different circumstances. Today, there are number of sophisticated tools to conduct this type of experiment. The aircraft simulator is one of them. It may be necessary to make few changes in the programs to collect the desired data. The possible outcomes from this experiment are as follows: 1) total reaction time of the pilots under different circumstances 2) conflicting decision area and its distribution in "do or do not" type responses 3) the performance differences between young and older pilots. As a result, this experiment will not only reveal the pilots behavioral pattern in the cockpit but will also show the way to shrink total reaction time and conflicting decision area by making some changes in the design.

Another possible observation may be the perception time of the pilots (without decision process) that can be found in similar experiments. Figure 11 depicts how the perception time duration (excluding decision process) can be found. The shifted logistic curve (PS2 in Figure 11) resulted from the light perception time. Even though the process seems simple, a very careful design would be necessary to observe the differences between to the logistic curves.

Consider a careful design where the subjects will decide according to the marked decision line when yellow light came on. Here, we need to emphasis the point that, car (or another moving subject) length must be small enough not to affect the subject decisions.

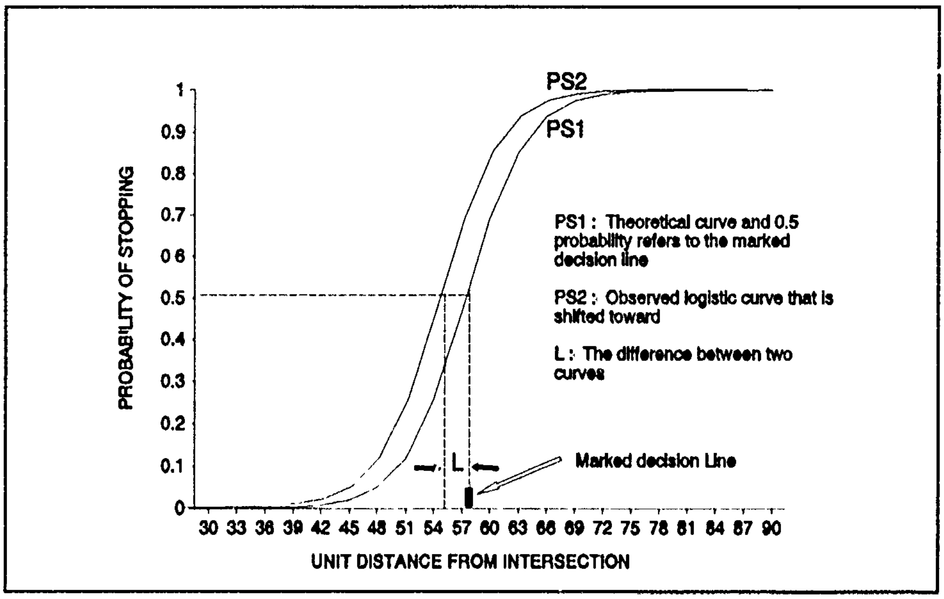


Figure 11. Theoretical and Observed logistic Curves

When the car is on the far side of the line, the decision will be stop otherwise the decision will be go. If we collected enough data around the marked decision line, we can compare the theoretical and observed go decisions (or stop decisions). Theoretically, when the yellow light is on just before the line, decision will be stop by assuming the response is instantaneous. Let's evaluate the situation in which the car is just before the marked decision line when the yellow light is turned on. We know that, nothing is instantaneous in human nature. So, the light perception will take time and during this time the car will move into the go decision area. When a subject perceives that the car is past the line, his/her decision will be go. This will result an increase in number of go decisions when compared to the theoretical expectations. In terms of the logistic curve, the observed logistic curve will shift to forward from the theoretical one.

The Figure 11 shows the two logistic curves: PS1 (theoretical) and PS2 (observed). The difference between these curves (L) refers to the yellow light perception time duration. In the same manner we showed previously, the distribution of "L" can be found by logistic regression coefficients. A careful experiment may allow us to decompose the total reaction time.

Variable Significance

We considered three explanatory variables in these experiments. Because we conducted the experiment in the laboratory, most of the variables (speed, deceleration rate, relative traffic, etc) were eliminated. The prime variable was the distance from the intersection. The other variables were age and sex. We found that, in our model, sex is not a significant variable to explain the length of the conflicting decision area. But in terms of stop and go decisions, the older subjects have a tendency to go at the optimum design point when compared to the younger subjects. The finding may indicate that the older subjects' light perception time (without decision process) may be longer than younger subjects'. Stratified Random Sampling will be helpful to see the difference between young and older groups. The suggested experiment in the previous part will be applicable to find this difference.

Conflicting Decision Area

The range of the conflicting decision area is important for optimum design. Its probabilistic range varies according to the design, individuals, and other possible variables (speed, expectancy, etc). We ran the experiment in two slightly different ways. When we ran the subjects with a marked decision line, the conflicting decision area is smaller than in the other case. In the experiment we used marked decision line to reduce the size of the conflicting decision area.

One of the important variables that can affect this range is the difference in perceived time to reach to intersection. This creates noise around the optimum design point. Hypothetically, the step function type of curve eliminates the conflicting decision area. But human nature does not allow that perfection. Even with the possible outside variables are eliminated, the muscle response time will still continue to create the difference between "do or do not" type responses. We know the fact that muscle response time is not involved for "do not" type decisions.

The most important explanation for this finding is that we can approximate the muscle response time by evaluating the conflicting decision area. The conflicting decision area, without any disturbance, represents the muscle response time distribution. In the experiment, it was never possible to obtain perfect conditions. But, it was possible to minimize the effects of the other variables. We eliminated all possible outside variables from our aspect, and we produced muscle response time distribution by evaluating the conflicting decision area. We concluded that muscle response time is also normally distributed.

Conflicting Decision Area Distribution

The distribution of the conflicting decision area or indirectly the muscle response time will depend on the slope parameter of the distance. Under the assumption that logistic regression coefficients are normally distributed, the muscle response time will also be normally distributed. If we evaluate another explanatory variable, such as age, at certain age the conflicting decision area will depend basically on the slope parameter when we replace the age variable with any constant in Eqs (16) and (17). At this time, apparently the mean and variance of the muscle response time will not change with the age differences. The logistic curve will not explain the muscle response time differences among the different ages because it is fitted for group not for any specific age. Instead, it gives the difference between their decisions. Such as, at a certain distance, what is the stop and go decision probability difference between 20 and 30 years old subjects. This will help to discriminate people according to their age. Mcst commonly, any design will not be for individuals so the group is more appropriate for evaluating the design. When required, the special parameters can be found for an individual.

Conflicting decision area distribution can be useful in the field by employing it to set the yellow light at signalized intersections. As long as the driver's distance perception differences are not eliminated, conflicting decision area will stay as a most important factor for determination yellow light duration.

Visual Perception Time

By using statistical properties, we subtracted the muscle response time from the total reaction time and we found the visual perception time duration. Because the perception time included visual information processing, it has more variability than muscle response time. Its quantified value is 0.35 seconds. When we compared the visual perception, muscle response time and total reaction time in their mean value, 70 percent of the total reaction time can explained by the visual perception time components. This highlights the importance of information processing in the two choice cases. Thirty percent of the reaction time belongs to the muscle response time. The quantitative values of the reaction time components can change with respect to the conditions in which the reaction occurs, but will always need to be considered to optimizing an interface design.

Summary

The results of this study showed that we can examine the visual-information processing mechanism by employing an indirect way of using a simple form of yellow light cognition. Potential extension of this research can be found in more complex visual signals. Instead of simple information corresponding to the yellow light, one can begin to examine the effectiveness of various signals and signs. A similar type of experiment is applicable to many areas such as a cockpit environment. Later extensions of this research should include mock-up simulator as well as three dimensional display on a full size monitor. Another aspect is to employ the model in auditory-information processing evaluation by replacing the visual stimulus with auditorial one. The results of the experiments can be interpreted in multiple ways. The number of results from the experiment prove that this experiment can meet several purposes at one time and will be very economic in practice.

APPENDIX A: LISTING OF THE COMPUTER PROGRAM

```
1  REM *** YELLOW LIGHT SIMULATION ***
2  REM *** HUNTINGTON III PROJECT  ***
3  REM *** NATIONAL SCIENCE FOUNDATION ***
4  REM *** DIRECTORS: DR. LUDWIG BRAUN AND DR. THOMAS LIAO
***
5  REM
6  REM *** ORIGINAL VERSION BY PHILIP REESE ***
7  REM *** REVISED BY DANIEL W. CORCORAN ***
8  REM *** ADAPTED FOR THE APPLE II BY DOUG HALUZA ***
9  REM *** LATEST VERSION 24-FEB-83 ***
10 IF PEEK (29696) < > 3 THEN PRINT CHR$ (4);"RUN YELLOW
YELLOW":   REM LOAD SHAPES & TEXT...
14 KB = - 16384: REM  KEYBOARD PEEK
16 HOME : HCOLOR= 7: ROT= 0: SCALE= 1
19 REM *** OPENING GRAPHIC ***
20 HGR2 : GOSUB 40000: GOSUB 40100
22 AX$ = "^YELLOW ^LIGHT":X = 25:Y = 7: GOSUB 20020
23 AX$ = "^SIMULATION":X = 33:Y = 17:GOSUB 20020
25 Y1 = 154:FOR X1 = ID - (159 - IB) - 13 TO ID - 34 STEP
Y1=Y1 -2
30 DRAW 1 AT X1,Y1
32 IF X1 < > 110 THEN 35
33 GOSUB 40130 :X = ID - 40: Y = IB + 50: AX$ =
   "^PRODUCED FOR          THE    ":GOSUB 20020
34 AX$ = "^NAT. ^SCIENCE ^FOUND.": Y = Y + 10 : GOSUB
   20020
35 IF X1 < > 130 THEN 38
36 GOSUB 40160:AX$ = "(C) 1984 ^DEPT. OF": Y= Y + 15:
   GOSUB  20020
37 AX$ = "^CIVIL & ^ENV. ENGG.":Y = Y + 10: GOSUB 20020
38 FOR I = 1 TO 25:NEXT
40 XDRAW 1 AT X1,Y1:NET X1
43 DRAW 1 AT X1,Y1 - 1
45 AX$ = "^WASHINGTON ^STATE":Y = Y + 10:GOSUB 20020
46 AX$ = "^UNIVERSITY ,^PULLMAN.":Y = Y + 10:GOSUB 20020
47 AX$ = "^ADAPTED ^BY ^M. ^Y. ^RAHI":Y = Y +
   10: GOSUB 20020
48 AX$ = "^MODIFIED IN ^A^F^I^T BY":Y = Y - 85: GOSUB 20020
49 AX$ = "^H. ^DEMIRARSLAN, 1991":Y = Y + 10: GOSUB 20020
50 HCOLOR= 1: DRAW 3 AT IG -5,16:HCOLOR= 6: DRAW 3 AT IG -
5,25:HCOLOR= 7
60 AX$ = "^ADJUST ^COLOR,HIT ANY KEY TO BEGIN...":X = 5 :
   Y = IB -11: GOSUB 20020
69 GET A$
70 DIM RT(25),A(25),V(25),YT(25),W(25),GD(25),SD(25),DZ(25),
   DZ(25),XM(25)
80 V$(1) = "RT":V$(2) = "A ":V$(3) = "V ":V$(4) = "YT":V$(5)
```

```
= "W "
82 VU$(1) = "(SEC)":VU$(2) = "(FT/SEC^2)":VU$(3) =
"(FT/SEC)"
83 VU$(4) = "(SEC)":VU$(5) = "(FT)"
1000 REM *** MAIN PROGRAM ***
1010 GOSUB 2100: REM *** MENU ***
1030 IF C = 6 THEN HOME : PRINT :PRINT "THANK YOU!": END
1040 HOME : ON C GOSUB 3000,4560,6000,7000,1500
1041 GOTO 1000
1500 REM *** CLEAR SUMMARY ***
1510 FOR X=1 TO 25: RT(X)=0:YT(X)=0:W(X)=0:V(X)=0:A(X)=0:J=0
     :NEXT X:
2099 REM *** MAIN MENU ***

2100 TEXT:HOME:PRINT TAB(7) "*** YELLOW LIGHT MENU ***"
2105 I=1
2110 PRINT:INVERSE:PRINT "R";:NORMAL:PRINT "UN HUMAN
RESPONSE TIME                     SIMULATION":PRINT
2120 INVERSE:PRINT "D";:NORMAL:PRINT "ETERMINE GO ,STOP,
DILEMNA                         ZONES":PRINT
2130 INVERSE:PRINT "P";:NORMAL:PRINT "RINT SUMMARY OF INPUTS
AND OUTPUTS":         PRINT
2140 INVERSE:PRINT "G";:NORMAL:PRINT "RAPH EFFECT OF INPUTS
ON OUTPUTS":          PRINT
2150 INVERSE:PRINT "C";:NORMAL:PRINT "LEAR SUMMARY":PRINT
2155 INVERSE:PRINT "D";:NORMAL:PRINT "ND PROGRAM":PRINT
2160 PRINT:PRINT "ENTER";:INVERSE:PRINT
"HIGHLIGHTED":NORMAL:PRINT                        "CHARACTER";
2165 INPUT C$:C$=LEFT$(C$,1):PRINT
2170 C=0:RESTORE:FOR X=1 TO 6:READ A$:IF A$=C$ THEN C=X
2180 NEXT X:IF C=0 THEN 2100
2190 IF C>4 THEN PRINT "ARE YOU SURE ?";:INPUT A$
2191 IF C>4 AND LEFT$(A$,1) < > "Y" THEN 2100
2195 RETURN
2200 DATA R,D,P,G,C,E,*** COMMANDS ***
2290 REM *** RESPONSE TIME SIMULATION ***
3000 REM *** RESPONSE TIME SIMULATION ***
3003 SS=0 : S=0:HGR2:PRINT CHR$(4)"BLOAD INSTRUCTIONS
3004 POKE -16368,0
3005 PRINT "HIT ANY KEY WHEN YOU READY";:GET A$
3006 HOME:PRINT "* RESPONSE TIME SIMULATION *"
3007 PRINT "  -----------------------":PR# 0
3008 POKE -16368,0
3010 HOME:GOSUB 40000:GOSUB 40100
4000 GZ=45:GY=154-GZ-12:GZ=ID-(GY-IB)
4008 AX$="^STOP ZONE":X=GX-18:Y=GY+25:GOSUB 20020
4009 AX$="^GO ZONE":X=GX+20:Y=GY-15:GOSUB 20020
4010 P=INT(RND(1)*25)*2+16:Y1=154:X1=ID-(159-IB)-13
4015 X2=IH+21 :Y2=IA+5:DRAW 2 AT X2,Y2:DRAW 1 AT X1,Y1
4017 AX$="^PRESS THE ^G (GAS) KEY TO GO ...":X=36:Y=IB-
```

```
10:GOSUB 20020
4020 GET A$:A=PEEK(KB):IF A$ < > "G" THEN 4020
4025 GOSUB 20020
4030 FOR K=1 TO P STEP 2:XDRAW 1 AT X1,Y1
4040 X1=X1+2 :Y1=Y1+2:DRAW 1 AT X1,Y1:FOR JJ=1 TO 10:NEXT JJ
4050 IF PEEK (KB)=71 THEN 4090
4060 Y=IB-10 :X=24:AX$="^WAIT FOR THE LIGHT TO TURN
YELLOW!":GOSUB 20020
4070 K=P:NEXT K:FOR I=1 TO 2000:NEXT:GOTO 3007
4090 NEXT K:XDRAW 1 AT X1,Y1
4095 GF=0:IF K>GZ THEN GF=-1
4100 T1=0:RT=0:X1=X1+2:Y1=Y1-2:GOSUB 40130:DRAW 1 AT
X1,Y1:X0=X1:YO=Y1
4101 IF GF THEN 4110
4102 FOR K=0 TO 1:RT=RT+1:XDRAW 1 AT X1,Y1:X1=X1+1:Y1=Y1-
1:P=P+1
4103 DRAW 1 AT X1,Y1:K=PEEK(KB)=160 OR P>GZ +12
4105 NEXT K
4107 HOME:VTAB 23:IF PEEK(KB) < > 160 THEN RT=0
4110 FOR K=P+2 TO 70 STEP 2
4130 XDRAW 1 AT X1,Y1
4140 X1=X1+2:Y1=Y1-2 :DRAW 1 AT X1,Y1:FOR JJ=1 TO
10+SF*20:NEXT JJ
4150 NEXT K
4200 IF RT > 0 AND GF=0 THEN 4300
4210 IF RT=0 AND GF=-1 AND PEEK(KB) < > 160 THEN 4250
4212 FOR K=70 TO 86 STEP 2:XDRAW 1 AT X1,Y1:XDRAW 2 X2,Y2
4214 X1=X1+2:Y1=Y1-2 :X2=X2-2:DRAW 1 AT X1,Y1:DRAW 2 AT
X2,Y2
4215 FOR JJ= 1 TO 10 : NEXT : NEXT K
4217 X2=0
4220 REM *** ACCIDENT ***
4225 XDRAW 1 AT X1,Y1
4230 ROT=48:DRAW 1 AT ID-3,IB-5:ROT=0
4240 X=99:Y=180:AX$="^YOU CAUSED AN ACCIDENT ":GOSUB 20020
4249 GOTO 4390
4250 REM *** SAFE TRIP ***
4260 FOR K=70 TO 135 STEP 2
4265 IF K=P+50 THEN GOSUB 4160
4270 XDRAW 1 AT X1,Y1
4280 X1=X1+2:Y1=Y1-2:DRAW 1 AT X1,Y1:FOR JJ=1 TO 10:NEXT JJ
4290 NEXT K
4295 XDRAW 1 AT X1,Y1
4299 GOTO 4390
4300 X=62:Y=183:AX$="^YOUR REACTION TIME IS"
4303 R=INT((RT+1)*8.5+.5)/100:IF R<1 THEN AX$=AX$+"0"
4305 PRINT "*) YOUR REACTION TIME IS";:PRINT R"SEC":PR# 0
4306 AX$=AX$+STR$(R)+"SEC.":GOSUB 20020
4307 HPLOT X,191 TO 279,191
4310 SS=SS+1 :S=S+RT
```

```
4320 FOR K=70 TO P+50 :FOR JJ=1 TO 10:NEXT JJ:NEXT K:GOSUB
40160
4390 X=50 :Y=150:AX$="^DISTANCE WAS":DS=SQR(((160-
X0)^2)+((70-Y0)^2)):
AX$=AX$+STR$(DS)+"UNITS":GOSUB 20020
4400 AX$="^PRESS '^T'TO TRY AGAIN,'^Q' TO QUIT...":X=5:Y=IB-
11:GOSUB 20020
4405 HCOLOR =2 :DRAW 1 AT X0,Y0:HCOLOR=7
4410 IF PEEK(KB)=212 THEN POKE -16368,0:GOTO 3007 :REM TRY
AGAIN
4420 IF PEEK(KB)=209 THEN POKE -16368,0:GOTO 4500 :REM QUIT
4422 IF X2 < 26 THEN 4410
4425 XDRAW 2 AT X2,Y2
4430 X2=X2-2
4440 DRAW 2 AT X2,Y2:FOR I=1 TO 10 :NEXT
4450 GOTO 4410
4500 IF SS=0 THEN RETURN
4510 TEXT
4520 PRINT :PRINT "YOUR AVERAGE REACTION TIME IS";
4522 :R=INT((S+SS)/SS*8.5+.5)/100:IF R < 1 THEN PRINT "0";
4525 PRINT R"SEC":PR# 0
4530 PRINT :PRINT "WOULD YOU LIKE TO CONTINUE AND "
4535 PRINT "ANALYZE AN INTERSECTION (Y OR N)";
4540 INPUT A$:A$=LEFT$(A$,1)
4545 IF A$ ="N" THEN RETURN
4550 FI A$ < > "Y" THEN 4530
4555 J=0
4559 REM *** ANALYZE INTERSECTION ***
4560 RT=RT(J):A=A(J):V=V(J):YT=YT(J):W=W(J)
4561 IF RT < > 0 AND A < > 0 AND V < > 0 AND YT < > 0 AND W
< > 0 THEN 4610
4562 TEXT:HOME:PRINT :PRINT "DATA FOR ANALYSIS OF
INTERSECTION"
4563 PRINT "---- --- -------- ------------"
4600 GOSUB 45600 :GOSUB 45700 :GOSUB 45800:GOSUB 45900:GOSUB
46000
4610 J= J+1 :RT(J)=RT:A(J)=A :V(J)=V:YT(J)=YT:W(J)=W
4615 V1=V*1.47
4660 SD=V1*RT+V1*V1/(2*A*1.47):SD(J)=SD
4670 GD=(V1*YT)-W-20:GD(J)=GD
4680 DZ=INT(SD-GD+.5):DZ(J)=DZ
4800 IS=.195
4810 IA=15:IB=IA+W*IS
4820 IC=170:ID=IC+W*1.414*IS
4825 D1=SD*IS/1.414+IB:D2=GD*IS/1.414+IB:IF D1 > 190 THEN
D1=190
4827 IF D2 > 190 THEN D2=179
4830 IG=IC+IB-IA:IH=ID+IB-IA
4835 HGR2:POKE 49234,0:HCOLOR=7:GOSUB 40045
4838 HCOLOR=1
```

```
4840 IF DZ <= 0 THEN D3=D2 :D2=D1:D1=D3
4843 I%=0:HCOLOR=7:FOR I=IB TO 190 STEP 20*IS/1.414
4845 X=ID-I+IB+1:HPLOT X,I TO X+4,I
4846 IF I%/5 < > INT(I%/5) OR I%=0 THEN 4848
4847 HPLOT TO X+9,I :X=X+10:Y=I-3:AX$=STR$(I%*20)+"'":GOSUB
20020
4848 I%=I%+1:NEXT I
4850 HCOLOR=1 :IF DZ < 0 THEN HCOLOR=2
4855 FOR I=D2 TO D1
4860 HPLOT IC-I+IB+1,I TO ID-I+IB,I
4870 NEXT I:HCOLOR=7
4872 Y=(D2-IB)/2+IB-4:X=IC-Y+IB-24:A$="GO":IF Y > IB+1 THEN
GOSUB 20020
4873 Y=(191-D1)/2+D1-4:X=IC-Y+IB-38:IF X >= 0 THEN
AX$="STOP":GOSUB 20020
4874 Y=(D1-D2)/2+D2-8:X=IC-Y+IB-64
4875 IF DZ > 0 THEN AX$="DILEMMA"
4876 IF DZ < 0 THEN AX$="OVERLAP"
4878 IF X >= 0 THEN GOSUB 20020
4879 IF DZ=0 THEN 4900
4880 X=160:Y=140:AX$=AX$+"ZONE IS":GOSUB 20020
4885 Y=Y+10:AX$=STR$(ABS(DZ))+"FEET LONG.":GOSUB 20020
4890 GOTO 5155
4900 Y=140:X=160:AX$="^THERE IS NO ":GOSUB 20020
4905 Y=Y+10:AX$="DILEMMA ZONE!":GOSUB 20020
5155 X=128:Y=173:AX$="^DO YOU WANT TO CHANGE":GOSUB 20020
5157 Y=Y+10:AX$="A PARAMETER ? (^Y OR ^N)":GOSUB 20020
5160 GET QQ$:IF QQ$ < > "Y" THEN 5180
5170 TEXT :GOSUB 45000:GOTO 4610
5180 IF QQ$="N" THEN RETURN
5190 TEXT :GOSUB 45000:GOTO 4610
6000 REM *** SUMMARY ***
6010 IF J=0 THEN TEXT :HOME:VTAB 12 :HTAB 12:PRINT "*** NO
DATA ***":GOTO          6180
6020 TEXT :HOME :PRINT:PRINT "*** YELLOW LIGHT SUMMARY TABLE
***"
6030 PRINT "    ----------------------":PRINT
6100 PRINT "RT   A    V    YT   W  ! GZ  SZ   DZ"
6102 PRINT "SEC  MI/ MPH SEC   FT ! FT  FT   FT"
6103 PRINT "     H/S              !            "
6110 PRINT "--------------------+------------"
6120 FOR X=1 TO J
6130 PRINT RT(X) TAB( 6) A(X) TAB( 11)V(X) TAB( 16)YT(X)
TAB( 22)W(X);
6140 PRINT TAB( 25)"! " INT (GD(X))TAB( 31) INT (SD(X)) TAB(
36) INT              (DZ(X))
6150 NEXT X
6180 VTAB 24:PRINT "     HIT ANY KEY TO CONTINUE:";:GET A$
6200 RETURN
7000 REM *** GRAPHING ***
```

```
7010 TEXT
7020 HOME:PRINT:PRINT "     *** GRAPHING MENU ***
7040 PRINT :PRINT "1) GO ZONE VS YELLOW LIGHT TIME (YT)
7050 PRINT :PRINT "2) GO ZONE VS WIDTH (W)
7055 PRINT :PRINT "3) GO ZONE VS VELOCITY (V)
7060 PRINT :PRINT "4) STOP ZONE VS RESPONSE TIME (RT)
7065 PRINT :PRINT "5) STOP ZONE VS DECELERATION (A)
7070 PRINT :PRINT "6) STOP ZONE VS VELOCITY (V)
7075 PRINT :PRINT "7) GO ZONE AND STOP ZONE VS VELOCITY (V)
7078 PRINT :PRINT "8) RETURN TO MAIN MENU
7080 PRINT :PRINT :INPUT "SELECT A GRAPH (TYPE NUMBER):";A$
7100 V=VAL (A$):IF V <= 0 OR V > 7 THEN RETURN
7800 YM=320 :SP=0:XS=5:XB=0
7900 GOSUB 26000:REM GET INFO ON GRAPH
8000 GOSUB 19000:REM PRINT AND LABEL AXIS
8001 CC=0:IF SP=1 THEN HCOLOR=6:V=3:CC=22
8030 CC=CC+1:GOSUB 22000:REM PLOT
8040 IF SP=1 THEN V=6 :HCOLOR =5: CC=35:GOSUB 22000
8050 HCOLOR=7
8100 AX$="^CONTINUE?(^Y OR ^N):":X=117:Y=184:GOSUB 20020:GET
A$
8120 IF A$="N" THEN 7000
8140 GOSUB 18000
8150 IF SP=1 THEN 8000
8200 PRINT :INPUT "CLEAR OLD GRAPH (Y OR N):";A$:A$=LEFT$
(A$,1)
8220 IF A$="Y" THEN HGR2:GOTO 8000
8230 IF A$ < > "N" THEN 8200
8235 POKE - 16297,0:POKE - 16299,0:POKE -16302,0:POKE -
16304,0
8237 GOSUB 20020:GOTO 8030
18000 TEXT:HOME:PRINT "*** CHANGE PARAMETERS FOR GRAPH
***":PRINT
18100 IF MID$ (V$,1,1) < > "1" THEN 18200
18110 PRINT :PRINT "RESPONSE TIME"V(1)"SEC"
18120 GOSUB 45600:V(1)=RT:PRINT
18200 IF MID$ (V$,2,1) < > "1" THEN 18300
18210 PRINT "DECELERATION "V(2)"MPH/S"
18220 GOSUB 45800:V(2)=A:PRINT
18300 IF MID$ (V$,3,1) < > "1" THEN 18400
18310 PRINT "SPEED LIMIT "V(3)"MPH"
18320 GOSUB 46700 :V(3)=VV:PRINT
18400 IF MID$ (V$,4,1) < > "1" THEN 18500
18410 PRINT "YELLOW LIGHT DURATION "V(4)"SEC"
18420 GOSUB 45900 :V(4)=YT:PRINT
18500 IF MID$ (V$,5,1) < > "1" 18900
18510 PRINT "WIDTH OF INTERSECTION"V(5)"FT":
18520 GOSUB 46000:V(5)=W
18900 RETURN
19000 REM *** DRAW AXES FOR GRAPH ***
```

```
19010 HGR2:HPLOT 68,3 TO 68,191:HPLOT 67,3 TO 67,191
19020 HPLOT 68,153 TO 268,153:HPLOT 68,152 TO 268,152
19030 FOR I=300 TO -80 STEP -25:HPLOT 63,153-I/2 TO 68,153-
I/2
19040 IF I/50 < > INT(I/50) THEN 19050
19045 AX$=RIGHT$("  "+STR$(I),3):X=40:Y=150-I/2:GOSUB 20020
19050 NEXT
19060 FOR I=20 TO 200 STEP 20:HPLOT I+68,153 TO I+68,158
19070 IF I/40 < > INT(I/40) THEN 19080
19075 AX$=STR$(I*XM/200):X=I+68-LEN(AX$)*3:Y=160:GOSUB 20020
19080 NEXT I
19100 X=168-3*LEN(X$):Y=170:AX$=X$:GOSUB 20020
19200 X=24:Y=99-4*LEN(Y$):AX$=Y$:GOSUB 21020
19300 IF SP=1 THEN X=9:Y=99-4*LEN(Y2$):AX$=Y2$:GOSUB 21020
19999 RETURN
20000 REM *** HI-RES TEXT PRINTER ***
20010 X=8*R:Y=8*D
20020 POKE 29953,(X > 255):POKE 29954,X-(X > 255) *256:POKE
29955,Y
20050 E=1:FOR IX=1 TO LEN(AX$)
20100 AX=ASC(MID$(AX$,IX,1))
20200 IF AX=94 THEN E=0:GOTO 20700
20300 IF E AND AX > 63 AND AX < 91 THAN AX = AX + 32
20400 IF E THEN 20600
20500 IF AX > 47 AND AX < 58 THEN AX=43 + (AX>52)*27+AX
20600 POKE 29957,AX:CALL 30445:E=1
20700 NEXT IX:RETURN
21000 REM VERTICAL TEXT
21020 POKE 29953,(X>255):POKE 29954,X-(X>255)*256:POKE
29955,Y
21030 E=1 :FOR IX=1 TO LEN(AX$):AX=ASC(MID$ (AX$,IX,1))
21035 IF AX=94 THEN E=0 :NEXT IX :RETURN
21040 POKE 29953,(X>255):POKE 29954,X-(X>255)*256:POKE
29955,PEEK (29955)+8
21050 GOTO 20300
22000 REM *** PLOT GRAPH ***
22002 IF V > 3 THEN 22010
22004 ON V GOSUB 24000,24100,24200
22005 XX=XM:YY=153-(M*XX+B)/2
22006 IF YY > 190 THEN XX=(-75-B)/M:YY=153-(M*XX+B)/2
22007 IF YY < 0 THEN XX=(300-B)/M:YY=153-(M*XX+B)/2
22008 X2=200*XX/XM+70:HPLOT 68,153-B/2 TO X2-2,YY:Y=YY-3:IF
Y < 0 THEN Y=0
22009 GOTO 22100
22010 FOR XX=1 TO 199 :X=XM/200*XX
22020 ON V GOSUB  24000,24100,24200,24300,24400,24500
22030 YY=153-Y/2
22040 IF YY <= 191 AND YY >= 0 THEN HPLOT XX+68,YY:X2=XX+70
22050 NEXT XX:Y=YY-3:IF Y < 0 THEN Y=0
22100 AX$=CHR$(CC+48):X=X2:IF CC > 20 THEN AX$="^"+AX$
```

```
22105 PRINT CC,AX$
22110 GOSUB 20020:RETURN
23999 REM *** GRAPH EQUATIONS ***
24000 M=V(3)*1.47:B=-V(5)-20:RETURN
24100 M=-1:B=V(3)*1.47*V(4)-20:RETURN
24200 M=1.47*V(4):B=-V(5)-20
24250 RETURN
24300 Y=1.47*V(3)*(X+V(3)/V(2)/2):RETURN
24400 Y=1.47*V(3)*(V(1)+V(3)/X/2):RETURN
24500 Y=1.47*X*(V(1)+X/V(2)/2):RETURN
26000 REM *** GET GRAPH PARAMETERS ***
26010 ON V GOTO 26100,26200,26300,26400,26500,26600,26700
26100 X$="^YELLOW ^LIGHT ^TIME IN SEC":Y$="^GO ^ZONE IN FT"
26110 V(3)=30:V(5)=40:XM=5:V$="00101":RETURN
26200 X$="^WIDTH IN FT":Y$="^GO ^ZONE IN FT"
26210 V(3)=30:V(4)=2:XM=100:V$="00110":RETURN
26300 X$="^VELOCITY IN MPH":Y$="^GO ^ZONE IN FT"
26310 V(4)=2:V(5)=40:XM=75:V$="00011":RETURN
26400 X$="^RESPONSE ^TIME IN SEC":Y$="^STOP ^ZONE IN FT"
26410 V(2)=10:V(3)=30:XM=1:V$="01100":RETURN
26500 X$="^DECELERATION IN MPH/SEC":Y$="^STOP ^ZONE IN FT"
26510 V(1)=1:V(3)=30:XM=25:V$="10100":XB=2:RETURN
26600 X$="^VELOCITY IN MPH":Y$="^STOP ^ZONE IN FT"
26610 V(1)=1:V(2)=10:XM=75:V$="11000":RETURN
26700 X$="^VELOCITY IN MPH":Y$="^STOP ^ZONE IN FT * RED
*":Y2$="^GO ^ZONE          IN FT * GREEN *"
26710
V(5)=40:V(4)=2:V(1)=1:V(2)=10:XM=75:SP=1:V$="11011":V=6:CC=-
30:RETURN
40000 REM *** PLOT INTERSECTION ***
40010 IA=40:IB=70:REM TOP & BOT
40020 IC=120:ID=170:REM LEFT & RIGHT
40025 GOSUB 40030: GOTO 40080
40030 IG=IC+IB-IA:IH=ID+IB-IA:REM FAR CORNERS OF
INTERSECTIONS
40040 HGR2:HCOLOR=7
40045 HPLOT 0,IB TO IC,IB TO IC-(190-IB),190
40050 HPLOT ID-(190-IB),190 TO ID,IB TO 279,IB
40060 HPLOT 279,IA TO IH,IA TO ID+IB,0
40070 HPLOT IG+IA,0 TO IG,IA TO 0,IA
40075 RETURN
40080 HPLOT IG,IA-11 TO IG,2 TO IG-9,2 TO IG-9,IA-11 TO
IG,IA-11
40082 HPLOT IG+1,IA-10 TO IG+1,1 TO IG-10,1 TO IG-10,IA-10
TO IG+1,IA-10
40085 HPLOT IG-9,11 TO IG-1,11:HPLOT IG-9,20 TO IG-1,20
40090 RETURN
40100 HCOLOR=6:DRAW 3 AT IG-5,25
40120 HCOLOR=4:DRAW 3 AT IG-5,20
40125 HCOLOR=7:RETURN
```

```
40130 HCOLOR=1:DRAW 3 AT IG-5,16
40150 HCOLOR=4:DRAW 3 AT IG-5,25
40155 HCOLOR=7:RETURN
40160 HCOLOR=5:DRAW 3 AT IG-5,7
40180 HCOLOR=4:DRAW 3 AT IG-5,16
40185 HCOLOR=7:RETURN
45000 HOME:REM *** CHANGE PARAMETERS ***
45001 REM (NOTE :LIMITS ON INPUT ARE OUTSIDE RECOMMENDED
GUIDELINES)
45100 PRINT:PRINT "1) RESPONSE TIME "RT" SEC":PRINT
45110 PRINT "2) SPEED LIMIT "V"MPH":PRINT
45120 PRINT "3) DECELERATION "A" MPH/SEC":PRINT
45130 PRINT "4) YELLOW LIGHT DURATION "YT" SEC":PRINT
45140 PRINT "5) WIDTH OF INTERSECTION "W" FT":PRINT
45150 PRINT:PRINT " WHICH PARAMETER DO YOU WANT TO CHANGE ?"
45200 PRINT :INPUT "TYPE NUMBER (1-5):";P
45250 IF P > 5 OR P < 1 THEN 45200
45300 ON P GOTO 45600,45700,45800,45900,46000
45600 PRINT :INPUT "RESPONSE TIME IN SEC (0-2):";RT
45650 IF RT < 0 OR RT > 2 THEN 45600
45675 RETURN
45700 PRINT :INPUT "SPEED LIMIT IN MPH (0-80):";V
45750 IF V < 0 OR V > 80 THEN 45700
45775 RETURN
45800 PRINT :INPUT "DECELERATION IN MPH/SEC (0-20):";A
45850 IF A < 0 OR A > 20 THEN 45800
45875 RETURN
45900 PRINT :INPUT "YELLOW LIGHT DURATION IN SEC (0-7):";YT
45950 IF YT < 0 OR YT > 7 THEN 45900
45975 RETURN
46000 PRINT :INPUT "WIDTH OF INTERSECTION OF IN FT ( 26-
200,FOR ANALYSIS;          0-55,FOR GRAPHS)  (CAR LENGTH OF
20 FT IS ASSUMED):";W
46050 IF W < 0 OR W > 200 THEN 46000
46075 RETURN
46700 PRINT :INPUT "SPEED LIMIT IN MPH (0-80):";VV
46750 IF VV < 0 OR VV > 80 THEN 46700
46775 RETURN
```

APPENDIX B: CHOICE REACTION TIME DATA WITH DISTANCE

AGE	SEX	DISTANCE	R. TIME	AGE	SEX	DISTANCE	R. TIME
30	1	99.15	0.68	19	0	73.75	0.43
30	1	62.48	0.60	19	0	73.75	0.43
30	1	62.48	0.68	19	0	96.33	0.51
30	1	90.68	0.43	19	0	93.50	0.34
30	1	59.66	0.77	19	0	82.21	0.43
30	1	82.21	0.60	19	0	76.57	0.77
30	1	73.75	0.68	19	0	96.33	0.68
30	1	90.68	0.60	19	0	93.50	0.43
30	1	79.39	0.68	19	0	62.48	0.34
30	1	59.66	0.77	19	0	96.33	0.43
30	1	70.93	0.60	19	0	79.39	0.34
30	1	99.15	0.51	19	0	96.33	0.34
30	1	90.68	0.68	19	0	87.86	0.43
30	1	90.68	0.60	19	0	59.66	0.51
30	1	79.39	0.34	19	0	79.39	0.34
30	1	93.50	0.85	19	0	59.66	0.34
30	1	96.33	0.77	19	0	76.75	0.34
30	1	82.21	0.60	19	0	68.11	0.34
30	1	82.21	0.85	19	0	85.04	0.34
30	1	65.29	0.51	19	0	65.29	0.34
30	1	70.93	0.85	19	0	59.66	0.34
30	1	87.86	0.60	19	0	87.86	0.34
30	1	90.68	0.51	19	0	65.29	0.34
30	1	99.15	0.43	19	0	96.33	0.34
30	1	59.66	0.77	19	0	65.29	0.43
30	1	65.29	0.60	19	0	68.11	0.43
30	1	93.50	0.68	19	0	87.86	0.43
30	1	85.04	0.77	19	0	93.50	0.43
30	1	87.86	0.51	19	0	87.86	0.43
30	1	85.04	0.51	19	0	96.33	0.43
30	1	65.29	0.68	19	0	82.21	0.34
30	1	59.66	0.68	19	0	34.40	0.43
30	1	70.93	0.68	19	0	93.50	0.43
30	1	87.86	0.85	19	0	68.11	0.43
30	1	73.75	0.51	19	0	70.93	0.43
30	1	82.21	0.51	19	0	59.66	0.34
30	1	90.68	0.51	19	0	99.15	0.34
30	1	65.29	0.68	19	0	90.68	0.34
30	1	65.29	0.85	19	0	82.21	0.34
30	1	87.86	0.51	19	0	99.15	0.43
30	1	87.86	0.60	19	0	93.50	0.34
30	1	73.75	0.60	19	0	85.04	0.34
30	1	93.50	0.68	19	0	70.93	0.34
30	1	65.29	0.94	19	0	96.33	0.43

30	1	68.11	0.77	19	0	85.04	0.34
30	1	79.39	0.85	19	0	68.11	0.43
30	1	85.04	0.68	19	0	93.50	0.34
30	1	70.93	0.51	19	0	68.11	0.43
30	1	79.39	0.68	19	0	68.11	0.43
30	1	73.75	0.77	19	0	73.75	0.43
28	0	93.50	0.60	25	1	82.21	0.51
28	0	99.15	0.60	25	1	85.04	0.60
28	0	90.68	0.68	25	1	59.66	1.02
28	0	59.66	0.60	25	1	70.93	0.43
28	0	82.21	0.43	25	1	99.15	0.51
28	0	70.93	0.43	25	1	87.86	0.77
28	0	73.75	0.43	25	1	99.15	0.60
28	0	90.68	0.51	25	1	62.48	0.85
28	0	73.39	0.34	25	1	73.75	0.51
28	0	93.50	0.43	25	1	76.57	0.51
28	0	59.66	0.51	25	1	73.75	0.85
28	0	70.93	0.34	25	1	68.11	0.68
28	0	99.15	0.43	25	1	68.11	0.77
28	0	90.68	0.43	25	1	73.75	0.51
28	0	79.39	0.34	25	1	90.68	0.68
28	0	93.50	0.34	25	1	59.66	0.51
28	0	96.33	0.34	25	1	76.57	0.60
28	0	82.21	0.34	25	1	65.29	0.51
28	0	82.21	0.77	25	1	85.04	0.43
28	0	65.29	0.43	25	1	85.04	0.34
28	0	70.93	0.34	25	1	79.39	0.34
28	0	87.86	0.34	25	1	99.15	0.34
28	0	90.68	0.43	25	1	82.21	0.34
28	0	59.66	0.60	25	1	79.39	0.34
28	0	65.29	0.43	25	1	68.11	0.43
28	0	93.50	0.43	25	1	73.75	0.51
28	0	85.04	0.43	25	1	87.86	0.34
28	0	87.86	0.34	25	1	82.21	0.60
28	0	85.04	0.34	25	1	65.29	0.60
28	0	70.93	0.34	25	1	65.29	0.51
28	0	73.75	0.26	25	1	62.48	0.51
28	0	73.75	0.34	25	1	70.93	0.34
28	0	82.21	0.34	25	1	70.93	0.51
28	0	90.68	0.34	25	1	90.68	0.43
28	0	65.29	0.34	25	1	99.15	0.51
28	0	65.29	0.34	25	1	99.15	0.34
28	0	65.29	0.51	25	1	93.50	0.43
28	0	82.21	0.43	25	1	73.75	0.43
28	0	65.29	0.51	25	1	76.75	0.60
28	0	87.86	0.68	25	1	70.93	0.34
28	0	73.75	0.34	25	1	68.11	0.43
28	0	82.21	0.26	25	1	59.66	0.43
28	0	70.93	0.34	25	1	62.48	0.34

28	0	99.15	0.51	25	1	87.86	0.60
28	0	68.11	0.43	25	1	90.68	0.34
28	0	76.57	0.43	25	1	93.50	0.34
28	0	99.15	0.43	25	1	73.75	0.34
28	0	85.04	0.34	25	1	82.21	0.51
28	0	93.50	0.34	25	1	85.04	0.60
28	0	99.15	0.34	25	1	65.29	0.60
26	1	90.68	0.77	27	1	59.66	0.77
26	1	70.93	0.51	27	1	82.21	0.77
26	1	73.75	0.68	27	1	70.93	0.51
26	1	90.68	0.51	27	1	73.75	0.77
26	1	79.39	0.51	27	1	90.68	0.77
26	1	93.50	0.51	27	1	93.50	0.43
26	1	59.66	0.60	27	1	59.66	0.68
26	1	90.68	0.51	27	1	70.93	0.51
26	1	90.68	0.51	27	1	90.68	0.43
26	1	79.39	0.51	27	1	79.39	0.51
26	1	96.33	0.60	27	1	96.33	0.85
26	1	82.21	0.60	27	1	82.21	0.77
26	1	65.29	0.60	27	1	65.29	0.51
26	1	70.93	0.51	27	1	70.93	0.68
26	1	87.86	0.51	27	1	87.86	0.68
26	1	99.15	0.85	27	1	90.68	0.51
26	1	65.29	0.51	27	1	65.29	0.77
26	1	93.50	0.51	27	1	93.50	0.85
26	1	85.04	0.51	27	1	85.04	0.43
26	1	87.86	0.43	27	1	87.86	0.60
26	1	85.04	0.43	27	1	85.04	0.51
26	1	65.29	0.51	27	1	59.66	0.51
26	1	59.66	0.51	27	1	70.93	0.34
26	1	70.93	0.43	27	1	87.86	0.51
26	1	87.86	0.51	27	1	73.75	0.77
26	1	73.75	0.43	27	1	73.75	0.43
26	1	73.75	0.43	27	1	73.75	0.51
26	1	73.75	0.94	27	1	82.21	0.43
26	1	82.21	0.43	27	1	65.29	0.77
26	1	90.68	0.51	27	1	65.29	0.43
26	1	62.48	0.77	27	1	87.86	0.77
26	1	96.33	0.60	27	1	87.86	0.43
26	1	76.57	0.94	27	1	73.75	0.68
26	1	85.04	0.34	27	1	93.50	0.94
26	1	68.11	0.51	27	1	68.11	0.68
26	1	65.29	0.34	27	1	79.39	0.77
26	1	85.04	0.34	27	1	62.48	0.43
26	1	93.50	0.34	27	1	85.04	0.43
26	1	70.38	0.43	27	1	85.04	0.60
26	1	62.48	0.43	27	1	70.93	0.77
26	1	85.04	0.34	27	1	79.39	0.60
26	1	70.93	0.43	27	1	73.75	0.51
26	1	82.21	0.34	27	1	82.21	0.51

26	1	90.68	0.43	27	1	82.21	0.85
26	1	82.21	0.34	27	1	65.29	0.94
26	1	87.86	0.60	27	1	87.86	0.77
26	1	68.11	0.43	27	1	73.75	0.77
26	1	73.75	0.34	27	1	82.21	0.85
26	1	79.39	0.34	27	1	93.50	0.68
26	1	79.39	0.34	27	1	85.04	0.68
26	1	93.50	0.34	23	0	68.11	0.60
26	1	62.48	0.26	23	0	59.66	0.60
26	1	90.68	0.51	23	0	99.15	0.94
26	1	73.75	0.51	23	0	73.75	0.51
26	1	90.68	0.34	23	0	70.93	0.85
26	1	79.39	0.26	23	0	82.21	0.51
26	1	93.50	0.34	23	0	76.57	0.60
26	1	96.33	0.34	23	0	82.21	0.43
26	1	73.75	0.26	23	0	85.04	0.43
26	1	82.21	0.34	23	0	79.39	0.51
26	1	65.29	0.34	23	0	79.39	0.43
26	1	70.93	0.26	23	0	79.39	0.51
26	1	87.86	0.26	23	0	79.39	0.68
26	1	90.68	0.26	23	0	76.57	0.43
26	1	70.93	0.34	23	0	65.29	0.60
26	1	65.29	0.26	23	0	93.50	0.68
26	1	85.04	0.43	23	0	70.93	0.51
26	1	87.86	0.26	23	0	96.33	0.43
26	1	85.04	0.26	23	0	59.66	0.60
26	1	65.29	0.26	23	0	68.11	0.43
26	1	70.93	0.26	23	0	90.68	0.43
26	1	87.86	0.26	23	0	93.50	0.43
26	1	73.75	0.26	23	0	79.39	0.43
26	1	82.21	0.26	23	0	79.39	0.43
26	1	90.68	0.26	23	0	87.86	0.43
26	1	65.29	0.26	23	0	76.57	0.34
26	1	65.29	0.26	23	0	76.57	0.43
26	1	87.86	0.34	23	0	99.15	0.60
26	1	87.86	0.34	23	0	68.11	0.51
26	1	73.75	0.34	23	0	90.68	0.51
26	1	93.50	0.43	23	0	59.66	0.43
26	1	65.29	0.51	23	0	93.50	0.34
26	1	68.11	0.34	23	0	90.68	0.51
26	1	62.48	0.34	23	0	85.04	0.34
26	1	85.04	0.26	23	0	82.21	0.43
26	1	85.04	0.34	23	0	79.39	0.43
26	1	70.93	0.34	23	0	70.93	0.43
26	1	79.39	0.34	23	0	96.33	0.51
26	1	73.75	0.34	23	0	68.11	0.43
26	1	65.29	0.34	23	0	90.68	0.43
26	1	82.21	0.34	23	0	76.57	0.34
26	1	82.21	0.34	23	0	59.66	0.94
26	1	87.86	0.43	23	0	76.57	0.68

26	1	73.75	0.26	23	0	82.21	0.68
26	1	82.21	0.34	23	0	65.29	0.43
26	1	93.50	0.34	23	0	96.33	0.77
26	1	85.04	0.43	23	0	62.48	0.43
26	1	62.48	0.34	23	0	96.33	0.34
26	1	70.93	0.43	23	0	73.75	0.68
26	1	68.11	0.26	23	0	62.48	0.43
27	1	59.66	0.34	20	1	90.68	0.51
27	1	82.21	0.34	20	1	93.50	0.51
27	1	70.93	0.34	20	1	87.86	0.43
27	1	73.75	0.26	20	1	68.11	0.43
27	1	90.68	0.34	20	1	85.04	0.43
27	1	79.39	0.26	20	1	68.11	0.51
27	1	93.50	0.26	20	1	87.86	0.60
27	1	59.66	0.34	20	1	90.68	0.51
27	1	70.93	0.26	20	1	73.75	0.60
27	1	99.15	0.34	20	1	82.21	0.60
27	1	90.68	0.26	20	1	70.93	0.68
27	1	90.68	0.26	20	1	85.04	0.51
27	1	79.39	0.34	20	1	59.66	0.60
27	1	96.33	0.34	20	1	59.66	0.51
27	1	82.21	0.34	20	1	85.04	0.43
27	1	70.93	0.34	20	1	96.33	0.94
27	1	87.86	0.26	20	1	87.86	0.43
27	1	90.68	0.26	20	1	70.93	0.60
27	1	99.15	0.34	20	1	68.11	0.60
27	1	59.66	0.26	20	1	70.93	0.68
27	1	65.29	0.43	20	1	90.68	0.60
27	1	93.50	0.26	20	1	82.21	0.85
27	1	85.04	0.26	20	1	73.75	0.68
27	1	87.86	0.34	20	1	96.33	0.68
27	1	85.04	0.26	20	1	93.50	0.43
27	1	65.29	0.26	20	1	93.50	0.43
27	1	70.93	0.34	20	1	73.75	0.68
27	1	87.86	0.26	20	1	79.39	0.51
27	1	73.75	0.26	20	1	70.93	0.43
27	1	73.75	0.26	20	1	70.93	0.77
27	1	73.75	0.34	20	1	76.57	0.51
27	1	82.21	0.26	20	1	68.11	0.68
27	1	90.68	0.34	20	1	87.86	0.51
27	1	65.29	0.34	20	1	96.33	0.43
27	1	65.29	0.43	20	1	79.39	0.51
27	1	87.86	0.34	20	1	82.21	0.60
27	1	87.86	0.34	20	1	59.66	0.60
27	1	73.75	0.34	20	1	65.29	0.68
27	1	93.15	0.26	20	1	70.93	0.68
27	1	65.29	0.34	20	1	73.75	0.60
27	1	68.11	0.26	20	1	90.68	0.85
27	1	79.39	0.26	20	1	82.21	0.51
27	1	85.04	0.34	20	1	79.39	0.68

27	1	85.04	0.34	20	1	82.21	0.51
27	1	70.93	0.26	20	1	62.48	0.51
27	1	79.39	0.26	20	1	85.04	0.34
27	1	73.75	0.34	20	1	62.48	0.51
27	1	82.21	0.34	20	1	87.86	0.68
27	1	82.21	0.26	20	1	70.93	0.60
27	1	87.86	0.34	20	1	96.33	0.60
34	1	99.15	0.60	23	1	87.86	0.43
34	1	62.48	0.77	23	1	96.33	0.43
34	1	59.66	0.60	23	1	65.29	0.51
34	1	70.93	0.60	23	1	68.11	0.43
34	1	90.68	0.60	23	1	85.04	0.43
34	1	93.50	0.68	23	1	73.75	0.43
34	1	59.66	0.60	23	1	62.48	0.43
34	1	70.93	0.60	23	1	65.29	0.43
34	1	79.39	0.51	23	1	59.66	0.68
34	1	96.33	0.85	23	1	76.57	0.43
34	1	82.21	0.60	23	1	62.48	0.43
34	1	82.21	0.43	23	1	68.11	0.43
34	1	65.29	0.85	23	1	68.11	0.43
34	1	87.86	0.94	23	1	65.29	0.43
34	1	90.68	0.85	23	1	79.39	0.77
34	1	99.15	0.60	23	1	65.29	0.43
34	1	65.29	0.60	23	1	79.39	0.51
34	1	93.50	0.60	23	1	79.39	0.43
34	1	85.04	0.60	23	1	76.57	0.51
34	1	87.86	0.60	23	1	68.11	0.34
34	1	85.04	0.51	23	1	99.15	0.68
34	1	65.29	0.60	23	1	59.66	0.43
34	1	70.93	0.68	23	1	65.29	0.51
34	1	87.86	0.43	23	1	65.29	0.51
34	1	90.68	0.85	23	1	82.21	0.51
34	1	96.93	0.43	23	1	59.66	0.51
34	1	73.75	0.51	23	1	70.93	0.51
34	1	70.93	0.43	23	1	70.93	0.43
34	1	73.75	0.60	23	1	79.39	0.68
34	1	82.21	0.43	23	1	93.50	0.51
34	1	87.86	0.60	23	1	85.04	0.43
34	1	68.11	0.43	23	1	76.57	0.34
34	1	59.66	0.85	23	1	68.11	0.43
34	1	79.39	0.68	23	1	62.48	0.43
34	1	96.33	0.51	23	1	73.75	0.43
34	1	73.75	0.51	23	1	76.57	0.51
34	1	65.29	0.60	23	1	65.29	0.51
34	1	76.57	0.77	23	1	68.11	0.34
34	1	76.57	0.60	23	1	70.93	0.77
34	1	96.33	0.43	23	1	85.04	0.43
34	1	85.04	0.60	23	1	68.11	0.51
34	1	68.11	0.51	23	1	96.33	0.43
34	1	65.29	0.51	23	1	87.86	0.43

34	1	85.04	0.51	23	1	70.93	0.43
34	1	90.68	0.51	23	1	59.66	0.51
34	1	93.50	0.68	23	1	76.57	0.43
34	1	70.93	0.43	23	1	76.57	0.43
34	1	62.48	0.60	23	1	90.68	0.43
34	1	85.04	0.43	23	1	68.11	0.51
34	1	70.93	0.34	23	1	59.66	0.43

APPANDIX C: SIMPLE REACTION TIME DATA

AGE	SEX	R. TIME	AGE	SEX	R. TIME	AGE	SEX	R. TIME
30	1	0.34	27	1	0.34	27	1	0.34
30	1	0.43	27	1	0.26	27	1	0.43
30	1	0.34	27	1	0.43	27	1	0.43
30	1	0.34	27	1	0.26	27	1	0.26
30	1	0.34	27	1	0.26	27	1	0.34
30	1	0.34	27	1	0.26	27	1	0.34
30	1	0.34	27	1	0.34	27	1	0.26
30	1	0.43	27	1	0.26	27	1	0.34
30	1	0.34	27	1	0.34	27	1	0.51
30	1	0.51	27	1	0.26	27	1	0.43
30	1	0.34	27	1	0.26	27	1	0.51
30	1	0.17	27	1	0.26	27	1	0.51
30	1	0.34	27	1	0.34	27	1	0.34
30	1	0.34	27	1	0.26	27	1	0.34
30	1	0.43	27	1	0.26	27	1	0.43
30	1	0.26	27	1	0.26	27	1	0.43
30	1	0.26	27	1	0.26	27	1	0.34
30	1	0.34	27	1	0.26	27	1	0.34
30	1	0.26	27	1	0.34	27	1	0.43
30	1	0.51	27	1	0.43	27	1	0.34
30	1	0.34	27	1	0.26	27	1	0.34
30	1	0.34	27	1	0.34	27	1	0.34
30	1	0.34	27	1	0.26	27	1	0.51
30	1	0.26	27	1	0.26	27	1	0.43
30	1	0.34	27	1	0.34	27	1	0.43
30	1	0.34	27	1	0.26	27	1	0.51
30	1	0.34	27	1	0.26	27	1	0.51
30	1	0.34	27	1	0.34	27	1	0.60
30	1	0.26	27	1	0.34	27	1	0.43
30	1	0.34	27	1	0.17	27	1	0.51
30	1	0.43	27	1	0.26	27	1	0.34
30	1	0.34	27	1	0.34	27	1	0.43
30	1	0.34	27	1	0.34	27	1	0.43
30	1	0.34	27	1	0.34	27	1	0.51
30	1	0.26	27	1	0.34	27	1	0.34
30	1	0.43	27	1	0.34	27	1	0.34
30	1	0.43	27	1	0.34	27	1	0.60
30	1	0.34	27	1	0.34	27	1	0.34
30	1	0.26	27	1	0.17	27	1	0.51
30	1	0.17	27	1	0.34	27	1	0.34
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.34

28	0	0.26	34	1	0.43	23	0	0.43
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.34	34	1	0.34	23	0	0.43
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.43
28	0	0.34	34	1	0.34	23	0	0.43
28	0	0.26	34	1	0.34	23	0	0.43
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.43
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.43	34	1	0.43	23	0	0.43
28	0	0.26	34	1	0.26	23	0	0.34
28	0	0.26	34	1	0.26	23	0	0.34
28	0	0.34	34	1	0.26	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.43
28	0	0.17	34	1	0.26	23	0	0.34
28	0	0.26	34	1	0.43	23	0	0.43
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.34	34	1	0.26	23	0	0.34
28	0	0.34	34	1	0.26	23	0	0.34
28	0	0.51	34	1	0.43	23	0	0.43
28	0	0.26	34	1	0.34	23	0	0.43
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.43	23	0	0.34
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.26	23	0	0.34
28	0	0.26	34	1	0.34	23	0	0.34
28	0	0.34	34	1	0.26	23	0	0.34
28	0	0.34	34	1	0.34	23	0	0.34
28	0	0.26	34	1	0.51	23	0	0.34
26	1	0.34	19	0	0.43	20	1	0.43
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.34	20	1	0.43
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.43	19	0	0.43	20	1	0.34
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.51	19	0	0.34	20	1	0.43
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.43	20	1	0.43
26	1	0.43	19	0	0.34	20	1	0.34
26	1	0.43	19	0	0.34	20	1	0.34
26	1	0.43	19	0	0.34	20	1	0.34

26	1	0.43	19	0	0.34	20	1	0.43
26	1	0.51	19	0	0.43	20	1	0.43
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.43	19	0	0.34	20	1	0.43
26	1	0.34	19	0	0.34	20	1	0.51
26	1	0.34	19	0	0.43	20	1	0.34
26	1	0.34	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.26	20	1	0.43
26	1	0.43	19	0	0.34	20	1	0.43
26	1	0.34	19	0	0.26	20	1	0.34
26	1	0.43	19	0	0.43	20	1	0.34
26	1	0.34	19	0	0.34	20	1	0.43
26	1	0.26	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.26	20	1	0.51
26	1	0.60	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.26	20	1	0.43
26	1	0.34	19	0	0.43	20	1	0.43
26	1	0.26	19	0	0.34	20	1	0.34
26	1	0.43	19	0	0.34	20	1	0.34
26	1	0.26	19	0	0.34	20	1	0.34
26	1	0.26	19	0	0.34	20	1	0.34
26	1	0.43	19	0	0.34	20	1	0.34
26	1	0.26	19	0	0.34	20	1	0.34
26	1	0.51	19	0	0.34	20	1	0.34
26	1	0.26	19	0	0.34	20	1	0.34
26	1	0.34	19	0	0.34	20	1	0.43
26	1	0.34	25	1	0.34	23	1	0.43
26	1	0.34	25	1	0.43	23	1	0.34
26	1	0.34	25	1	0.51	23	1	0.34
26	1	0.26	25	1	0.34	23	1	0.34
26	1	0.34	25	1	0.43	23	1	0.34
26	1	0.34	25	1	0.43	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.34	25	1	0.43	23	1	0.43
26	1	0.34	25	1	0.60	23	1	0.34
26	1	0.43	25	1	0.51	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.43	25	1	0.51	23	1	0.34
26	1	0.26	25	1	0.51	23	1	0.34
26	1	0.26	25	1	0.34	23	1	0.34
26	1	0.34	25	1	0.34	23	1	0.34
26	1	0.43	25	1	0.34	23	1	0.34
26	1	0.26	25	1	0.34	23	1	0.34
26	1	0.17	25	1	0.51	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.43
26	1	0.34	25	1	0.51	23	1	0.34

26	1	0.34	25	1	0.43	23	1	0.34
26	1	0.34	25	1	0.43	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.34	25	1	0.51	23	1	0.34
26	1	0.34	25	1	0.51	23	1	0.26
26	1	0.34	25	1	0.34	23	1	0.34
26	1	0.43	25	1	0.34	23	1	0.43
26	1	0.26	25	1	0.34	23	1	0.34
26	1	0.34	25	1	0.34	23	1	0.34
26	1	0.26	25	1	0.34	23	1	0.34
26	1	0.34	25	1	0.43	23	1	0.43
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.34	25	1	0.43	23	1	0.34
26	1	0.26	25	1	0.43	23	1	0.34
26	1	0.43	25	1	0.43	23	1	0.34
26	1	0.26	25	1	0.34	23	1	0.34
26	1	0.34	25	1	0.43	23	1	0.34

APPENDIX D: CHOICE DATA FROM EXPERIMENT 1 (WITH LINE)

AGE	SEX	DISTANCE	CHOICE	AGE	SEX	DISTANCE	CHOICE
30	1	99.15	1	19	0	48.41	0
30	1	45.60	0	19	0	73.75	1
30	1	62.48	1	19	0	51.22	0
30	1	56.85	0	19	0	73.75	1
30	1	31.62	0	19	0	96.33	1
30	1	62.48	1	19	0	93.50	1
30	1	42.80	0	19	0	48.41	0
30	1	90.68	1	19	0	34.40	0
30	1	42.80	0	19	0	82.21	1
30	1	40.00	0	19	0	76.57	1
30	1	59.66	1	19	0	96.33	1
30	1	82.21	1	19	0	93.50	1
30	1	40.00	0	19	0	51.22	0
30	1	73.75	1	19	0	37.20	0
30	1	90.68	1	19	0	34.40	0
30	1	79.39	1	19	0	56.85	1
30	1	42.80	0	19	0	62.48	1
30	1	42.80	0	19	0	56.85	0
30	1	59.66	1	19	0	42.80	0
30	1	37.20	0	19	0	96.33	1
30	1	70.93	1	19	0	37.20	0
30	1	99.15	1	19	0	79.39	1
30	1	90.68	1	19	0	96.33	1
30	1	31.62	0	19	0	40.00	0
30	1	90.68	1	19	0	31.62	0
30	1	31.62	0	19	0	87.86	1
30	1	51.22	0	19	0	59.66	1
30	1	31.62	0	19	0	79.39	1
30	1	45.60	0	19	0	37.20	0
30	1	79.39	1	19	0	42.80	0
30	1	51.22	0	19	0	59.66	1
30	1	48.41	0	19	0	48.41	0
30	1	93.50	1	19	0	76.75	1
30	1	40.00	0	19	0	42.80	0
30	1	48.41	0	19	0	68.11	1
30	1	96.33	1	19	0	85.04	1
30	1	82.21	1	19	0	65.29	1
30	1	42.80	0	19	0	34.40	0
30	1	37.20	0	19	0	59.66	1
30	1	45.60	0	19	0	87.86	1
30	1	82.21	1	19	0	37.20	0
30	1	65.29	1	19	0	37.20	0
30	1	70.93	1	19	0	65.29	1
30	1	87.86	1	19	0	96.33	1

30	1	90.68	1	19	0	65.29	1
30	1	99.15	1	19	0	68.11	1
30	1	59.66	1	19	0	87.86	1
30	1	48.41	0	19	0	40.00	0
30	1	56.85	0	19	0	93.50	1
30	1	65.29	1	19	0	34.40	0
30	1	93.50	1	19	0	87.86	1
30	1	85.04	1	19	0	96.33	1
30	1	87.86	1	19	0	82.21	1
30	1	85.04	1	19	0	34.40	0
30	1	54.03	0	19	0	93.50	1
30	1	65.29	1	19	0	68.11	1
30	1	59.66	1	19	0	48.41	0
30	1	48.41	0	19	0	70.93	1
30	1	70.93	1	19	0	31.62	0
30	1	87.86	1	19	0	59.66	1
30	1	48.41	1	19	0	99.15	1
30	1	73.75	1	19	0	90.68	1
30	1	82.21	1	19	0	82.21	1
30	1	90.68	1	19	0	99.15	1
30	1	56.85	0	19	0	93.50	1
30	1	34.40	0	19	0	85.04	1
30	1	65.29	1	19	0	70.93	1
30	1	65.29	1	19	0	96.33	1
30	1	48.41	0	19	0	85.04	1
30	1	54.03	0	19	0	68.11	1
30	1	87.86	1	19	0	93.50	1
30	1	45.60	0	19	0	45.60	0
30	1	87.86	1	19	0	68.11	1
30	1	56.85	0	19	0	68.11	1
30	1	73.75	1	19	0	37.20	0
30	1	42.80	0	19	0	73.75	1
30	1	93.50	1	19	0	45.60	0
30	1	65.29	1	19	0	54.03	1
30	1	45.60	0	19	0	37.20	0
30	1	68.11	1	19	0	65.29	1
30	1	37.20	0	19	0	76.57	1
30	1	51.22	0	19	0	70.93	1
30	1	54.03	1	19	0	37.20	0
30	1	37.20	0	19	0	59.66	1
30	1	79.39	1	19	0	90.68	1
30	1	62.48	0	19	0	99.15	1
30	1	85.04	1	19	0	99.15	1
30	1	45.60	0	19	0	93.50	1
30	1	70.93	1	19	0	85.04	1
30	1	79.39	1	19	0	54.03	0
30	1	73.75	1	19	0	93.50	1
30	1	31.62	0	19	0	62.48	1
30	1	56.85	0	19	0	79.39	1

30	1	65.29	1	19	0	59.66	1
30	1	82.21	1	19	0	54.03	1
30	1	34.40	0	19	0	51.22	0
30	1	51.22	0	19	0	54.03	1
30	1	65.29	1	19	0	51.22	0
30	1	56.85	1	19	0	65.29	0
30	1	73.75	1	19	0	56.85	0
28	0	93.50	1	25	1	34.40	0
28	0	99.15	1	25	1	37.20	0
28	0	45.60	0	25	1	42.80	0
28	0	56.85	1	25	1	31.62	0
28	0	31.62	0	25	1	82.21	1
28	0	42.80	0	25	1	40.00	0
28	0	90.68	1	25	1	85.04	1
28	0	42.80	0	25	1	56.85	0
28	0	40.00	0	25	1	59.66	1
28	0	40.00	0	25	1	48.41	0
28	0	59.66	1	25	1	70.93	1
28	0	82.21	1	25	1	54.03	0
28	0	70.93	1	25	1	56.85	1
28	0	40.00	0	25	1	99.15	1
28	0	73.75	1	25	1	45.60	0
28	0	90.68	1	25	1	87.86	1
28	0	73.39	1	25	1	99.15	1
28	0	42.80	0	25	1	62.48	1
28	0	93.50	1	25	1	73.75	1
28	0	42.80	0	25	1	45.60	0
28	0	59.66	1	25	1	76.57	1
28	0	37.20	0	25	1	51.22	0
28	0	70.93	1	25	1	34.40	0
28	0	99.15	1	25	1	73.75	1
28	0	90.68	1	25	1	56.85	1
28	0	31.62	0	25	1	68.11	1
28	0	51.22	0	25	1	34.40	0
28	0	31.62	0	25	1	42.80	0
28	0	45.60	0	25	1	68.11	1
28	0	79.39	1	25	1	56.85	1
28	0	51.22	0	25	1	73.75	1
28	0	48.41	1	25	1	90.68	1
28	0	93.50	1	25	1	59.66	1
28	0	40.00	0	25	1	76.57	1
28	0	48.41	0	25	1	59.66	0
28	0	96.33	1	25	1	54.03	0
28	0	82.21	1	25	1	65.29	1
28	0	42.80	0	25	1	42.80	0
28	0	37.20	0	25	1	85.04	1
28	0	45.60	0	25	1	85.04	1
28	0	82.21	1	25	1	45.60	0
28	0	65.29	1	25	1	79.33	1
28	0	70.93	1	25	1	56.85	1

28	0	87.86	1	25	1	99.15	1
28	0	90.68	1	25	1	82.21	1
28	0	59.66	1	25	1	79.39	1
28	0	48.41	0	25	1	37.20	0
28	0	56.85	0	25	1	42.80	0
28	0	65.29	1	25	1	68.11	1
28	0	93.50	1	25	1	73.75	1
28	0	85.04	1	25	1	87.86	1
28	0	87.86	1	25	1	40.00	0
28	0	85.04	1	25	1	82.21	1
28	0	65.29	0	25	1	45.60	0
28	0	70.93	1	25	1	34.40	0
28	0	48.41	0	25	1	65.29	1
28	0	73.75	1	25	1	65.29	1
28	0	73.75	1	25	1	31.62	0
28	0	82.21	1	25	1	62.48	1
28	0	90.68	1	25	1	70.93	1
28	0	56.85	0	25	1	70.93	1
28	0	34.40	0	25	1	90.68	1
28	0	65.29	1	25	1	99.15	1
28	0	65.29	1	25	1	99.15	1
28	0	65.29	1	25	1	93.50	1
28	0	34.40	0	25	1	73.75	1
28	0	42.80	0	25	1	76.75	1
28	0	82.21	1	25	1	70.93	1
28	0	51.22	0	25	1	45.60	0
28	0	65.29	1	25	1	68.11	1
28	0	87.86	1	25	1	59.66	1
28	0	51.22	0	25	1	65.29	0
28	0	45.60	0	25	1	56.85	1
28	0	73.75	1	25	1	62.48	1
28	0	82.21	1	25	1	59.66	0
28	0	62.48	0	25	1	87.86	1
28	0	56.85	0	25	1	54.03	0
28	0	70.93	1	25	1	31.62	0
28	0	99.15	1	25	1	56.85	1
28	0	68.11	1	25	1	90.68	1
28	0	76.57	1	25	1	93.50	1
28	0	99.15	1	25	1	73.75	1
28	0	56.85	0	25	1	51.22	0
28	0	85.04	1	25	1	82.21	1
28	0	31.62	0	25	1	65.29	0
28	0	93.50	1	25	1	85.04	1
28	0	99.15	1	25	1	65.29	1
28	0	45.60	0	25	1	56.85	0
28	0	62.48	0	25	1	42.80	0
28	0	56.87	1	25	1	34.40	0
28	0	90.68	1	25	1	56.85	0
28	0	42.80	0	25	1	76.57	1
28	0	40.00	0	25	1	54.03	0

28	0	59.66	1	25	1	87.86	1
28	0	82.21	1	25	1	51.22	1
28	0	70.93	1	25	1	59.66	1
28	0	73.75	1	25	1	65.29	1
28	0	90.68	1	25	1	76.57	1
28	0	79.39	1	25	1	51.22	1
28	0	42.80	0	25	1	56.85	1
26	1	42.80	0	27	1	59.66	1
26	1	90.68	1	27	1	82.21	1
26	1	42.80	0	27	1	70.93	1
26	1	40.00	0	27	1	40.00	0
26	1	59.66	1	27	1	73.75	1
26	1	70.93	1	27	1	90.68	1
26	1	40.00	0	27	1	42.80	0
26	1	73.75	1	27	1	93.50	1
26	1	90.68	1	27	1	59.66	1
26	1	79.39	1	27	1	37.20	0
26	1	42.80	0	27	1	70.93	1
26	1	93.50	1	27	1	90.68	1
26	1	42.80	0	27	1	31.62	0
26	1	59.66	1	27	1	31.62	0
26	1	37.20	0	27	1	51.22	0
26	1	90.68	1	27	1	31.62	0
26	1	31.62	0	27	1	45.60	0
26	1	90.68	1	27	1	79.39	1
26	1	31.62	0	27	1	51.22	0
26	1	51.22	0	27	1	48.41	0
26	1	31.62	0	27	1	48.41	1
26	1	45.60	0	27	1	96.33	1
26	1	79.39	1	27	1	42.80	0
26	1	51.22	0	27	1	37.20	0
26	1	48.41	0	27	1	45.60	0
26	1	40.00	0	27	1	82.21	1
26	1	48.41	0	27	1	65.29	1
26	1	96.33	1	27	1	70.93	1
26	1	42.80	0	27	1	87.86	1
26	1	37.20	0	27	1	90.68	1
26	1	45.60	1	27	1	59.66	0
26	1	82.21	1	27	1	56.85	0
26	1	65.29	1	27	1	65.29	1
26	1	70.93	1	27	1	93.50	1
26	1	87.86	1	27	1	85.04	1
26	1	99.15	1	27	1	87.86	1
26	1	59.66	0	27	1	85.04	1
26	1	56.85	0	27	1	54.03	0
26	1	65.29	1	27	1	65.29	0
26	1	93.50	1	27	1	59.66	1
26	1	85.04	1	27	1	48.41	0
26	1	87.86	1	27	1	70.93	1
26	1	85.04	1	27	1	87.86	1

26	1	54.03	0	27	1	48.41	0
26	1	65.29	1	27	1	73.75	1
26	1	59.66	1	27	1	73.75	1
26	1	48.41	0	27	1	73.75	1
26	1	70.93	1	27	1	82.21	1
26	1	87.86	1	27	1	56.85	0
26	1	48.41	0	27	1	34.40	0
26	1	73.75	1	27	1	65.29	1
26	1	73.75	1	27	[illegible]	65.29	1
26	1	73.75	1	27	1	48.41	0
26	1	82.21	1	27	1	54.03	0
26	1	90.68	1	27	1	87.86	1
26	1	56.85	0	27	1	45.60	0
26	1	34.40	0	27	1	87.86	1
26	1	42.80	0	27	1	56.85	0
26	1	34.40	0	27	1	73.75	1
26	1	62.48	1	27	1	93.50	1
26	1	56.85	0	27	1	65.29	0
26	1	96.33	1	27	1	45.60	0
26	1	48.41	0	27	1	68.11	1
26	1	59.66	0	27	1	51.22	0
26	1	76.57	1	27	1	37.20	0
26	1	42.80	0	27	1	54.03	0
26	1	85.04	1	27	1	79.39	1
26	1	68.11	1	27	1	62.48	1
26	1	65.29	1	27	1	37.20	0
26	1	85.04	1	27	1	85.04	1
26	1	42.80	0	27	1	45.60	0
26	1	40.00	0	27	1	85.04	1
26	1	93.50	1	27	1	70.93	1
26	1	45.60	0	27	1	79.39	1
26	1	34.40	0	27	1	73.75	1
26	1	70.38	1	27	1	31.62	0
26	1	62.48	1	27	1	56.85	1
26	1	85.04	1	27	1	82.21	1
26	1	70.93	1	27	1	34.40	0
26	1	82.21	1	27	1	42.80	0
26	1	90.68	1	27	1	82.21	1
26	1	45.60	0	27	1	51.22	0
26	1	82.21	1	27	1	65.29	1
26	1	37.20	0	27	1	87.86	1
26	1	87.86	1	27	1	51.22	0
26	1	68.11	1	27	1	73.75	1
26	1	73.75	1	27	1	82.21	1
26	1	51.22	0	27	1	40.00	0
26	1	79.39	1	27	1	93.50	1
26	1	79.39	1	27	1	85.04	1
26	1	96.33	1	27	1	62.48	1
26	1	87.86	1	27	1	56.85	1
26	1	85.04	1	27	1	70.93	1

26	1	62.48	0	27	1	56.85	1
26	1	87.86	1	27	1	51.22	1
26	1	73.75	1	27	1	54.03	0
26	1	51.22	0	27	1	54.03	1
26	1	70.93	1	27	1	54.03	0
26	1	73.75	1	27	1	59.66	1
26	1	54.03	0	27	1	56.85	1
26	1	93.50	1	23	0	68.11	1
26	1	45.60	0	23	0	59.66	1
26	1	62.48	1	23	0	56.85	0
26	1	56.85	1	23	0	56.85	1
26	1	31.62	0	23	0	31.62	0
26	1	62.48	0	23	0	51.22	0
26	1	42.80	0	23	0	99.15	1
26	1	90.68	1	23	0	73.75	1
26	1	40.00	0	23	0	48.41	0
26	1	59.66	0	23	0	70.93	1
26	1	73.75	1	23	0	82.21	1
26	1	90.68	1	23	0	76.57	1
26	1	79.39	1	23	0	82.21	1
26	1	42.80	0	23	0	85.04	1
26	1	93.50	1	23	0	42.80	0
26	1	42.80	0	23	0	79.39	1
26	1	59.66	0	23	0	48.41	0
26	1	40.00	0	23	0	79.39	1
26	1	48.41	0	23	0	40.00	0
26	1	96.33	1	23	0	79.39	1
26	1	73.75	1	23	0	79.39	1
26	1	42.80	0	23	0	45.60	0
26	1	37.20	0	23	0	56.85	0
26	1	45.60	0	23	0	76.57	1
26	1	82.21	1	23	0	65.29	1
26	1	65.29	1	23	0	51.22	0
26	1	70.93	1	23	0	34.40	0
26	1	87.86	1	23	0	56.85	1
26	1	90.68	1	23	0	54.03	0
26	1	70.93	1	23	0	93.50	1
26	1	59.66	0	23	0	51.22	0
26	1	48.41	0	23	0	70.93	1
26	1	56.85	0	23	0	96.33	1
26	1	65.29	0	23	0	51.22	1
26	1	85.04	1	23	0	40.00	0
26	1	87.86	1	23	0	45.60	0
26	1	85.04	1	23	0	42.80	0
26	1	54.03	0	23	0	59.66	1
26	1	65.29	1	23	0	68.11	1
26	1	59.66	0	23	0	90.68	1
26	1	48.41	0	23	0	51.22	0
26	1	70.93	1	23	0	93.50	1
26	1	87.86	1	23	0	42.80	0

26	1	48.41	0	23	0	79.39	1
26	1	73.75	1	23	0	79.39	1
26	1	82.21	1	23	0	87.86	1
26	1	90.68	1	23	0	31.62	0
26	1	56.85	1	23	0	76.57	1
26	1	65.29	1	23	0	76.57	1
26	1	65.29	1	23	0	99.15	1
26	1	48.41	0	23	0	34.40	0
26	1	54.03	0	23	0	42.80	0
26	1	87.86	1	23	0	68.11	1
26	1	45.60	0	23	0	90.68	1
26	1	87.86	1	23	0	45.60	0
26	1	56.85	0	23	0	56.85	0
26	1	73.75	1	23	0	59.66	1
26	1	42.80	0	23	0	42.80	0
26	1	93.50	1	23	0	93.50	1
26	1	65.29	1	23	0	48.41	0
26	1	45.60	0	23	0	90.68	1
26	1	68.11	1	23	0	85.04	1
26	1	37.20	0	23	0	56.85	0
26	1	51.22	0	23	0	51.22	0
26	1	54.03	0	23	0	82.21	1
26	1	62.48	1	23	0	79.39	1
26	1	37.20	0	23	0	70.93	1
26	1	85.04	1	23	0	56.85	1
26	1	45.60	0	23	0	54.03	0
26	1	85.04	1	23	0	96.33	1
26	1	70.93	1	23	0	68.11	1
26	1	79.39	1	23	0	90.68	1
26	1	73.75	1	23	0	34.40	0
26	1	31.62	0	23	0	76.57	1
26	1	56.85	1	23	0	45.60	0
26	1	65.29	1	23	0	51.22	0
26	1	82.21	1	23	0	59.66	1
26	1	34.40	0	23	0	31.62	0
26	1	42.80	0	23	0	48.41	0
26	1	82.21	1	23	0	76.57	1
26	1	51.22	0	23	0	34.40	0
26	1	87.86	1	23	0	56.85	1
26	1	51.22	0	23	0	31.62	0
26	1	73.75	1	23	0	82.21	1
26	1	82.21	1	23	0	65.29	1
26	1	40.00	0	23	0	56.85	1
26	1	93.50	1	23	0	96.33	1
26	1	37.20	0	23	0	62.48	1
26	1	85.04	1	23	0	34.40	0
26	1	37.20	0	23	0	42.80	0
26	1	62.48	1	23	0	96.33	1
26	1	56.85	1	23	0	73.75	1
26	1	70.93	1	23	0	51.22	0

26	1	68.11	1	23	0	62.48	1
26	1	76.57	1	23	0	62.48	1
26	1	99.15	1	23	0	54.03	1
26	1	56.85	1	23	0	56.85	1
26	1	85.04	1	23	0	51.22	0
26	1	62.48	0	23	0	56.85	1
26	1	87.86	1	23	0	87.86	1
27	1	59.66	1	20	1	90.68	1
27	1	82.82	1	20	1	93.50	1
27	1	70.93	1	20	1	48.41	0
27	1	40.00	0	20	1	40.00	0
27	1	73.75	1	20	1	87.86	1
27	1	90.68	1	20	1	68.11	1
27	1	79.39	1	20	1	48.41	0
27	1	42.80	0	20	1	85.04	1
27	1	93.50	1	20	1	68.11	1
27	1	42.80	0	20	1	87.86	1
27	1	59.66	1	20	1	90.68	1
27	1	37.20	0	20	1	73.75	1
27	1	70.93	1	20	1	37.20	0
27	1	99.15	1	20	1	82.21	1
27	1	90.68	1	20	1	45.60	0
27	1	31.62	0	20	1	48.41	0
27	1	90.68	1	20	1	70.93	1
27	1	31.62	0	20	1	85.04	1
27	1	51.22	0	20	1	59.66	1
27	1	31.62	0	20	1	40.00	0
27	1	45.60	0	20	1	59.66	1
27	1	97.39	1	20	1	85.04	1
27	1	51.22	0	20	1	96.33	1
27	1	48.41	0	20	1	87.86	1
27	1	40.00	0	20	1	42.80	0
27	1	48.41	0	20	1	70.93	1
27	1	96.33	1	20	1	68.11	1
27	1	42.80	0	20	1	70.93	1
27	1	37.20	0	20	1	90.68	1
27	1	45.60	0	20	1	59.66	0
27	1	82.21	1	20	1	82.21	1
27	1	65.29	0	20	1	73.75	1
27	1	70.93	1	20	1	96.33	1
27	1	87.86	1	20	1	93.50	1
27	1	90.68	1	20	1	40.00	0
27	1	99.15	1	20	1	93.50	1
27	1	59.66	1	20	1	73.75	1
27	1	48.41	0	20	1	79.39	1
27	1	56.85	0	20	1	70.93	1
27	1	65.29	1	20	1	70.93	1
27	1	93.50	1	20	1	76.57	1
27	1	85.04	1	20	1	68.11	1
27	1	87.86	1	20	1	87.86	1

27	1	85.04	1	20	1	96.33	1
27	1	54.03	0	20	1	79.39	1
27	1	65.29	1	20	1	40.00	0
27	1	59.66	0	20	1	82.21	1
27	1	48.41	0	20	1	59.66	1
27	1	70.93	1	20	1	65.29	1
27	1	87.86	1	20	1	37.20	0
27	1	48.41	0	20	1	70.93	1
27	1	73.75	1	20	1	45.60	0
27	1	73.75	1	20	1	73.75	1
27	1	73.75	1	20	1	90.68	1
27	1	82.21	1	20	1	82.21	1
27	1	90.68	1	20	1	79.39	1
27	1	34.40	0	20	1	82.21	1
27	1	65.29	1	20	1	62.48	1
27	1	65.29	1	20	1	42.80	0
27	1	48.41	0	20	1	85.04	1
27	1	54.03	0	20	1	62.48	1
27	1	87.86	1	20	1	31.62	0
27	1	45.60	0	20	1	87.86	1
27	1	87.86	1	20	1	40.00	0
27	1	56.85	0	20	1	70.93	1
27	1	73.75	1	20	1	96.33	1
27	1	42.80	0	20	1	48.41	0
27	1	93.15	1	20	1	37.20	0
27	1	65.29	1	20	1	93.50	1
27	1	45.60	0	20	1	68.11	1
27	1	68.11	1	20	1	65.29	1
27	1	37.20	0	20	1	90.68	1
27	1	51.22	0	20	1	87.86	1
27	1	37.20	0	20	1	79.39	1
27	1	54.03	0	20	1	45.60	0
27	1	37.20	0	20	1	79.39	1
27	1	79.39	1	20	1	99.15	1
27	1	62.48	0	20	1	65.29	1
27	1	37.20	0	20	1	65.29	1
27	1	85.04	1	20	1	90.68	1
27	1	45.60	0	20	1	87.86	1
27	1	85.04	1	20	1	56.85	1
27	1	70.93	1	20	1	37.20	0
27	1	79.39	1	20	1	68.11	1
27	1	73.75	1	20	1	40.00	0
27	1	31.62	0	20	1	82.21	1
27	1	56.85	0	20	1	56.85	0
27	1	65.29	0	20	1	65.29	1
27	1	82.21	1	20	1	48.41	0
27	1	34.40	0	20	1	68.11	1
27	1	42.80	0	20	1	79.39	1
27	1	82.21	1	20	1	70.93	1
27	1	51.22	0	20	1	59.66	0

27	1	65.29	0	20	1	51.22	1
27	1	87.86	1	20	1	73.75	1
27	1	51.22	0	20	1	59.66	0
27	1	45.60	0	20	1	62.48	1
27	1	73.75	1	20	1	51.22	1
27	1	82.21	1	20	1	68.11	1
27	1	40.00	0	20	1	59.66	0
34	1	99.15	1	23	1	87.86	1
34	1	45.60	0	23	1	96.33	1
34	1	62.48	1	23	1	45.60	0
34	1	56.85	0	23	1	65.29	1
34	1	31.62	0	23	1	34.40	0
34	1	42.80	0	23	1	68.11	1
34	1	42.80	0	23	1	85.04	1
34	1	40.00	0	23	1	42.80	0
34	1	40.00	0	23	1	73.75	1
34	1	59.66	1	23	1	51.22	0
34	1	70.93	1	23	1	62.48	1
34	1	40.00	0	23	1	65.29	1
34	1	90.68	1	23	1	42.80	0
34	1	42.80	0	23	1	48.41	0
34	1	93.50	1	23	1	48.41	0
34	1	42.80	0	23	1	59.66	1
34	1	59.66	1	23	1	40.00	0
34	1	37.20	0	23	1	34.40	0
34	1	70.93	1	23	1	76.57	1
34	1	31.62	0	23	1	62.48	1
34	1	51.22	1	23	1	68.11	1
34	1	31.66	0	23	1	68.11	1
34	1	45.60	0	23	1	65.29	1
34	1	79.39	1	23	1	79.39	1
34	1	51.22	0	23	1	37.20	0
34	1	48.41	0	23	1	45.60	0
34	1	96.33	1	23	1	65.29	1
34	1	82.21	1	23	1	79.39	1
34	1	42.80	0	23	1	79.39	1
34	1	37.20	0	23	1	76.57	1
34	1	45.60	0	23	1	62.48	0
34	1	82.21	1	23	1	48.41	1
34	1	65.29	1	23	1	68.11	1
34	1	87.86	1	23	1	99.15	1
34	1	90.68	1	23	1	59.66	1
34	1	99.15	1	23	1	65.29	1
34	1	59.66	0	23	1	65.29	1
34	1	48.41	0	23	1	82.21	1
34	1	56.85	0	23	1	59.66	1
34	1	65.29	1	23	1	70.93	1
34	1	93.50	1	23	1	70.93	1
34	1	85.04	1	23	1	45.60	0
34	1	87.86	1	23	1	54.03	1

34	1	85.04	1	23	1	79.39	1
34	1	54.03	0	23	1	56.85	1
34	1	65.29	1	23	1	93.50	1
34	1	59.66	0	23	1	42.60	0
34	1	48.41	0	23	1	48.41	0
34	1	70.93	1	23	1	85.04	1
34	1	87.86	1	23	1	76.57	1
34	1	48.41	0	23	1	68.11	1
34	1	90.68	1	23	1	62.48	1
34	1	96.93	1	23	1	51.22	1
34	1	40.00	0	23	1	45.60	0
34	1	54.03	0	23	1	73.75	1
34	1	73.75	1	23	1	45.60	0
34	1	31.62	0	23	1	48.41	0
34	1	54.03	0	23	1	76.57	1
34	1	48.41	0	23	1	65.29	1
34	1	37.20	0	23	1	51.22	0
34	1	45.60	0	23	1	68.11	1
34	1	70.93	1	23	1	70.93	1
34	1	73.75	1	23	1	85.04	1
34	1	82.21	1	23	1	68.11	1
34	1	87.86	1	23	1	96.33	1
34	1	68.11	1	23	1	56.85	1
34	1	54.03	0	23	1	87.86	1
34	1	42.80	0	23	1	70.93	1
34	1	34.40	0	23	1	59.66	1
34	1	59.66	1	23	1	37.22	0
34	1	62.48	0	23	1	42.80	0
34	1	79.39	1	23	1	51.22	0
34	1	56.85	0	23	1	76.57	1
34	1	96.33	1	23	1	76.57	1
34	1	73.75	1	23	1	40.00	0
34	1	48.41	0	23	1	37.20	0
34	1	65.29	1	23	1	48.41	0
34	1	59.66	0	23	1	45.60	0
34	1	40.00	0	23	1	90.68	1
34	1	76.57	1	23	1	68.11	1
34	1	42.80	0	23	1	59.66	1
34	1	76.57	1	23	1	82.21	1
34	1	96.33	1	23	1	62.48	1
34	1	85.04	1	23	1	73.75	1
34	1	68.11	1	23	1	42.80	0
34	1	65.29	1	23	1	31.62	0
34	1	85.04	1	23	1	87.86	1
34	1	42.80	0	23	1	37.20	0
34	1	40.00	0	23	1	45.60	0
34	1	90.68	1	23	1	56.85	1
34	1	37.20	0	23	1	65.29	1
34	1	93.50	1	23	1	56.85	0
34	1	34.40	0	23	1	87.86	1

34	1	34.40	0	23	1	54.03	0
34	1	70.93	1	23	1	56.85	0
34	1	62.48	1	23	1	56.85	1
34	1	85.04	1	23	1	62.48	1
34	1	70.93	1	23	1	54.03	0
34	1	82.21	1	23	1	54.03	1
34	1	90.68	1	23	1	59.66	1

APPENDIX E: CHOICE DATA FROM EXPERIMENT 2 (WITHOUT LINE)

AGE	SEX	DISTANCE	CHOICE	AGE	SEX	DISTANCE	CHOICE
30	1	31.62	0	19	0	96.33	1
30	1	93.50	1	19	0	54.03	0
30	1	99.15	1	19	0	82.21	1
30	1	45.60	0	19	0	34.40	0
30	1	62.48	1	19	0	48.41	0
30	1	56.85	1	19	0	59.66	0
30	1	31.62	0	19	0	70.93	1
30	1	62.48	1	19	0	99.15	1
30	1	42.80	0	19	0	82.21	1
30	1	42.80	0	19	0	42.80	0
30	1	90.68	1	19	0	51.22	1
30	1	42.80	0	19	0	48.41	1
30	1	40.00	0	19	0	62.48	1
30	1	82.21	1	19	0	82.21	1
30	1	70.93	1	19	0	79.39	1
30	1	40.00	0	19	0	82.21	1
30	1	73.75	1	19	0	68.11	1
30	1	90.68	1	19	0	42.80	0
30	1	79.39	1	19	0	31.62	0
30	1	42.80	0	19	0	87.86	1
30	1	93.50	1	19	0	79.39	1
30	1	42.80	0	19	0	45.60	0
30	1	59.66	1	19	0	31.62	0
30	1	37.20	0	19	0	40.00	0
30	1	70.93	1	19	0	31.62	0
30	1	99.15	1	19	0	45.60	0
30	1	90.68	1	19	0	59.66	1
30	1	31.62	0	19	0	51.22	0
30	1	90.68	1	19	0	79.39	1
30	1	31.62	0	19	0	68.11	1
30	1	51.22	0	19	0	45.60	0
30	1	31.62	0	19	0	42.80	0
30	1	93.50	1	19	0	96.33	1
30	1	99.15	1	19	0	82.21	1
30	1	45.60	0	19	0	51.22	1
30	1	62.48	1	19	0	51.22	1
30	1	56.85	1	19	0	99.15	1
30	1	31.62	0	19	0	54.05	1
30	1	62.48	1	19	0	51.22	0
30	1	42.80	0	19	0	65.29	1
30	1	31.62	0	19	0	99.15	1
30	1	93.50	1	19	0	87.86	1
30	1	99.15	1	19	0	85.04	1
30	1	45.60	0	19	0	37.20	0

30	1	62.48	1	19	0	68.11	1
30	1	56.85	0	19	0	76.57	1
30	1	31.62	0	19	0	48.41	0
30	1	62.48	1	19	0	56.85	1
30	1	42.80	0	19	0	99.15	1
30	1	42.80	0	19	0	51.22	0
30	1	90.68	1	19	0	68.11	1
30	1	42.80	0	19	0	68.11	1
30	1	31.62	0	19	0	31.62	0
30	1	93.50	1	19	0	37.20	0
30	1	99.15	1	19	0	51.22	0
30	1	45.60	0	19	0	70.93	1
30	1	62.48	0	19	0	37.20	0
30	1	56.85	0	19	0	45.60	0
30	1	31.62	0	19	0	93.50	1
30	1	62.48	0	19	0	82.21	1
30	1	42.80	0	19	0	56.85	0
30	1	42.80	0	19	0	99.15	1
30	1	90.68	1	19	0	48.41	0
30	1	42.80	0	19	0	79.39	1
30	1	40.00	0	19	0	34.40	0
30	1	59.66	1	19	0	34.40	0
30	1	82.21	1	19	0	90.68	1
30	1	70.93	1	19	0	56.85	0
30	1	40.00	0	19	0	51.22	0
30	1	73.75	1	19	0	99.15	1
30	1	42.[illegible]	0	19	0	65.29	1
30	1	93.50	1	19	0	40.00	0
30	1	42.80	0	19	0	59.66	0
30	1	59.66	0	19	0	90.68	1
30	1	37.20	0	19	0	79.39	1
30	1	70.93	0	19	0	99.15	1
30	1	99.15	1	19	0	45.60	0
30	1	90.68	1	19	0	73.75	1
30	1	31.62	0	19	0	73.75	1
30	1	90.68	1	19	0	65.29	1
30	1	31.62	0	19	0	82.21	1
30	1	51.22	0	19	0	51.22	0
30	1	45.60	0	19	0	93.50	1
30	1	79.39	1	19	0	59.66	1
30	1	51.22	1	19	0	68.11	1
30	1	48.41	0	19	0	70.93	1
30	1	93.50	1	19	0	65.29	1
30	1	48.41	0	19	0	68.11	1
30	1	96.33	1	19	0	56.85	1
30	1	82.21	1	19	0	90.68	1
30	1	42.80	0	19	0	62.48	0
30	1	45.60	0	19	0	51.22	1
30	1	82.21	1	19	0	56.85	0

30	1	65.29	1	19	0	62.48	0
30	1	70.93	0	19	0	54.03	0
30	1	87.86	1	19	0	54.03	1
30	1	90.68	1	19	0	51.22	0
30	1	99.15	1	19	0	59.66	1
30	1	59.66	1	19	0	62.48	1
30	1	56.85	0	19	0	54.03	0
28	0	31.62	0	25	1	48.41	0
28	0	56.85	1	25	1	93.50	1
28	0	65.29	1	25	1	96.33	1
28	0	82.21	1	25	1	79.39	1
28	0	34.40	0	25	1	42.80	0
28	0	42.80	0	25	1	54.03	1
28	0	82.21	1	25	1	62.48	1
28	0	51.22	0	25	1	90.68	1
28	0	65.29	1	25	1	73.75	1
28	0	87.86	1	25	1	45.60	1
28	0	51.22	0	25	1	73.75	1
28	0	73.75	1	25	1	48.41	1
28	0	82.21	1	25	1	85.04	1
28	0	40.00	0	25	1	87.86	1
28	0	93.50	1	25	1	93.50	1
28	0	37.20	0	25	1	48.41	0
28	0	85.04	1	25	1	56.85	0
28	0	37.20	0	25	1	76.57	1
28	0	62.48	1	25	1	79.39	1
28	0	56.85	1	25	1	90.68	1
28	0	70.93	0	25	1	62.48	1
28	0	99.15	1	25	1	31.62	0
28	0	76.57	1	25	1	59.66	1
28	0	99.15	1	25	1	90.68	1
28	0	56.85	0	25	1	59.66	1
28	0	85.04	1	25	1	79.39	1
28	0	62.48	0	25	1	34.40	0
28	0	87.86	1	25	1	56.85	1
28	0	68.11	1	25	1	42.80	0
28	0	85.04	1	25	1	48.41	0
28	0	51.22	0	25	1	82.21	1
28	0	90.68	1	25	1	37.20	0
28	0	96.33	1	25	1	31.62	0
28	0	40.00	0	25	1	79.39	1
28	0	73.75	1	25	1	70.93	1
28	0	82.21	1	25	1	76.57	1
28	0	87.86	1	25	1	56.85	0
28	0	68.11	1	25	1	68.11	1
28	0	54.03	0	25	1	79.39	1
28	0	42.80	0	25	1	37.20	0
28	0	34.40	0	25	1	34.40	0
28	0	62.48	1	25	1	76.57	1
28	0	79.39	1	25	1	70.93	1

28	0	56.85	0	25	1	68.11	1
28	0	96.33	1	25	1	51.22	1
28	0	73.75	1	25	1	82.21	1
28	0	48.41	0	25	1	51.22	1
28	0	65.29	1	25	1	48.41	0
28	0	40.00	0	25	1	76.57	1
28	0	76.57	1	25	1	45.60	0
28	0	42.80	0	25	1	54.03	1
28	0	76.57	1	25	1	45.60	0
28	0	96.33	1	25	1	99.15	1
28	0	85.04	1	25	1	87.86	1
28	0	68.11	1	25	1	79.39	1
28	0	65.29	1	25	1	76.57	1
28	0	85.04	1	25	1	93.50	1
28	0	42.80	0	25	1	93.50	1
28	0	40.00	0	25	1	96.33	1
28	0	90.68	1	25	1	99.15	1
28	0	37.20	0	25	1	96.33	1
28	0	93.51	1	25	1	70.93	1
28	0	34.40	0	25	1	42.80	0
28	0	45.60	0	25	1	73.75	1
28	0	70.93	1	25	1	73.75	1
28	0	62.48	1	25	1	40.00	0
28	0	85.04	1	25	1	82.21	1
28	0	70.93	1	25	1	93.50	1
28	0	82.21	1	25	1	62.48	1
28	0	90.68	1	25	1	45.60	0
28	0	45.60	0	25	1	51.22	1
28	0	68.11	1	25	1	93.50	1
28	0	82.21	1	25	1	93.50	1
28	0	65.29	1	25	1	62.48	1
28	0	68.11	1	25	1	99.15	1
28	0	73.75	1	25	1	34.40	0
28	0	51.22	0	25	1	56.85	1
28	0	79.39	1	25	1	40.00	0
28	0	79.39	1	25	1	59.66	1
28	0	45.60	0	25	1	79.39	1
28	0	48.41	0	25	1	68.11	1
28	0	96.33	1	25	1	59.66	0
28	0	87.86	1	25	1	70.93	1
28	0	85.04	1	25	1	82.21	1
28	0	62.48	0	25	1	51.22	0
28	0	87.86	1	25	1	70.93	1
28	0	73.75	1	25	1	76.57	1
28	0	51.22	0	25	1	62.48	1
28	0	70.93	1	25	1	34.40	0
28	0	37.20	0	25	1	93.50	1
28	0	73.75	1	25	1	59.66	1
28	0	45.50	0	25	1	70.93	1
28	0	48.41	0	25	1	96.33	1

28	0	59.66	0	25	1	54.03	1
28	0	59.66	1	25	1	56.85	0
28	0	34.40	0	25	1	82.21	1
28	0	85.04	1	25	1	54.03	0
28	0	48.41	0	25	1	56.85	0
28	0	68.11	1	25	1	56.85	1
28	0	73.75	1	25	1	51.22	0
26	1	99.15	1	27	1	31.62	0
26	1	45.65	0	27	1	93.50	1
26	1	62.48	0	27	1	99.15	1
26	1	56.85	0	27	1	45.60	0
26	1	31.62	0	27	1	62.48	1
26	1	62.48	0	27	1	56.85	0
26	1	42.80	0	27	1	31.62	0
26	1	90.68	1	27	1	62.48	1
26	1	42.80	0	27	1	42.80	1
26	1	40.00	0	27	1	42.80	0
26	1	59.66	0	27	1	90.68	1
26	1	82.21	1	27	1	42.80	1
26	1	70.93	0	27	1	40.00	0
26	1	40.00	0	27	1	59.66	1
26	1	73.75	1	27	1	82.21	1
26	1	90.68	1	27	1	70.93	1
26	1	79.39	1	27	1	40.00	0
26	1	93.50	1	27	1	73.75	1
26	1	42.80	0	27	1	90.68	1
26	1	59.66	0	27	1	79.39	1
26	1	37.20	0	27	1	42.80	0
26	1	70.93	1	27	1	93.50	1
26	1	99.15	1	27	1	42.80	0
26	1	90.68	1	27	1	59.66	1
26	1	31.62	0	27	1	37.20	0
26	1	90.68	1	27	1	70.93	1
26	1	31.62	0	27	1	99.15	1
26	1	51.22	0	27	1	90.68	1
26	1	31.62	0	27	1	31.62	0
26	1	45.60	0	27	1	90.68	1
26	1	79.39	1	27	1	31.62	0
26	1	51.22	0	27	1	51.22	0
26	1	48.41	0	27	1	45.60	0
26	1	93.50	1	27	1	79.39	1
26	1	40.00	0	27	1	51.22	0
26	1	48.41	0	27	1	48.41	1
26	1	96.33	1	27	1	93.50	1
26	1	82.21	1	27	1	48.41	0
26	1	42.80	0	27	1	96.33	1
26	1	37.20	0	27	1	82.21	1
26	1	45.60	0	27	1	37.20	0
26	1	82.21	1	27	1	45.60	0
26	1	65.29	0	27	1	82.21	1

26	1	70.93	1	27	1	65.29	1
26	1	87.86	1	27	1	70.93	1
26	1	90.68	1	27	1	87.86	1
26	1	99.15	1	27	1	90.68	1
26	1	59.66	1	27	1	99.15	1
26	1	48.41	0	27	1	59.66	1
26	1	56.85	0	27	1	48.41	0
26	1	65.29	0	27	1	56.85	1
26	1	93.95	1	27	1	65.29	1
26	1	87.86	1	27	1	93.50	1
26	1	85.04	1	27	1	85.04	1
26	1	54.03	0	27	1	85.04	1
26	1	65.29	0	27	1	54.03	0
26	1	70.93	1	27	1	65.29	1
26	1	87.86	1	27	1	59.66	0
26	1	48.41	0	27	1	48.41	0
26	1	73.75	1	27	1	70.93	0
26	1	73.75	1	27	1	87.86	1
26	1	82.21	1	27	1	48.41	1
26	1	90.68	1	27	1	73.75	1
26	1	56.85	0	27	1	73.75	1
26	1	34.40	0	27	1	73.75	1
26	1	65.29	0	27	1	82.21	1
26	1	65.29	0	27	1	90.68	1
26	1	48.41	0	27	1	56.85	0
26	1	54.03	0	27	1	65.29	1
26	1	87.86	1	27	1	65.29	1
26	1	45.60	0	27	1	48.41	0
26	1	87.86	1	27	1	54.03	0
26	1	56.85	0	27	1	87.86	1
26	1	73.75	1	27	1	45.60	0
26	1	42.80	0	27	1	87.86	1
26	1	93.50	1	27	1	56.85	0
26	1	65.29	1	27	1	73.75	1
26	1	45.60	0	27	1	42.80	0
26	1	68.11	1	27	1	93.50	1
26	1	51.22	0	27	1	65.29	1
26	1	37.20	0	27	1	45.60	0
26	1	54.03	0	27	1	68.11	1
26	1	37.20	1	27	1	37.20	0
26	1	79.39	1	27	1	51.22	0
26	1	62.48	0	27	1	54.03	0
26	1	37.20	0	27	1	79.39	1
26	1	85.04	1	27	1	62.48	0
26	1	45.60	0	27	1	37.20	0
26	1	85.04	1	27	1	85.04	1
26	1	70.93	1	27	1	45.60	0
26	1	79.39	1	27	1	70.93	1
26	1	73.75	1	27	1	79.39	1
26	1	56.85	0	27	1	73.75	1

26	1	34.40	0	27	1	56.85	0
26	1	42.80	0	27	1	65.29	1
26	1	82.21	1	27	1	82.21	1
26	1	51.22	0	27	1	62.48	0
26	1	65.29	0	27	1	56.85	0
26	1	87.86	1	27	1	56.85	1
26	1	51.22	0	27	1	62.48	0
26	1	70.93	1	23	0	76.57	1
26	1	40.00	0	23	0	96.33	1
26	1	73.75	1	23	0	85.04	1
26	1	90.68	1	23	0	68.11	1
26	1	79.39	1	23	0	65.29	1
26	1	42.80	0	23	0	42.80	0
26	1	93.50	1	23	0	40.00	0
26	1	42.80	0	23	0	90.68	1
26	1	59.66	0	23	0	37.20	0
26	1	37.20	0	23	0	93.50	1
26	1	70.93	1	23	0	45.60	0
26	1	99.15	1	23	0	34.40	0
26	1	90.68	1	23	0	70.93	1
26	1	90.68	1	23	0	62.48	1
26	1	31.62	0	23	0	85.04	1
26	1	51.22	0	23	0	70.93	1
26	1	31.62	0	23	0	82.21	1
26	1	45.60	0	23	0	90.68	1
26	1	51.22	0	23	0	45.60	0
26	1	48.41	0	23	0	68.11	1
26	1	93.50	1	23	0	82.21	1
26	1	40.00	0	23	0	37.20	0
26	1	48.41	0	23	0	87.86	1
26	1	82.21	1	23	0	65.29	1
26	1	42.80	0	23	0	68.11	1
26	1	37.20	0	23	0	73.75	1
26	1	82.21	1	23	0	51.22	0
26	1	65.29	0	23	0	79.39	1
26	1	70.93	1	23	0	79.39	1
26	1	87.86	1	23	0	45.60	0
26	1	90.68	1	23	0	48.41	0
26	1	99.15	1	23	0	87.86	1
26	1	48.41	0	23	0	85.04	1
26	1	56.85	0	23	0	62.48	0
26	1	73.75	1	23	0	87.86	1
26	1	93.50	1	23	0	99.15	1
26	1	85.04	1	23	0	73.75	1
26	1	87.86	1	23	0	51.22	0
26	1	85.04	1	23	0	37.20	0
26	1	54.03	0	23	0	73.75	1
26	1	65.29	1	23	0	54.03	0
26	1	59.66	0	23	0	45.60	0
26	1	48.41	0	23	0	48.41	0

26	1	70.93	1	23	0	59.66	1
26	1	87.86	1	23	0	59.66	1
26	1	48.41	0	23	0	34.40	0
26	1	73.75	1	23	0	85.04	1
26	1	82.21	1	23	0	48.41	0
26	1	90.68	1	23	0	68.11	1
26	1	56.85	0	23	0	73.75	1
26	1	65.29	1	23	0	82.21	1
26	1	65.29	0	23	0	79.39	1
26	1	48.41	0	23	0	48.41	0
26	1	54.03	0	23	0	65.29	1
26	1	87.86	1	23	0	93.50	1
26	1	45.60	0	23	0	85.04	1
26	1	87.86	1	23	0	42.80	0
26	1	56.85	1	23	0	79.39	1
26	1	73.75	1	23	0	54.03	1
26	1	42.80	0	23	0	76.57	1
26	1	93.50	1	23	0	93.50	1
26	1	45.60	0	23	0	65.29	1
26	1	68.65	1	23	0	96.33	1
26	1	37.20	0	23	0	87.86	1
26	1	51.22	0	23	0	76.57	1
26	1	54.03	0	23	0	85.04	1
26	1	37.20	0	23	0	79.39	1
26	1	79.39	1	23	0	99.15	1
26	1	62.48	1	23	0	56.85	1
26	1	37.20	0	23	0	99.15	1
26	1	85.04	1	23	0	93.50	1
26	1	45.06	0	23	0	51.22	0
26	1	85.04	1	23	0	48.41	0
26	1	70.93	1	23	0	31.62	0
26	1	79.39	1	23	0	82.21	1
26	1	73.75	1	23	0	34.40	0
26	1	31.62	0	23	0	54.03	1
26	1	56.85	0	23	0	59.66	1
26	1	65.29	1	23	0	76.57	1
26	1	82.21	1	23	0	56.85	1
26	1	51.22	0	23	0	68.11	1
26	1	65.29	1	23	0	87.86	1
26	1	51.22	0	23	0	59.66	1
26	1	45.60	0	23	0	56.85	1
26	1	73.75	1	23	0	56.85	1
26	1	86.21	1	23	0	31.62	0
26	1	40.00	0	23	0	51.22	0
26	1	93.50	1	23	0	99.15	1
26	1	37.20	0	23	0	73.75	1
26	1	85.04	1	23	0	48.41	0
26	1	37.20	0	23	0	70.93	1
26	1	62.48	1	23	0	82.21	1
26	1	56.85	0	23	0	76.57	1

26	1	70.93	1	23	0	82.21	1
26	1	99.15	1	23	0	85.04	1
26	1	76.57	1	23	0	42.80	0
26	1	85.04	1	23	0	79.39	1
26	1	62.48	1	23	0	48.41	0
26	1	87.86	1	23	0	79.39	1
26	1	54.03	1	23	0	79.39	1
27	1	54.03	0	20	1	99.15	1
27	1	31.62	0	20	1	45.60	0
27	1	48.41	0	20	1	62.48	1
27	1	37.20	0	20	1	56.85	0
27	1	45.60	0	20	1	62.48	0
27	1	73.75	1	20	1	42.80	0
27	1	82.21	1	20	1	90.68	1
27	1	82.21	1	20	1	42.80	0
27	1	68.11	0	20	1	40.00	0
27	1	54.03	0	20	1	59.66	0
27	1	42.80	0	20	1	82.21	1
27	1	34.40	0	20	1	70.93	1
27	1	59.66	0	20	1	40.00	0
27	1	62.48	1	20	1	90.68	1
27	1	79.39	1	20	1	79.39	1
27	1	56.85	1	20	1	42.80	0
27	1	96.33	1	20	1	93.50	1
27	1	73.75	1	20	1	42.80	0
27	1	48.41	0	20	1	59.66	1
27	1	65.29	1	20	1	37.20	0
27	1	59.66	0	20	1	70.93	1
27	1	40.00	0	20	1	99.15	1
27	1	76.75	1	20	1	90.68	1
27	1	42.80	0	20	1	31.62	0
27	1	76.75	1	20	1	90.68	1
27	1	96.33	1	20	1	31.62	0
27	1	85.04	1	20	1	51.22	0
27	1	68.11	1	20	1	31.62	0
27	1	65.29	1	20	1	45.60	1
27	1	85.04	1	20	1	79.39	1
27	1	42.80	0	20	1	51.22	0
27	1	40.00	0	20	1	48.41	0
27	1	90.68	1	20	1	93.50	1
27	1	34.40	0	20	1	40.00	0
27	1	45.60	0	20	1	48.41	0
27	1	34.40	0	20	1	96.33	1
27	1	62.48	1	20	1	82.21	1
27	1	85.04	1	20	1	42.80	0
27	1	73.75	1	20	1	37.20	0
27	1	82.21	1	20	1	45.60	0
27	1	90.68	1	20	1	82.21	1
27	1	68.11	1	20	1	65.29	1
27	1	82.21	1	20	1	70.93	1

27	1	37.20	0	20	1	87.86	1
27	1	87.86	1	20	1	90.68	1
27	1	65.29	0	20	1	99.15	1
27	1	73.75	1	20	1	59.66	0
27	1	51.22	1	20	1	48.41	0
27	1	79.39	1	20	1	56.85	0
27	1	79.39	1	20	1	65.29	1
27	1	45.60	0	20	1	93.50	1
27	1	48.41	0	20	1	85.04	1
27	1	96.33	1	20	1	87.86	1
27	1	87.86	1	20	1	54.03	0
27	1	85.04	1	20	1	65.29	1
27	1	62.48	0	20	1	59.66	0
27	1	87.86	1	20	1	48.41	0
27	1	99.15	1	20	1	70.93	1
27	1	73.75	1	20	1	87.86	1
27	1	51.22	0	20	1	48.41	0
27	1	70.93	1	20	1	73.75	1
27	1	37.20	0	20	1	73.75	1
27	1	73.75	1	20	1	82.21	1
27	1	54.03	0	20	1	90.68	1
27	1	45.60	0	20	1	56.85	0
27	1	48.41	0	20	1	34.40	0
27	1	59.66	0	20	1	65.29	1
27	1	59.66	1	20	1	48.41	0
27	1	34.40	0	20	1	65.29	1
27	1	85.04	1	20	1	54.03	1
27	1	48.41	0	20	1	45.60	0
27	1	68.11	1	20	1	56.85	0
27	1	73.75	1	20	1	73.75	1
27	1	82.21	1	20	1	42.80	0
27	1	79.39	1	20	1	93.50	1
27	1	48.41	0	20	1	65.29	1
27	1	65.29	1	20	1	45.60	0
27	1	93.50	1	20	1	68.11	1
27	1	85.04	1	20	1	37.20	0
27	1	42.80	0	20	1	51.22	1
27	1	34.40	0	20	1	37.20	0
27	1	79.73	1	20	1	54.03	0
27	1	54.03	0	20	1	79.39	1
27	1	56.57	1	20	1	62.48	1
27	1	93.50	1	20	1	37.20	0
27	1	65.29	1	20	1	85.04	1
27	1	96.33	1	20	1	45.60	0
27	1	87.86	1	20	1	85.04	1
27	1	76.75	1	20	1	70.93	1
27	1	85.04	1	20	1	79.39	1
27	1	79.39	1	20	1	73.75	1
27	1	99.15	1	20	1	56.85	1
27	1	56.85	0	20	1	65.29	1

27	1	99.15	1	20	1	82.21	1
27	1	48.41	0	20	1	62.48	1
27	1	31.62	0	20	1	56.85	0
27	1	34.40	0	20	1	56.85	0
27	1	54.03	1	20	1	54.03	0
27	1	59.66	0	20	1	54.03	1
27	1	56.85	0	20	1	54.03	0
34	1	99.15	1	23	1	96.33	1
34	1	45.60	0	23	1	73.75	1
34	1	62.48	0	23	1	48.41	0
34	1	56.85	0	23	1	65.29	1
34	1	62.48	1	23	1	59.66	1
34	1	42.80	0	23	1	40.00	0
34	1	42.80	0	23	1	76.57	1
34	1	90.68	1	23	1	42.80	0
34	1	42.80	0	23	1	76.57	1
34	1	40.00	0	23	1	96.33	1
34	1	40.00	0	23	1	85.04	1
34	1	59.66	1	23	1	68.11	1
34	1	82.21	1	23	1	65.29	1
34	1	70.93	1	23	1	85.04	1
34	1	40.00	0	23	1	42.80	0
34	1	73.75	1	23	1	40.00	0
34	1	90.68	1	23	1	90.68	1
34	1	79.39	1	23	1	37.20	0
34	1	42.80	0	23	1	93.50	1
34	1	93.50	1	23	1	34.40	0
34	1	42.80	0	23	1	45.60	0
34	1	59.66	1	23	1	34.40	0
34	1	37.20	0	23	1	70.93	1
34	1	70.93	1	23	1	62.48	1
34	1	99.15	1	23	1	85.04	1
34	1	90.68	1	23	1	70.93	1
34	1	31.62	0	23	1	82.21	1
34	1	90.68	1	23	1	90.68	1
34	1	31.62	0	23	1	45.60	1
34	1	51.22	1	23	1	68.11	1
34	1	31.62	0	23	1	82.21	1
34	1	45.60	0	23	1	37.20	0
34	1	79.39	1	23	1	87.86	1
34	1	51.22	0	23	1	65.29	1
34	1	48.41	0	23	1	68.11	1
34	1	93.50	1	23	1	73.75	1
34	1	40.00	0	23	1	51.22	1
34	1	48.41	0	23	1	79.39	1
34	1	96.33	1	23	1	79.39	1
34	1	82.21	1	23	1	45.60	0
34	1	42.80	0	23	1	48.41	0
34	1	37.20	0	23	1	96.33	1
34	1	82.21	1	23	1	87.86	1

34	1	65.29	1	23	1	85.04	1
34	1	70.93	1	23	1	62.48	1
34	1	87.86	1	23	1	87.86	1
34	1	90.68	1	23	1	99.15	1
34	1	99.15	1	23	1	73.75	1
34	1	59.66	0	23	1	51.22	0
34	1	48.41	0	23	1	70.93	1
34	1	56.85	0	23	1	37.20	0
34	1	65.29	1	23	1	73.75	1
34	1	93.50	1	23	1	54.03	1
34	1	87.86	1	23	1	45.60	0
34	1	85.04	1	23	1	59.66	1
34	1	54.03	0	23	1	59.66	1
34	1	59.66	0	23	1	34.40	0
34	1	48.41	0	23	1	48.41	1
34	1	70.93	1	23	1	68.11	1
34	1	87.86	1	23	1	73.75	1
34	1	73.75	1	23	1	82.21	1
34	1	73.75	1	23	1	79.39	1
34	1	82.21	1	23	1	48.41	0
34	1	90.68	1	23	1	65.29	1
34	1	56.85	0	23	1	93.50	1
34	1	34.40	0	23	1	85.04	1
34	1	65.29	1	23	1	42.80	0
34	1	48.41	0	23	1	34.40	0
34	1	54.03	1	23	1	79.39	1
34	1	87.86	1	23	1	54.03	0
34	1	45.60	0	23	1	76.75	1
34	1	87.86	1	23	1	93.50	1
34	1	56.85	0	23	1	65.29	1
34	1	73.75	1	23	1	96.33	1
34	1	42.80	0	23	1	87.86	1
34	1	93.50	1	23	1	76.57	1
34	1	65.29	1	23	1	85.04	1
34	1	45.60	0	23	1	79.39	1
34	1	68.11	1	23	1	99.15	1
34	1	51.22	0	23	1	56.85	0
34	1	37.20	0	23	1	99.15	1
34	1	54.03	0	23	1	93.50	1
34	1	37.20	0	23	1	51.22	0
34	1	79.39	1	23	1	48.41	0
34	1	62.48	1	23	1	31.62	0
34	1	37.20	0	23	1	82.21	1
34	1	85.04	1	23	1	34.40	0
34	1	45.60	0	23	1	54.03	0
34	1	85.04	1	23	1	59.66	1
34	1	70.93	1	23	1	76.57	1
34	1	56.85	0	23	1	56.85	1
34	1	65.29	1	23	1	45.60	0
34	1	51.22	0	23	1	68.11	1

34	1	65.29	1	23	1	87.86	1
34	1	51.22	0	23	1	59.66	1
34	1	73.75	1	23	1	56.85	1
34	1	62.48	1	23	1	56.85	0
34	1	56.85	1	23	1	51.22	0
34	1	68.11	1	23	1	54.03	0
34	1	62.48	1	23	1	54.03	1

APPENDIX F: FINDING CONFLICTING DECISION AREA DISTRIBUTION

After finding the best fitted logistic regression curve for data, we defined the "go" and "stop" distances. We used the cut probabilities to find these distances because the logistic regression curve never converges to one or zero. The difference between two lines gives the conflicting decision area.

In order to find the distribution of conflicting decision area, we need to solve following equations:

$$0.95 = \frac{1}{1 + e^{\alpha + \beta * D_s}}$$

$$0.05 = \frac{1}{1 + e^{\alpha + \beta * D_g}}$$

And we can rewrite them in following form:

$$1 + \exp(\alpha + \beta * D_s) = 1/0.95$$

$$1 + \exp(\alpha + \beta * D_g) = 1/0.05$$

By readjusting and taking the natural logarithm of each side, we will have following equations.

$$\alpha + \beta * D_s = \ln(0.0526)$$

$$\alpha + \beta * D_g = \ln(19.00)$$

By subtracting second equation from the first one and we can express $D_s - D_g$ in terms of coefficients:

$$D_s - D_g = -5.8888/\beta$$

where β is normally distributed with mean (-0.313) and variance (0.000507). The result seems the inverse of normal distribution. We know that, $D_s - D_g$ is always positive. Theoretically, β can get any value between minus and plus infinity; if it takes zero, the conflicting decision area will be infinity. So the direct transformation from the β distribution will be discontinuous at $\beta = 0.0$

In order to find the distribution of area, we created 8000 data points that represent the β coefficient. We applied the above transformation to the data and we defined the new variable as "U". We evaluated the new variable. First we looked at its histogram, we checked its normality by applying the Wilk-Shapiro Test. The new variable is normally distributed with mean (18.91) and variance (1.91). By subtracting the constant car length from the mean value we converted the results in time. So, the result was the muscle response time and it is normally distributed with mean (0.15) and variance (0.003). The following pages are MCAD (Mathematical software) output and gives the above mentioned steps and graphs.

FINDING MUSCLE RESPONSE TIME DISTRIBUTION

We need to find the distribution of Ds - Dg = -5.888/β, and β is normally distributed with following parameters (μ, σ2). Let's define U = -5.8888/β. The parameters are:

$\sigma 2 := 0.0005071537 \quad \mu := -.3130$

$\sigma := \sqrt{\sigma 2} \qquad \sigma = 0.02252$

where σ2 gives the variance of β and μ gives the mean value of the β.

$$f(\beta) := \frac{1}{\sqrt{2\cdot\pi}\cdot\sigma}\cdot e^{\frac{-1}{2}\cdot\left[\frac{\beta-\mu}{\sigma}\right]^2}$$

Above f(β) gives the probability density function of β.

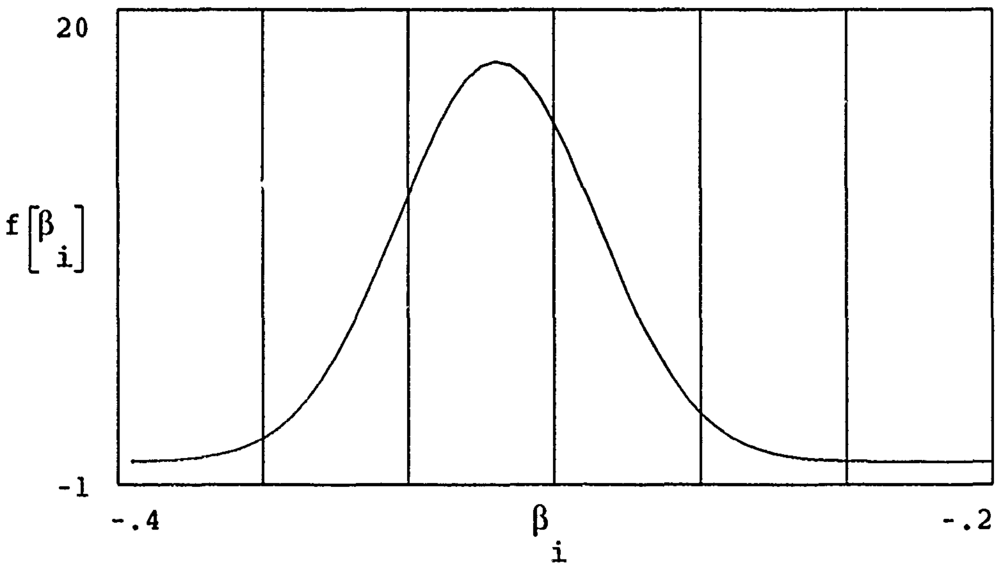


Figure 1. Distribution of β Coefficient

FINDING EXPECTED VALUES AND VARIANCE OF "U".

Before finding the possible distribution of Ds-Dg = U = -5.8888/β, let's find the expected value and variance of "U".

$$\int_{-1}^{0} f(\beta)\cdot -5.8888\cdot\frac{1}{\beta}\,d\beta = 18.913007$$ This is the expected value of U.

$$\int_{-1}^{0} f(\beta)\cdot\frac{5.8888^2}{\beta^2}\,d\beta = 359.613641$$ This is the expected value of U^2.

The variance of U can be found by following calculation:

$$\left[359.6136408 - 18.913007^2\right] = 1.911807$$ This is the variance of U.

-5.8888/β is; random variable with mean 18.91 and variance 1.91

$$std := \sqrt{1.911807}$$

std = 1.382681   "std" represents the standard deviation of U.

Ds-Dg represents the distance, in other words, U = Ds-Dg = tm*V where tm represents the muscle response time and V represents the approach speed.

When we make a transformation to get the mean values and variance in terms of the time duration, we need to divide by the approach speed. It is a constant and 25.6 units/second or 35 mph. In terms of time, the results are:

$$\frac{18.91 - 15}{25.6} = 0.152734$$

The mean is 0.15 second, and it is obtained by subtracting the car length (15 units) from the expected distance. The standard deviation of U can be transformed to the time duration, it is 0.05 second.

$$1.382 \cdot \frac{1}{25.6} = 0.053984$$

$$\text{Vartm} := 0.053984^2$$

$$\text{Vartm} = 0.002914$$

This is the variance of the muscle response time, and approximately 0.003.

We concluded that, the muscle response time's parameters are

Mean = 0.15 second and

Variance = 0.003.

The following section imperically checks the distribution of "U" by generating data representative of "β" coefficient. "β" and "U" are represented by "X" and "Y" respectively.

CHECK FOR DISTRIBUTION

This part generates 8000 data, that are normally distributed with mean, -0.313, and variance, 0.0005072. We called the original variable X and transformed variable Y.

$$Z_i := \frac{U_i^{.1349} - \left[1 - U_i\right]^{.1349}}{.1975}$$

This is normal random generator, U is random number between 0 and 1.

$$X_i := \mu + \sqrt{\sigma 2} \cdot Z_i$$

The random variable X is normally distributed with mean(-.313) and variance (0.00051)

mean(X) = -0.313091 var(X) = 0.000511

Now, we can examine Y, a random variable that is defined:

$$Y_i := \frac{-5.8888}{X_i}$$

The new random variable is a function of X

mean(Y) = 18.908096 Mean of new random variable

var(Y) = 1.920828 Variance of new random variable

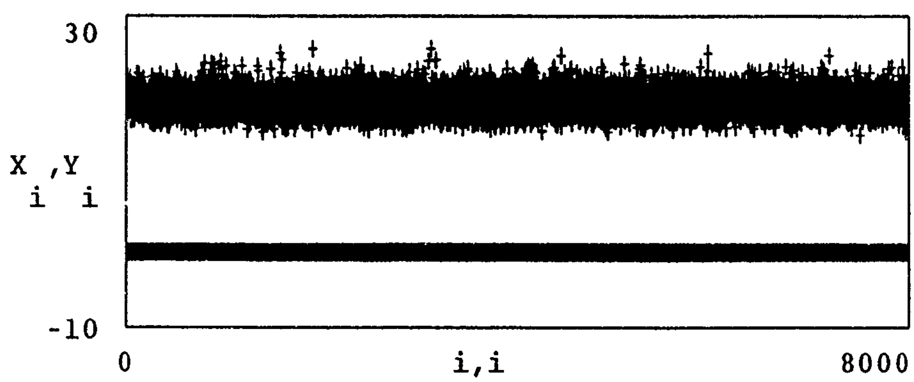


Figure 2. The Scatter Plots of X and Y Variables.

From the scatter plot, one can see that the variance of the new variable is larger than the variance of the original variable.

HISTOGRAM OF THE X AND Y VARIABLES

The following histograms represent the original generated data histogram (Fig 3) and transformed data histogram (Fig 4). The histograms are very clearly show the normality of the data. Figure 4 shows the normal distribution with mean (18.91) and variance (1.91). Figure 3 shows the original data that is normally distributed with mean (-0.313) and variance (0.0005).

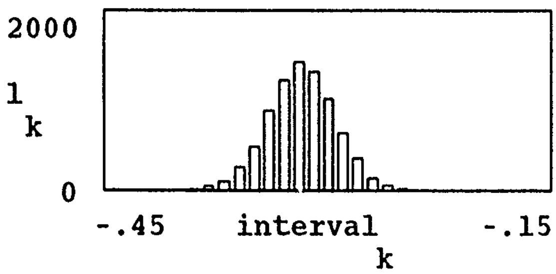


Figure 3. Histogram of Original Data

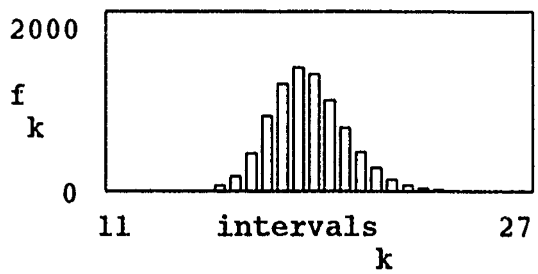


Figure 4. Histogram of Transformed Data.

The new random variable (Y) is normally distributed. When we applied the normality test, at the $\alpha = 0.01$ level, they are normally distributed.

As a result, we created 8000 normal data points and we checked the distribution of -5.8888/X. Where "X" is normally distributed random variable. We checked the normality of these variables and concluded that transformed data can be represented by a normal distribution.

INVERSE GAUSSIAN DISTRIBUTION TO EXPRESS THE MUSCLE RESPONSE TIME

The inverse Gaussian Distribution has two parameters, mean(μ) and scale parameter(λ). We found them from transformed data.

$\mu := \text{mean}(Y)$ and $\mu = 18.908096$ Mean of the Inverse Gaussian Distribution.

$$V := \sum_i \left[\frac{1}{Y_i} - \frac{1}{\text{mean}(Y)}\right]$$

$$\lambda := \frac{\text{samplesize}}{V} \qquad \lambda = 3573.518045$$

Scale parameter of Inverse Gaussian Distribution.

The probability density function of IG Distribution with "U" independent random variable is:

$$f(u) := \sqrt{\frac{\lambda}{2\cdot\pi}}\cdot u^{\frac{-3}{2}}\cdot e^{-\lambda\cdot\frac{(u-\mu)^2}{2\cdot\mu^2\cdot u}} \qquad u > 0$$

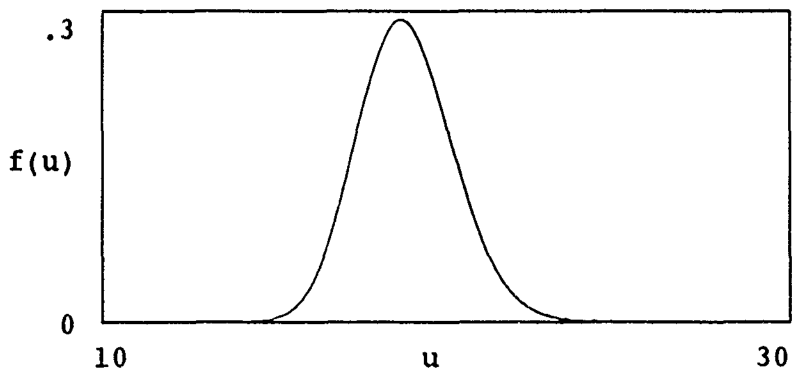


Figure 5. Pdf of Inverse Gaussian Dist.

We can find the mean and variance at the same manner. We can express the same data with a Normal Distribution with the same mean and variance. Let's call the independent variable as "Ul" at this time. The normal probability density function and graph (Fig 6) are:

$$f(ul) := \frac{1}{\sqrt{2\cdot\pi}\cdot\sigma}\cdot e^{\frac{-1}{2}\cdot\left[\frac{ul-\mu}{\sigma}\right]^2}$$

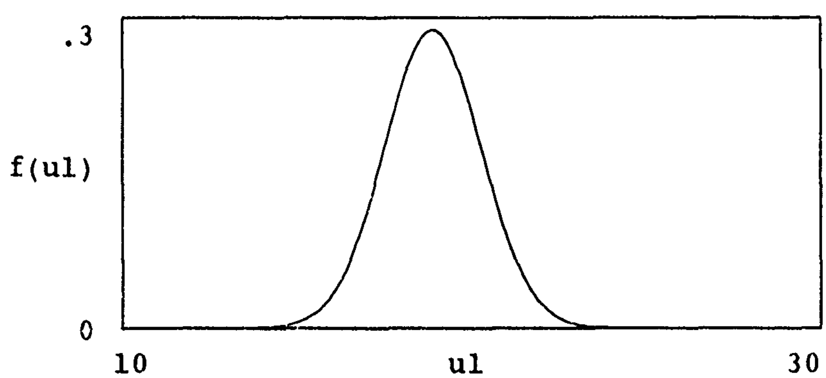


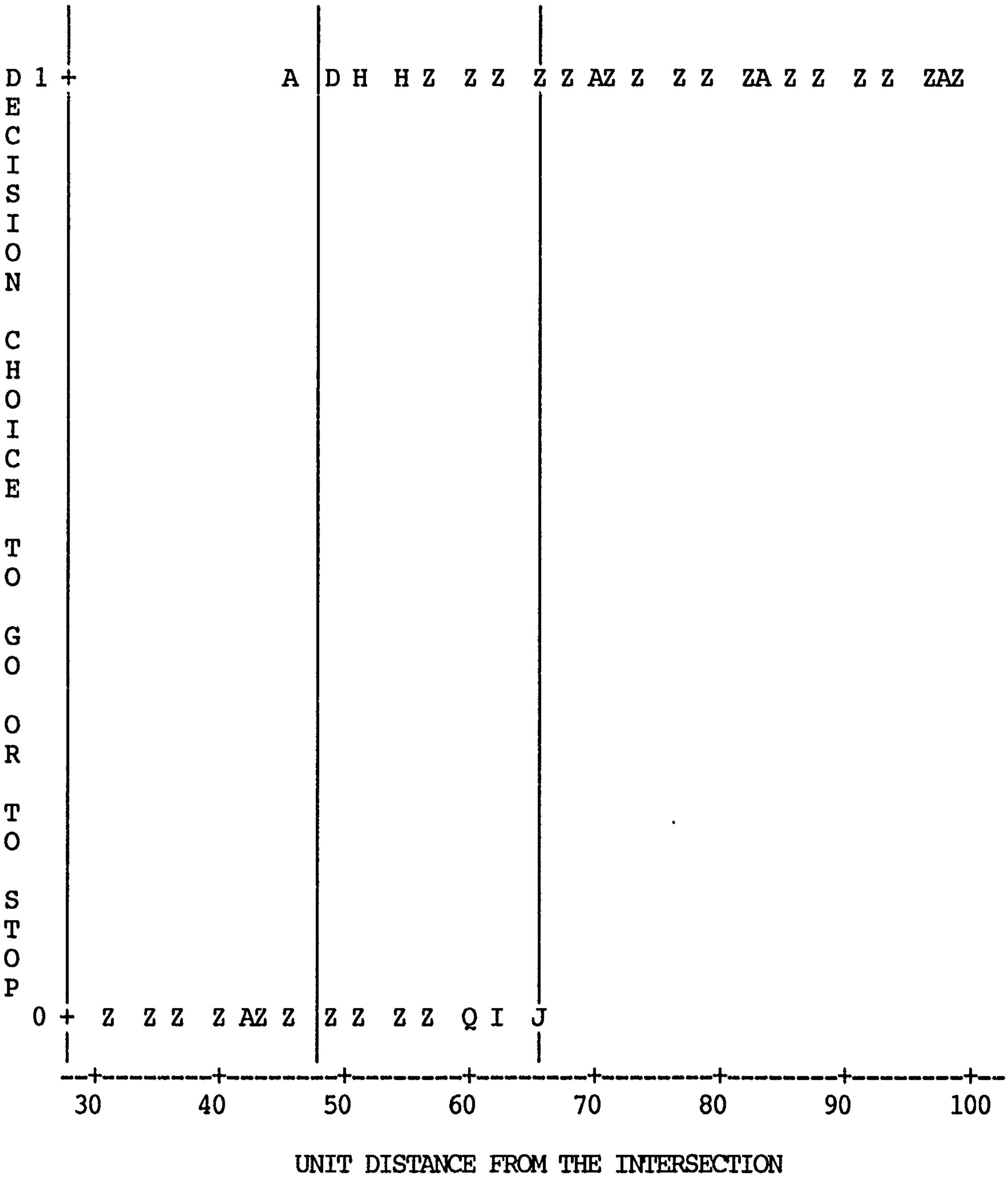
Figure 6. Pdf of Normal Distribution

We checked the two type of distributions, they have same mean and variance. They are symmetric. Because the Inverse Gaussian Distribution is defined with scale parameter, it can change from the skewed to the symmetric Normal Distribution. We can approximate from Inverse Gaussian Distribution to the Normal Distribution with our data.

APPENDIX G: SAS OUTPUT DATA FROM FIRST EXPERIMENT

CHOICE EVALUATION WITH RESPECT TO DISTANCE
AT SIGNALIZED INTERSECTION APPROACH SIMULATION
(With marked decision line experiment)

Plot of CHOICE*DIST. Legend: A = 1 obs, B = 2 obs, etc.



The LOGISTIC Procedure

Response Variable: CHOICE
Response Levels: 2
Number of Observations: 1200
Link Function: Logit

Response Profile

Ordered Value	CHOICE	Count
1	0	470
2	1	730

Maximum Likelihood Iterative Phase

Iter	Step	-2 Log L	INTERCPT	DIST
0	INITIAL	1606.770653	-0.440312	0
1	IRLS	714.229161	5.162860	-0.086648
2	IRLS	514.155282	8.495491	-0.145564
3	IRLS	429.906219	12.133126	-0.210176
4	IRLS	403.070507	15.525106	-0.270107
5	IRLS	398.976150	17.505059	-0.304869
6	IRLS	398.840888	17.954754	-0.312728
7	IRLS	398.840696	17.972590	-0.313038
8	IRLS	398.840696	17.972616	-0.313039

Last Change in -2 Log L: 0.0001913021

Last Evaluation of Gradient

INTERCPT	DIST
-7.390515E-7	-0.00094336

Criteria for Assessing Model Fit

Criterion	Intercept Only	Intercept and Covariates	Chi-Square for Covariates
AIC	1608.771	402.841	.
SC	1613.861	413.021	.
-2 LOG L	1606.771	398.841	1207.930 with 1 DF (p=0.0001)
Score	.	.	781.643 with 1 DF (p=0.0001)

Analysis of Maximum Likelihood Estimates

Variable	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate
INTERCPT	17.9726	1.3018	190.6080	0.0001	.
DIST	-0.3130	0.0225	193.2222	0.0001	-3.294691

Association of Predicted Probabilities and Observed Responses

Concordant	= 97.7%	Somers' D	= 0.964
Discordant	= 1.3%	Gamma	= 0.974
Tied	= 1.0%	Tau-a	= 0.460
(343100 pairs)		c	= 0.982

Estimated Covariance Matrix

Variable	INTERCPT	DIST
INTERCPT	1.6946557468	-0.029174079
DIST	-0.029174079	0.0005071537

Estimated Correlation Matrix

Variable	INTERCPT	DIST
INTERCPT	1.00000	-0.99515
DIST	-0.99515	1.00000

APPENDIX H: SAS OUTPUT DATA FOR SECOND EXPERIMENT

CHOICE EVALUATION WITH RESPECT TO DISTANCE
AT SIGNALIZED INTERSECTION APPROACH SIMULATION
(Without decision line experiment)

Plot of CHOICE*DIST. Legend: A = 1 obs, B = 2 obs, etc.

```
      |                     |                  |
      |                     |                  |
  D 1 +      A       B C   |E L  N V  Z Z   Z ZA Z Z  X ZA Z   ZAZ   Z ZA Y Z
  E   |                     |                  |
  C   |                     |                  |
  I   |                     |                  |
  S   |                     |                  |
  I   |                     |                  |
  O   |                     |                  |
  N   |                     |                  |
      |                     |                  |
  C   |                     |                  |
  H   |                     |                  |
  O   |                     |                  |
  I   |                     |                  |
  C   |                     |                  |
  E   |                     |                  |
      |                     |                  |
  T   |                     |                  |
  O   |                     |                  |
      |                     |                  |
  G   |                     |                  |
  O   |                     |                  |
      |                     |                  |
  O   |                     |                  |
  R   |                     |                  |
      |                     |                  |
  T   |                     |                  |
  O   |                     |                  |
      |                     |                  |
  S   |                     |                  |
  T   |                     |                  |
  O   |                     |                  |
  P   |                     |                  |
    0 +  Z  Z Z  Z  Z Z    |Z Z  Z Z  S P    I A  E
      |                     |                  |
      --+---------+---------+---------+---------+---------+---------+---------+--
        30        40        50        60        70        80        90        100
                          UNIT DISTANCE FROM THE INTERSECTION
```

The LOGISTIC Procedure

Response Variable: CHOICE
Response Levels: 2
Number of Observations: 1200
Link Function: Logit

Response Profile

Ordered Value	CHOICE	Count
1	0	485
2	1	715

Maximum Likelihood Iterative Phase

Iter	Step	-2 Log L	INTERCPT	DIST
0	INITIAL	1619.195946	-0.388134	0
1	IRLS	754.874007	5.022062	-0.083071
2	IRLS	583.410488	8.047982	-0.135857
3	IRLS	524.710810	10.893853	-0.186100
4	IRLS	512.376303	12.906283	-0.221619
5	IRLS	511.589929	13.585346	-0.233559
6	IRLS	511.585665	13.640654	-0.234528
7	IRLS	511.585665	13.640978	-0.234534

Last Change in -2 Log L: 0.0042643981

Last Evaluation of Gradient

INTERCPT	DIST
-0.000293057	-0.041928711

Criteria for Assessing Model Fit

Criterion	Intercept Only	Intercept and Covariates	Chi-Square for Covariates
AIC	1621.196	515.586	.
SC	1626.286	525.766	.
-2 LOG L	1619.196	511.586	1107.610 with 1 DF (p=0.0001)
Score	.	.	759.061 with 1 DF (p=0.0001)

Analysis of Maximum Likelihood Estimates

Variable	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate
INTERCPT	13.6410	0.8780	241.3621	0.0001	.
DIST	-0.2345	0.0150	243.1034	0.0001	-2.523797

Association of Predicted Probabilities and Observed Responses

Concordant	= 96.5%	Somers' D	= 0.942
Discordant	= 2.3%	Gamma	= 0.953
Tied	= 1.2%	Tau-a	= 0.454
(346775 pairs)		c	= 0.971

Estimated Covariance Matrix

Variable	INTERCPT	DIST
INTERCPT	0.7709423847	-0.013097533
DIST	-0.013097533	0.0002262667

Estimated Correlation Matrix

Variable	INTERCPT	DIST
INTERCPT	1.00000	-0.99167
DIST	-0.99167	1.00000

APPENDIX I: SAS OUTPUT FOR THREE EXPLANATORY VARIABLES

CHOICE EVALUATION WITH RESPECT TO DISTANCE, AGE AND SEX
AT SIGNALIZED INTERSECTION APPROACH SIMULATION

The LOGISTIC Procedure

Response Variable: CHOICE
Response Levels: 2
Number of Observations: 1200
Link Function: Logit

Response Profile

Ordered Value	CHOICE	Count
1	0	470
2	1	730

Last Evaluation of Gradient

INTERCPT	DIST	AGE
-2.871869E-6	-0.001586671	-0.000043646

Criteria for Assessing Model Fit

Criterion	Intercept Only	Intercept and Covariates	Chi-Square for Covariates
AIC	1608.771	395.260	.
SC	1613.861	410.530	.
-2 LOG L	1606.771	389.260	1217.511 with 2 DF (p=0.0001)
Score	.	.	784.999 with 2 DF (p=0.0001)

Residual Chi-Square = 0.2365 with 1 DF (p=0.6268)

Summary of Stepwise Procedure

Step	Variable Entered	Variable Removed	Number In	Score Chi-Square	Wald Chi-Square	Pr > Chi-Square
1	DIST		1	781.6	.	0.0001
2	AGE		2	9.4982	.	0.0021

Analysis of Maximum Likelihood Estimates

Variable	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate
INTERCPT	15.5224	1.4721	111.1909	0.0001	.
DIST	-0.3180	0.0232	188.6258	0.0001	-3.346725
AGE	0.1067	0.0351	9.2529	0.0024	0.233249

Association of Predicted Probabilities and Observed Responses

Concordant	= 98.3%	Somers' D	= 0.966
Discordant	= 1.6%	Gamma	= 0.968
Tied	= 0.1%	Tau-a	= 0.461
(343100 pairs)		c	= 0.983

Estimated Covariance Matrix

Variable	INTERCPT	DIST	AGE
INTERCPT	2.1669493902	-0.027065945	-0.023101757
DIST	-0.027065945	0.0005360513	-0.000146976
AGE	-0.023101757	-0.000146976	0.0012293258

Estimated Correlation Matrix

Variable	INTERCPT	DIST	AGE
INTERCPT	1.00000	-0.79414	-0.44760
DIST	-0.79414	1.00000	-0.18106
AGE	-0.44760	-0.18106	1.00000

APPENDIX J: FINDING REACTION TIME STATISTICS AND NORMAL PROBABILITY PLOTTING

In the tables below the discrete reaction time data are given. The following equations show the calculations of parameters, mean and variance.

Simple Reaction Time Data (480 Observations)

Data Points(X_i)	.17	.26	.34	.43	.51	.6
Frequency(n_i)	6	85	267	92	26	4

Choice Reaction Time Data (600 Observations)

X_i	.26	.34	.43	.51	.6	.68	.7	.85	.94	1.02
n_i	45	127	141	107	69	48	32	21	9	1

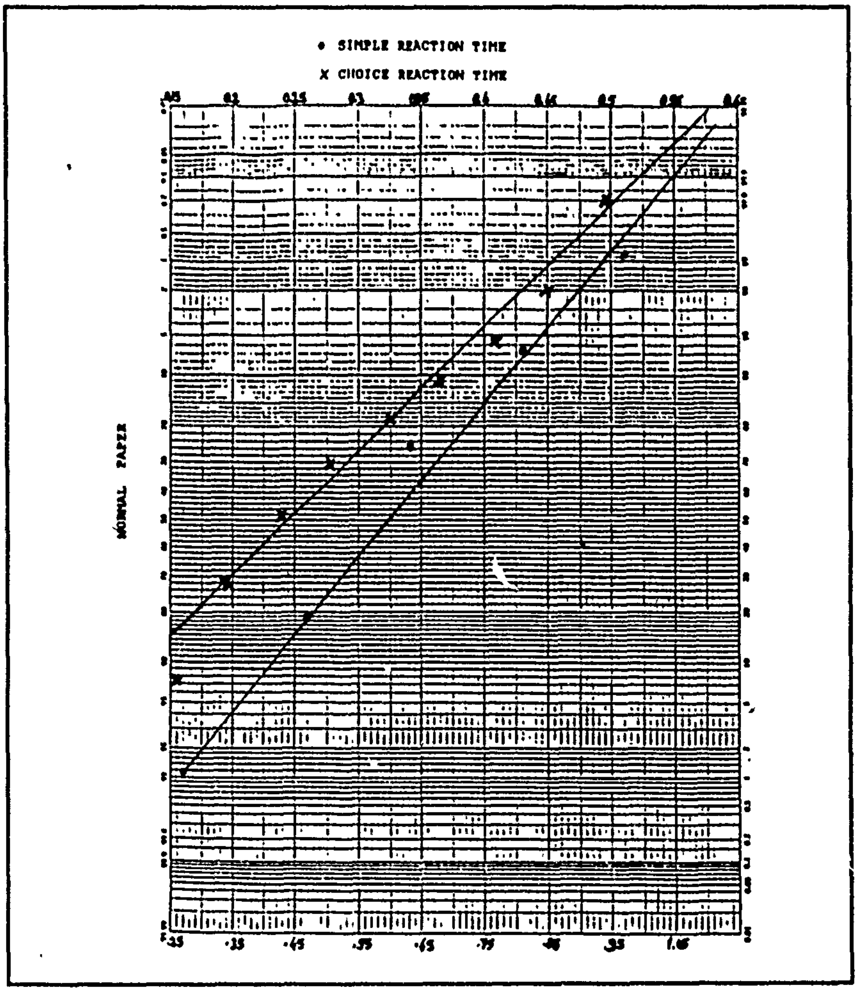
In the above tables, i represents the number of discrete points that were observed. Also X_i is the observed discrete point, n_i is number of observations at that point. The following formulas were used to estimate the population parameters (mean and variance).

$$\overline{x} = \frac{\sum n_i * x_i}{\sum n_i}$$

$$s^2 = \frac{\sum n_i \, (x_i - \overline{x})^2}{\sum n_i - 1}$$

In the above equations mean and variance of the samples are estimated.

We plotted the data on normal probability paper to investigate the goodness-of-fit of the data to the normal distribution. The plotting is given by figure below. The plotting is achieved by using already prepared normal probability paper. The normal approximation appears to be sufficient on the normal paper.



Normal Probability Plotting of Reaction Times on Normal Paper

BIBLIOGRAPHY

Ben-Akiva, Moshe and Lerman Steven R. Discrete Choice Analysis: Theory and Application to Travel Demand. The MIT Press: Massachusetts, 1985.

Chan, Y. "The change interval at signalized intersections," Department of Civil and Environmental Engineering, Washington State University, Pullman, Washington, 1986.

----- and Liao, T. "Setting Change Lights at Signalized Intersections", ITE Journal, (February 1987).

-----. "My recent interest in operational sciences," WP91-01, Air Force Institute of Technology, Working Paper, Wright-Patterson Air Force Base, Ohio, (March 1991).

Chhikara, Raj S. and Folks, J. Leory. The Inverse Gaussian Distribution. Marcel Dekker, Inc. New York, 1989.

D'Agostino , Ralph B. and Stephens, Michael A. Goodness-of-Fit Techniques. Marcel Dekker, Inc.: New York, 1986.

Frantzeskis, John M. "Signal Change Intervals and Intersection Geometry," Transportation Quarterly, 38: 47-58 (January 1984).

Gazis, Denos Herman, Robert, Maradudin, Alexei. "The Problem of The Amber Signal Light In Traffic Flow." Operations Research, 8(1): 112-132 (Jan-Feb. 1960).

Hosmer, D. W. and Lemeshow, S. Applied Logistic Regression. New York: A Wiley-Interscience Publication, 1989.

Johansson, G. and Rumar, K. Driver's Brake Reaction Times. Human Factors: 13(1): 23-27 (1971).

Kortelling, J. E. "Perception-Response speed and Driving Capabilities of Brain-Damaged and Older Drivers." Human Factors, 32: 95-108 (February 1990).

Lin, Feng-Bor. "Timing Design of Signal Change intervals." Transportation Research Record 1069, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, N.Y., 1986.

Mahael, D. and Zaidel, D. "A probabilistic Approach for Determining the Change Interval," Transportation Research Record 1069, presented at the 65th Annual Meeting of Transportation Research Board, Washington, DC., 1986.

Maxwell, Scott E. and Delaney, Harold D. Designing Experiment and Analyzing Data. Wadsworth Publishing Company: Belmont, California, 1990.

Olsen Paul L. and Rothery Richard W. "Driver Response to the Amber Phase of Traffic Signals." Operations Research, 650-663 (September-October 1961).

Prashker Joseph N. and Mahalel David. "The Relationship between an Option Space and Drivers' Indecision at Signalized Intersection Approaches," Transpn. Res. -B, 23B(6): 401-413, 1989.

Ross, Sheldom M. Introduction to Probability Models. Academic Press: San Diago, California, 1989.

SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2, 1990, 1072-1074, SAS Institute Inc., Cary, NC, USA.

Sheffi Y. and Mahmassani H. "A Model of Driver Behavior at High-Speed Signalized Intersections. " Transportation Science, 15(1): 50-55 (February 1981).

Stein, Howard S. Traffic Signal Change Intervals: Policies, Practices, and Safety, Transportation Quarterly, 40: 433-444 (July 1986).

Taoka, George T. "Break Reaction Times of Unalerted Drivers," ITE Journal, 19-21 (March 1989).

U.S. Department of Transportation, Traffic Control Devices handbook - An Operating Guide, prepared by the National Advisory Committee on Uniform Traffic Control Devices, Federal Highway Administration, 1975

Wargo, Michael J. "Human Operator Response Speed, Frequency, and Flexibility: A review and Analysis." Human Factors, 9(3): 221-227 (1967).

William A. Stimpson, Paul L. Zador and Philip J. Tarnoff. "The Influence of the Time Duration of Yellow Traffic Signals On Driver Response," ITE Journal, (November 1980).

William D. Kosnic. "Self-Reported Visual Problems of Older Drivers," Human Factors, 32(5): 605 (1990).

Woodson E. Wesley. Human Factors Design Handbook. New York: McGraw-Hill Book Company, 1981.

Vita

Hasan H. Demirarslan was born in Canakkale, Turkiye, on January 1, 1962. He graduated from Canakkale High School in 1978 and attended the Turkish Air Force Academy. After graduation, he completed his pilot training in 1984. He was assigned as a F-5A/B fighter pilot and served six years. His last assignement was to Air Training Command as a T-38/T-33 instructer pilot. In June 1990, he entered the Air Force Institute of technology's Graduate Program in Operation Research.

He is married to Mehtap. They presently have one child: Goktug.

Permanent Address: 18 Mart Yapi Koop.
A-Blok, No:1
Canakkale/TURKIYE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1992	Master's Thesis

4. TITLE AND SUBTITLE
VISUAL INFORMATION PROCESSING AND RESPONSE TIME IN TRAFFIC-SIGNAL COGNITION

5. FUNDING NUMBERS

6. AUTHOR(S)
Hasan H. DEMIRARSLAN, Capt, TUAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology, WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GOR/ENS/92M-8

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release: distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
In man-machine design, it is important to quantify the reaction time components instead of simply determining the lump-sum reaction time to stimulus. The primary purpose of this thesis was to investigate the reaction time components, such as visual perception and muscle response time, and to quantify them by separating from their aggregated sum. The prime example, traffic-signal cognition simulation was used to examine human reaction time to signal change. With a modified computer program that simulates the driver's approach to the intersection, we measured the subject's reaction times and examined behavioral patterns. Twelve subjects were involved in the experiment. A logistic regression procedure was applied to the data to define subjects' choices at different distances. Decision process time and the conflicting decision area were examined. Logistic regression was used to reveal the distribution of the conflicting decision area and muscle response time. The results revealed the visual perception time distribution. The most important part of total reaction time was visual perception. Overall, the study showed the possibility of quantifying the reaction time components by using a simple computer simulation.

14. SUBJECT TERMS
Reaction Time, Visual Information Processing, Perception, Muscle Response, Logistic Regression

15. NUMBER OF PAGES
147

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102