REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/CI/NR-84-59T	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) USAF Security Police Officer Leadership: Effectiveness, Agreement, And The Effects Of Education And Experience		5. TYPE OF REPORT & PERIOD COVERED THESIS/DISSERTATION
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Buddy G. Smith		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS AFIT STUDENT AT: California State University - Sacramento		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS AFIT/NR WPAFB OH 45433		12. REPORT DATE 1984
		13. NUMBER OF PAGES 84
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASS
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

APPROVED FOR PUBLIC RELEASE: IAW AFR 190-17

LYNN E. WOLAVER
Dean for Research and
Professional Development
AFIT, Wright-Patterson AFB OH

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ATACHED

AD-A145 371

DTIC FILE COPY

DTIC
ELECTE
SEP 1 3 1984
B

84 09 13 023

AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to ascertain the value and/or contribution of research accomplished by students or faculty of the Air Force Institute of Technology (AU). It would be greatly appreciated if you would complete the following questionnaire and return it to:

AFIT/NR
Wright-Patterson AFB OH 45433

RESEARCH TITLE: USAF Security Police Officer Leadership: Effectiveness, Agreement, And The Effects Of Education And Experience

AUTHOR: Buddy G. Smith

RESEARCH ASSESSMENT QUESTIONS:

1. Did this research contribute to a current Air Force project?

( ) a. YES   ( ) b. NO

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not?

( ) a. YES   ( ) b. NO

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency achieved/received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of manpower and/or dollars?

( ) a. MAN-YEARS _____   ( ) b. $_____

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3. above), what is your estimate of its significance?

( ) a. HIGHLY   ( ) b. SIGNIFICANT   ( ) c. SLIGHTLY   ( ) d. OF NO
       SIGNIFICANT   SIGNIFICANT   SIGNIFICANCE

5. AFIT welcomes any further comments you may have on the above questions, or any additional details concerning the current application, future potential, or other value of this research. Please use the bottom part of this questionnaire for your statement(s).

NAME _____ GRADE _____ POSITION _____

ORGANIZATION _____ LOCATION _____

STATEMENT(s):

AFIT/NR
WRIGHT-PATTERSON AFB OH 45433

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

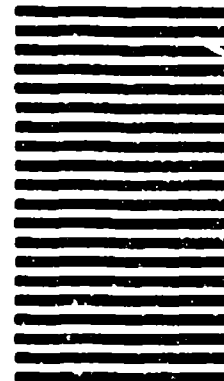## BUSINESS REPLY MAIL
FIRST CLASS   PERMIT NO. 73236   WASHINGTON D.C.

POSTAGE WILL BE PAID BY ADDRESSEE

AFIT/ DAA
Wright-Patterson AFB OH 45433

USAF SECURITY POLICE OFFICER
LEADERSHIP:
EFFECTIVENESS, AGREEMENT, AND THE
EFFECTS OF EDUCATION AND EXPERIENCE

Buddy G. Smith
B.S., Texas Christian University,
Ft. Worth, Texas

THESIS

Submitted in Partial Satisfaction of
the requirements for the degree of

MASTER OF ARTS

in

CRIMINAL JUSTICE

at

CALIFORNIA STATE UNIVERSITY, SACRAMENTO

Summer
1984

84 09 13 023

USAF SECURITY POLICE OFFICER

LEADERSHIP:

EFFECTIVENESS, AGREEMENT, AND THE

EFFECTS OF EDUCATION AND EXPERIENCE

A Thesis

by

Buddy G. Smith

_____, Chair
James M. Poland, Ph.D.

_____, Second Reader
Thomas R. Phelps, Ph.D.

Date:_____

ii

Name of Student: Buddy G. Smith

I certify that this student has met the requirement for
format contained in the Manual of Instructions for the
Preparation and Submission of the Master's Thesis, and that
this thesis is suitable for shelving in the Library and
credit is to be awarded for the thesis.

Thomas R. Phelps, Ph.D   Date
Department of Criminal Justice

iii

Abstract

of

USAF SECURITY POLICE OFFICER

LEADERSHIP

EFFECTIVENESS, AGREEMENT, AND THE

EFFECTS OF EDUCATION AND EXPERIENCE

by

Buddy G. Smith

Statement of the Problem

The effects of education and experience on leadership
are at best disputed. In the USAF both are viewed as
methods of creating effective leaders. Professional
militray education teaches leadership theory while
experience is believed to increase an officer's ability to
lead. This study asked four questions concerning: (1) the
leadership effectiveness of security police officers; (2)
the level of agreement between the officers, their
subordinates and/or superiors, on the officer's behavior in
given leadership situations; (3) the relationship between
professional military education and leadership
effectiveness; and, (4) the relationship between experience
and leadership effectiveness.

Sources of Data

Thirty-three security police officers and 126 subordinates/superiors in eight security police squadrons in California were surveyed. Data was gathered using a Professional Military Education and Experience Survey and Hersey and Blanchard's LEAD-instruments.

Conclusions Reached

(1) Security police officers are effective leaders as measured by the LEAD-instruments;

(2) There is a significant level of agreement between officers, subordinates and/or superiors on an officer's behavior in given situations;

(3) Professional military education was not found to be a significant factor in determining the leadership effectiveness of the officers surveyed;

(4) Experience was not found to be a significant factor in determining the leadership effectiveness of the officers surveyed.

James M. Poland, Ph.D.
Committee Chairman

v

Dedication

This thesis is dedicated to my wife, Therese, who provided outstanding support to me during the last year, and to my childred, Stacey and Ryan, who were often neglected because of the rigors of higher education.

Secondly, this effort is dedicated to those military personnel who have endured or are enduring poor leadership. Many officers sincerely care about how they lead and strive to be good leaders. Understanding how to lead is difficult, and, for some, actually leading is impossible. Hopefully, this effort will shed some light on understanding more about a little understood problem.

Table of Contents

Tables

CHAPTER 1

The Problem

Introduction

The United States Air Force (USAF) has a vital mission in the defense of the United States of America. This mission varies depending upon foreign policy and the current political administration. The Air Force is required to maintain resources, installations, and people to fulfill its missions.

In many ways the Air Force is a microcosm of our larger society only with more structure. As an organized society, the USAF requires special skills to fulfill its mission. Many of these skills relate directly to civilian occupations. Police services are included in this category.

USAF police services are provided by security police organizations. These organizations have two basic missions or goals: Training; and, Military Readiness. These units provide security and law enforcement services to USAF installations while maintaining their readiness and training missions.

1

Like other police organizations, each USAF securi-
ty police mission is carried out by people: officers
and enlisted personnel. Using people to accomplish
goals necessitates the use of leadership and management
practices. Security Police leaders are required to
lead and manage subordinate personnel in the
accomplishment of the missioned assigned by the USAF.

Statement of the Problem

The diversity of security police missions is de-
signated by regulation and policies. Organizational
goals are predetermined by USAF regulations particular
to the security police career field. However,
regulations nor policies can specify how security
police personnel or organizations will be led.

Because security police goals are achieved through
people, it can be argued that effective leadership is
necessary to achieve predetermined organizational goals.
Security police officers are normally charged with the
respon ibility of attaining and maintaining the preset
goals. How officers reach the goals may or may not be
questioned. Since the actual work is normally accom-
plished by subordinate personnel the leadership style
of the officer becomes a key issue.

In a given situation the use of a particular leadership style may or may not be conducive to goal accomplishment. Because security police personnel are charged with protecting millions of dollars worth of resources and lives, security police effectiveness in accomplishing assigned missions is paramount.

If subordinates fail to carry out the assigned tasks because the officer used a leadership style inappropriate for the situation, then both are ineffective. Consequently, the officer's role in leading subordinates to goal attainment is also paramount.

Officers must learn how to lead. It is assumed, for the purposes of this paper, that officers learn to use a particular leadership style because of factors in their background, such as education and experience

The crux of the problem rests on the assumption that USAF security police officers need to be effective leaders in order to carry out assigned missions which is one reason why there are approximately 1000 security police officers. The factors which cause security police officers to be effective leaders need to be examined to determine how to create effective officers in the future. Specifically, the purpose of this study will explore the relationship between security police officer experience, professional military education, and

leadership effectiveness.

Need

Leadership has been researched and analyzed from the perspectives of leader traits to how leaders function in a group.[1] Many civilian and military organizations have been studied and analyzed from one or more of these research perspectives.[2,3,4,5,6] However, little empirical analysis has been done concerning the leadership effectiveness of USAF security police officers.

Past problems associated with military effectiveness during and since the Vietnam conflict have been studied from perspectives such as the failure of military officers to properly lead in combat and/or in organizational effectiveness.[7,8,9] The inability to lead effectively is a critical issue in the military.[10,11,12]

Because USAF security police organizations must be able to transition from a peace time mission into a conflict role on short notice, and to engage in combat operations in the event of war or conflict, as well as preforming their normal police and security duties, effective leadership must be present. Effective

leadership has been a historical requirement of the military.[13] It is still a requirement today. However the reasons behind leader- ship effectiveness are not always known.[14]

There exists a need to both to identify and understand the reasons for effective or ineffective leadership ability in security police officers. Determining what causes security police officers to be effective leaders will allow a better understanding of how to develop such effective leadership in security police junior officers as well as how to eliminate ineffectiveness. Such understanding will also provide a picture of the leadership styles and effectiveness of the security police officers studied.

General Research Questions

In exploring the relationship between security police officers leadership experience, professional military education and leadership effectiveness, the following research questions will be addressed:

1. Are USAF security police officers effec-
   tive leaders?

2. How much agreement is there between
   officers, and their followers and

superiors on an officers behavior in
a given set of leadership situations?

3. Is security police officer leader effec-
tiveness associated with the number of
professional military education courses
completed?

4. Is USAF security police officer leader
effectiveness directly related to his or
her experience?

The answers to these four questions should lead
to a better understanding of the causes of USAF secu-
rity police officer leader effectiveness or in-
effectiveness, verifying or negating the effect of
professional military education and experience on
leadership effectiveness.

Research Variables

To answer the research questions, relationships
between specific variables will be explored. First,
data will be gathered on two independent variables: (1)
the number of professional military education courses
completed; and (2) the experience level of security
police officers. Then twelve leadership situations
will act as intervening variables from which the

leadership effectiveness of security police officers
(dependent variable) will be determined. The
effectiveness determination will be made by comparing
the leadership style which the officer believes he
would use in the given situations with the perceptions
which both superiors and followers have of that
officer's leadership style in the same situation.

Theory

The theory used in this study is drawn from re-
search by Paul Hersey and Ken Blanchard.[15] This
theory is based on the leader understanding both the
leadership situation and the maturity levels of his/
her followers prior to attempting to influence the
followers in the accomplishment of a task[16]. Hersey
and Blanchard state that leaders must remain flexible
because of the dynamics involved in the followers and
the situation. Effectiveness depends upon an accurate
assessment of each and an appropriate response. The
focus is on whether the leader understand the maturity
level of his/her followers in relation to the situation
and whether he/she leads them in a manner which will
enable them to not only complete the task but also to
complete it willingly.[17]

Closely related to and expounded on by Hersey and Blanchard[18] is Likert's identification of variables which affect organizational effectiveness.[19] Likert's intervening variables contain various dimensions of leadership skills and communication, each being a key element in Hersey and Blanchard's leadership style and effectiveness.[20] Hersey and Blanchard indicate that leaders develop their style(s) over a period of time from experience, training, and education.[21] These factors, as they affect leadership effectiveness, are to be explored.

Professional military education falls into the training and education dimensions used by Hersey and Blanchard. These schools are the primary tools which the USAF uses to teach officers leadership theory, while at the same time allowing officers to use the theories in controlled leadership situations. Security police officer leadership effectiveness will be explored based on the theory that professional military education does directly affect leadership skills.

Terms and Definitions

There are specific terms and concepts used in the study of leadership many of which are employed here.

For clarity, specific terms and concepts used in this study are defined as follows:

1. Leadership is the process of influencing the activities of an individual or a group in efforts toward goal achievement in a given situation.[22]

2. Management is working with and through individuals and groups to accomplish organizational goals.[23]

3. Leadership Effectiveness is the use of a leadership style that is appropriate for a given situation.[24]

4. Leadership Success is leading subordinates to the successful completion of a task.[24]

5. A Leadership Style is the consistent behavior patterns used by leaders when working with and through other people, as they are perceived by other people.[25]

6. Professional Military Education is military education (in-residence or by correspondence) that is general in nature and which, in part, deals with leadership roles in military life.

7. USAF Security Police Officers are those USAF officers whose primary, full-time Air Force duty is in the security police career field.

8. Subordinates are USAF personnel responsible to USAF security police officers.

9. Peers are defined as USAF security police officers, equivalent by position or rank, to other security police officers.

10. Superiors are those USAF officers assigned by regulation to be responsible for the actions of subordinate personnel.

11. Leadership Communication is the written, verbal, and non-verbal communication used by a security police officer attempting to lead subordinate personnel.

12. Perceived Behavior is the perception other people (peers, subordinates, and superiors) have about the way a particular officer leads subordinates.

13. Leader Perception is the way each security police officer perceives his/her behavior in situations where the leader attempts to use leadership skills.

14. Leadership Situations are those instances in which a security police officer uses a leadership style.

15. Maturity Levels:

A. Job Maturity is the ability of a fol-
lower to do a task;

B. Psychological Maturity is the willing-
ness or motivation to do the job.[26]

16. Four Specific Leadership Styles:

A. A Telling Style is one in which the
leader defines what, how, and where
work is tp be done.

B. A Selling Style is one in which the
leader directs what is to be done but
supports the follower's desires to do
the task willingly.

C. A Participating Style is one where the
leader does not direct subordinates
but shares decision making with them.

D. A Delegating Style is one in which the
leader provides little direction or
support. He/she lets subordinates
decide how the task is to be completed
and when.[27]

Organization of Remainder of Thesis

Detailed aspects of this research are dealt with
in subsequent chapters of this study. First,

leadership literature pertinent to this study is
reviewed in Chapter 2. In Chapter 3 the methodological
plan of this study is explained in detail. Third,
Chapter 4 contains an analysis of the data collected by
the method detailed in Chapter 3. Fourth, a section
dealing with conclusions and recommendations is
presented. Fifth are the appendices and lastly is the
bibliography.

Before dealing with the methodology and analysis,
it is necessary to review the literature pertinent to
this particular work.

Notes

[1] Ralph M. Stogdill, Handbook of Leadership (New York: Free Press, 1974), pp. 5-6.

[2] Martin G. Evans, "Leadership Behavior: Demographic Factors and Agreement Between Subordinate and Self-Descriptions," Personnel Psychology 25 (1972): 649-653.

[3] Paul R. Bleda et al, "Enlisted Men's Perception of Leader Attributes and Satisfaction With Military Life," Journal of Applied Psychology 62, no. 3 (1977): 43-49.

[4] Henry P. Sims, Jr. and Andrew D. Szilagyi, "Leader Reward Behavior and Subordinate Satisfaction and Performance," Organizational Behavior and Human Preformance 14 (1975): 426-438.

[5] Charles N. Greene, "The Reciprocal Nature of Influence Between Leader and Subordinate," Journal of Applied Psychology 60, no. 2 (1975): 187-193.

[6] Fred E. Fiedler, "Organizational Determinants of Managerial Incompetence," in Crosscurrents in Leadership, eds. James G. Hunt and Lars L. Larsen (Carbondale: Southern Illinois University Press, 1979), pp. 11-23.

[7] Richard A. Gabriel and Paul L. Savage, _Crisis in Command: Mismanagement in the Army_ (New York: Hill and Wang, 1978).

[8] Sam C. Sarkesian, ed., _Combat Effectiveness_ (Beverly Hills: Sage, 1980), pp. 8-18.

[9] Office of Military Leadership, United States Military Academy, _A Study of Organizational Leadership_ (Harrisburg: Stockpole Books, 1976).

[10] Gabriel and Savage, p. 51-96.

[11] William L. Hauser, "The Will To Fight," in _Combat Effectiveness_, ed. Sam C. Sarkesian (Beverly Hills: Sage, 1980), pp. 206-211.

[12] Norman Grunstad, "Overview, USAWC Study of Leadership for the 1970's," in _A Study of Organizational Leadership_, eds. Office Of Military Leadership, United States Military Academy (Harrisburg: Stockpole, 1976), pp. 322-329.

[13] General Sir John Hackett, _The Profession of Arms_ (New York: Macmillian, 1983), pp. 215-228.

[14] Wayne L. Gosnell, "The Air Force Is Making Occupationalist Of Its Junior Officers" (Research Report to the USAF Air War College, 1980), p. 28.

[15] Paul Hersey and Ken Blancard, _Management of Organizational Behavior_ (Englewood Cliffs: Prentice-Hall, 1982).

[16] Hersey and Blanchard, pp. 152-155.

[17] Hersey and Blanchard, pp. 153-257.

[18] Hersey and Blanchard, pp. 111-112.

[19] Rensis Likert, The Human Organization (New York: McGraw-Hill, 1967), pp. 26-29.

[20] Hersey and Blanchard, pp. 243-245.

[21] Hersey and Blanchard, pp. 127-128.

[22] Hersey and Blanchard. p. 83.

[23] Hersey and Blanchard, p. 3.

[24] Hersey and Blanchard, p. 109.

[25] Hersey and Blanchard, p. 126.

[26] Hersey and Blanchard, p. 157.

[27] Hersey and Blanchard, p. 153.

Chapter 2

Literature Review

Introduction

In this century many different aspects of
leadership have been identified and researched.[1] In
fact, more has been written about leadership than any
other single topic. The preponderance of research
agrees that leadership does not exist in a vacuum. Four
basic perequisites must be present for leadership to
exist: (1) a Leader; (2) Followers; (3) a Situation;
and, (4) a Goal to be achieved with and through people.

Researchers often disagree on exactly how these
elements interact.[2,3,4,5] Some researchers focus on
the leader, some on the followers, while others focus
on the situation. There have been attempts to fuse
these elements into an integrated concept. For example,
Hersey and Blanchard developed a theory which explains
the leader's role and actions in relation to both the
followers and the situation.[6]

Hersey and Blanchard state that their Situational
Leadership Theory involves an interplay between the

guidance a leader gives, the amount of socioemotional support a leader provides, and the maturity level which followers exhibit in performing a specific task.[7]

The use of a particular leadership style may or may not be conducive to leadership effectiveness depending upon the situational factors involved. Determining how to evaluate the situational factors and then how to select and apply a particular type of leadership behavior to a particular situation is a learned process. There are many sources from which USAF security police officers learn to lead. Two readily stand out: (1) Professional Military Education; and, (2) Experience in security police squadrons.

Leadership theory and practice are taught at professional military education schools. Correspondence courses teach leadership theory only, while in-residence courses teach theory and also allow officers the opportunity to practice leadership on the sports field and in the classroom. Consequently, professional military education serves as one of the primary methods through which the USAF teaches leadership to its officers. Leadership experience is gained during professional military education; however, this constitutes a small percentage of security police officer leadership experience because not all

officers attend professional military education schools and the schools are short in duration compared to the assignments to squadrons. Most leadership experience is gained during the years an officer serves in security police squadrons. The activities of security police squadrons are accomplished by and through people. Security police officers are required to ensure that the mission of the organization is accomplished and this, in turn. entails the use of management and leadership techniques.

This study contends that these two processes (professional military education and experience) significantly help determine both an officers leadership behavior in given situations and his/her level of leadership effectiveness. The idea that leadership can be taught is generally supported by other theorists.[8,9,10,11,12] They state that leadership education, in one form or another, helps make leaders more effective and each supports the contention that leadership can be successfully taught. However, not every article supports or is aligned with the way the USAF teaches leadership. Several theories are used by the USAF in its professional military education schools. Each is based on the idea that people can be taught to lead effectively.

Of secondary concern to this study is the idea
that agreements between leaders and others on percep-
tions of leader behavior is necessary for effective
leadership. This concern stems from Stogdill's
observation that leadership training which is not
related to follower actions is ineffective.[13]
Consequently this study determines the relationship
between professional military education, experience,
and leadership effectiveness using followers as partial
evaluators of leader effectiveness.

Effective leadership affects the actions of the
followers. When a leader knowingly uses a particular
leadership style in a given situation, clearly
communicates the style being used, and ensures that
subordinates, and possibly superiors, perceive it
properly, he/she is effective. If the leader's act is
purposeful, and subordinates perceive that way and
relate to it properly, then the leader is effec-
tive.[14]

Subordinates' reactions to leader behavior is
complex. They can react positively toward the leader
or the job, or negatively if they misperceive the
leader's intention. Knowledge of the varying kinds and
degrees of subordinate reaction to leader behavior is
limited only by the extent of the research conducted in

this area.

When subordinate misperception occurs, task accomplishment can be threatened. This is especially true for long-range tasks. Short-range goals can usually be accomplished regardless of leader/subordinate rapport. However, long term goals such as combat effectiveness demands proper leader/subordinate interaction without which combat effectiveness may not be attained or maintained. In the event of a national emergency in which USAF security police personnel are employeed, ineffective leadership could result in the unnecessary loss of life and/or resources.

It is, therefore, imperative to determine the leadership effectiveness levels of USAF security police officers. This will be accomplished by determining the level of agreement between the officer and his/her subordinates. Perceptual agreement on leader behavior is an indicator of effective leadership. Accordingly, officers with higher levels of professional military education and experience at the security police squadron level should be more effective leaders.

Understanding the consequence of education and experience on leadership effectiveness necessitiated a review of the available literature. It became readily apparent that the magnitude of leadership literature

was a problem in itself. Stogdill stated that the
endless accumulation of empirical data over the last 40
years has failed to produce and integrated
understanding of leadership.[15]   A vast amount of
leadership literature deals with the perception of
leader behavior between leaders and followers and the
ramification of this agreement or disagreement on sub-
ordinate personnel and organization effectiveness.[16]
The problem with reviewing a large quanity of empirical
research in the area of leadership was compounded by a
scarcity of research on the relationship between leader
background factors and leadership effectiveness. The
scarcity of empirical studies which deal with this
relationship necessitated a review of the literature
which concentrated on whether or not individuals can be
trained to become effective leaders.

The studies and theories reviewed are listed in
Tables 2.1 and 2.2. Table 2.1 lists leadership
training theories by author(s) with a brief description
of their leadership training theory. Table 2.2 shows
research studies on the perceptions of leadership
behavior and subsequent effects. The table contains a
listing of authors and a synopsis of their hypotheses
or research questions, variables, and research findings.
Authors are listed alphabetically in each table. Ideas

or findings specifically used in this study are further reviewed in the summary of this chapter.

Table 2.1
Leadership Training Theories

Author(s) & Year	Theory
Blake and Mouton[17] (1982)	Leaders can be taught to use one style of leadership for every situation.
Fiedler[18] (1981)	Leadership behavior is affected by intelligence and experience combined with organizational and situational factors.
Hersey and Blanchard[19] (1982)	Leaders can be trained to select the proper leadership style based on the situation and maturity levels of the followers.
Isenhart[20] (1983)	People can be trained to lead effectively by placing them in group situations, rotating leader responsibility in a low threat environment.

Litzinger and Schaefer[21] (1982)	People learn to lead from experiences as followers They experience the problems of leadership from a followers point of view and are able to become more effective leaders because of it.
Metcalfe[22] (1982)	Leaders should be trained to lead based upon the behavioral sciences and social interaction between individuals.
Sinetar[23] (1981)	Leadership can be taught by developing skills, experiences, knowledge, and intuitive understanding of the requirements of leadership in a particular organizational environment.
Tannenbaum and Schmidt[24] (1973)	Leader behavior is greatly influenced by background, knowledge, and experience factors.
Vroom[25] (1976)	Leaders can be taught to enlarge their leadership styles and to match the right style to the demands of the leadership situation.

Table 2.2
Leadership Studies

Author & Year	Synopsis of Study
Barrow[26] (1976)	Hypotheses: (1) Under conditions of low subordinate performance the leader will be more task oriented. (2) Under conditions of high subordinate performance the leader will be more supportive. (3) Under conditions of high task complexity the leader will be task oriented. (4) Under conditions of low task complexity the leader will be more supportive. (5) When subordinate performance improves the leader will become more supportive. (6) When subordinate performance declines the leader will use task oriented behavior.
	Variables: The Independent Variable was subordinate performance. The Dependent Variable was leader behavior.
	Findings: Subordinate performance was a strong causal factor force in determining the behavior of a leader. Low subordinate performance caused leaders to behave in an autocratic manner, while high performance caused leaders to behave in a more considerate manner.
Bass et al[27] (1975)	Purpose: To describe how the frequency of the appearance of leadership style is related to the situational requirements.
	Variables: Independent Variables were the task, organizational style, and interpersonal inputs. The Dependent Variables were leader effectiveness and subordinate satisfaction.
	Findings: Situational Variables are directily associated with the use of a particular leadership style. An explanation of style difference must consider

the organizational clarity, climate,
task, and consequence of interpersonal
relations.

Bleda et al[28]
(1977)

Hypotheses: (1) Satisfaction with the
quality of Army life is related to the
behavior of both the orginators of
orders and the givers of orders. (2)
The association between satisfaction
and orginator behavior would be re-
latively greater than the corresponding
relation for the giver.

Variables: The Independent Variable was
the perception of difference in leader
functions, while the Dependent Variable
was satisfaction with Army life.

Findings: Overall mangement, not just
the immediate leader, plays a crucial
role in determining the nature of the
rank and file's experience in the mil-
itary. Improve the actions of the lead-
ers who formulate the duties rather
than the one who relays the orders.

Evans[29]
(1972)

Purpose: To explore the demographic
characteristics of the supervisors and
followers to see if the demographic
characteristics contribute to the like-
lihood of agreement or disagreement in
describing leadership styles of the
supervisors.

Variables: Independent Variable was
demographic factors. The Dependent
Variable was agreement between the
leaders and followers.

Findings: There are no demographic
factors that consistently result in the
supervisor and his followers being more
likely to agree in describing super-
visory leadership behavior.

Ferris[30]
(1983)

Hypothesis: Leadership behavior focused on job autonomy will influence subordinate perception of the job and will not affect other job characteristics.

Variables: The Independent Variable was leadership behavior, while the Dependent Variable was the perception of job automony.

Findings: Subordinates working under conditions of high consideration and low structure perceived a high level of job autonomy but at a lower level than did those whose leaders used low consideration and high structure.

Greene[31]
(1975)

Purpose: To assess the causal relationship between leader style and subordinate satisfaction and performance.

Variables: (1) The Independent Variable was leadership styles used. The Dependent Variable was subordinate satisfaction and performance.

Findings: Leaders using a consideration style cause subordinates' satisfaction with the job to be higher while subordinate performance can cause leaders to use both higher consideration and structure. Leaders can positively affect subordinate performance by increased emphasis on both consideration and structure.

Jones et al[32]
(1975)

Position: High job-involvement persons, having greater identification with the job, will place greater emphasis on effective leadership.

Variables: The Independent Variable was the perception of a leader's job orien-

tation behavior and effectiveness. The Dependent Variable was employee confidence and trust in the leader.

Findings: Job involvement did not influence perceived leader behavior. It did seem to affect relationships between leader behavior and subordinate trust and confidence in the leader.

Kuykendall and Unsinger[33] (1982)

Purpose: To describe and analyze the leadership styles of 155 police managers.

Findings: Police managers are at least as effective, if not more so, when compared with other managers. Police managers primarily use the selling, telling, and participating styles. The delegating style is infrequently used due to factors unique to police jobs.

Rees and O'Karma[34] (1980)

Purpose: To determine the differences between the supervisor's self-perception of his leader behavior style and subordinates' perception of that same style.

Findings: Found statistically significant differences between perceptions of leader and subordinates on given leadership behavior.

Sims and Szilagyi[35] (1975)

Hypothesis: Leader reward behavior will have a direct relationship on subordinate satisfaction and performance.

Variables: Independent Variable is leader reward behavior. Dependent variable is subordinate job satisfaction and performance.

> Findings: Results supported the
> hypothesis that when the leader provides
> positive reward behavior, subordinates
> performed better and had better job
> satisfaction.

Summary

The effects and value of education and experience
on leadership are, at best, disputed. Regardless, this
study contends that these two factors have a direct
bearing on leadership effectiveness and will examine
the relationship between the USAF security police
officer's leadership effectiveness, his/her experience,
and his/her professional military education completion
rates. The literature reviewed in this chapter served
as a guide in developing the variables, research
questions, and methodology of this study. Hersey and
Blanchard's Situational Leadership Theory served as the
base from which this study evolved.[36] Kuykendall and
Unsinger's study of leadership styles in police
managers provided insights into leadership styles used
by police managers.[37] In addition, their methods of
reporting the data was used as a guide when preparing
Chapter 4 of this study. Lastly, their results are

compared with the leadership data found on security
police officers.

The disparities in perceptions between leaders and
subordinates in given leader behavior found by Rees and
O'Karma provides a comparison between security police
and civilian managers.[38] Their findings which state
that leaders and subordinates disagree over the
perception of leader behavior served as the basis for
one of the questions in this study.

Evans provided the idea that certain factors
affect a leader's ability to lead effectively.[39] His
study looked at demographic factors which he thought
assisted in the perceptual agreement between leader and
followers for given leadership behavior. He compared
these factors with the level of agreement between
leaders and supervisors but found no factors which
affected agreement in every case.[40] Evans'
thought-provoking study served as a reference point
when filling in the conceptual void encountered during
the early phases of this research.

The aforementioned studies aided in the
conceptualization of exactly what comprises effective
leadership, each providing either ideas or comparative
data which assisted in this study of USAF security
police officer leadership effectiveness.

Locating research studies on the causes of leader-
ship effectiveness proved difficult yet a wide range of
theories on those factors which affect leader behavior
were readily available and many ideas were put forth.
Several writers stated that education and background
were important.[41,42,43]   Others stated training was
an important element in determining leadership style.
[44,45,46]   Regardless of divergent views, they
corporately reinforced the belief that each of these
two factors (education and experience) in some way
directly affects leadership style and effectiveness.
As a result, these theories directed this study toward
the evalua- tion of professional military education and
experience as factors which affect USAF security police
officers' leadership effectiveness. Each theory
provided a clearer understanding of the problem and
helped formulate the method by which the problem was
studied.

Notes

[1] Ralph M. Stogdill, Handbook of Leadership (New York: The Free Press, 1974), pp. 6-7.

[2] Fred E. Fiedler, "Leadership Effectiveness," American Behavioral Scientist 24, no. 5 (May/June 1981): 619-632.

[3] Victor H. Vroom, "Can Leaders Learn to Lead?" Organizational Dynamics 3-4 (Winter 1976): 17-28.

[4] Robert Tannenbaum and Warren H. Schmidt, "How to Choose a Leadership Pattern," Harvard Business Review (May-June 1973): 162-180.

[5] Paul Hersey and Ken Blanchard, Management of Organizational Behavior (Englewood Cliffs: Prentice-Hall, 1982), p. 151.

[6] Hersey and Blanchard, pp. 150-175.

[7] Hersey and Blanchard, pp. 151-154.

[8] Robert R. Blake and Jane S. Mouton, "How to Choose a Leadership Style," Training and Development Journal, (February 1982): 39-47.

[9] Myra W. Isenhart, "An Investigation of the Interface Between Corporate Leadership Needs and The Outward Bound Experience," Communication Education 32 (January 1983): 123-129.

[10] Beverly M. Alban Metcalfe, "Leadership:

Extrapolating From Theory and Research to Practical Skills Training," Journal Of Management Studies 19, no. 3 (1982): 295-304.

[11] Marsha Sinetar, "Developing Leadership Potential," Personnel Journal (March 1981): 193-196.

[12] Vroom, pp. 17-28.

[13] Stogdill, pp. 198-199.

[14] Hersey and Blanchard, pp. 232-261.

[15] Stogdill, p. vii.

[16] Stogdill, pp. 327-403.

[17] Blake and Mouton, pp. 39-47.

[18] Fiedler, pp. 619-632.

[19] Paul Hersey and Ken Blanchard, "Leadership Style: Attitues and Behaviors," Training and Development Journal, (May 1982): 50-52.

[20] Isenhart, pp. 123-129.

[21] William Litzinger and Thomas Schaefer, "Leadership Through Followership," Business Horizons 25, no. 5 (1982): 78-81.

[22] Metcalfe, pp. 295-304.

[23] Sinetar, pp. 193-196.

[24] Tannenbaum and Schmidt, pp. 162-180.

[25] Vroom, pp. 17-28.

[26] Jeffrey C. Barrow, "Worker Performance and Task Complexity as Causal Determinants of Leader

Behavior Style and Flexibility," Journal of Applied Psychology 61, no. 4 (1976): 433-440.

27 Bernard M. Bass et al, "Management Styles Associated with Organizational, Task, Personal, and Interpersonal Contigencies," Journal of Applied Psychology 60, no. 6 (1975): 720-729.

28 Paul Bleda et al, "Enlisted Men's Perception of Leader Attributes and Satisfaction with Military Life," Journal of Applied Psychology 62, no. 1 (1977): 43-49.

29 Martin G. Evans, "Leadership Behavior: Demographic Factors and Agreement Between Subordinate and Self-Descriptions," Personnel Psychology 25 (1972): 649-653.

30 Gerald R. Ferris, "The Influence of Leadership On Perceptions Of Job Automony," The Journal of Psychology 114 (1983): 253-258.

31 Charles N. Greene, "The Reciproral Nature of Influence Between Leader and Subordinate," Journal of Applied Psychology 60, no. 2 (1975): 187-193.

32 Allan P. Jones et al, "Perceived Leadership Behavior and Employee Confidence in the Leader as Moderated by Job Involvement," Journal of Applied Psychology 60, no. 1 (1975): 146-149.

[33] Jack Kuykendall and Peter C. Unsinger, "The Leadership Styles of Police Managers," Journal of Criminal Justice 10 (1982): 311-321.

[34] Richard T. Rees and James G. O'Karma, "Perception of Supervisor Leadership Style in a Formal Organization," Group and Organizational Studies 5, no. 1 (March 1980): 65-69.

[35] Henry P. Sims and Andrew D. Szilagyi, "Leader Reward Behavior and Subordinate Satisfaction and Performance," Organizational Behavior and Human Performance 14 (1975): 426-438.

[36] Hersey and Blanchard, Management, pp. 150-175.

[37] Kuykendall and Unsinger, pp. 313-316.

[38] Rees and O'Karma, pp. 67-68.

[39] Evans, p. 651.

[40] Evans, p. 651.

[41] Tannenbaum and Schmidt, p. 173.

[42] Litzinger and Schaefer, p. 79.

[43] Hersey and Blanchard, Management, p. 111.

[44] Sinetar, p. 195.

[45] Vroom, pp. 21-26.

[46] Isenhart, pp. 123-125.

Chapter 3

Methodology

Introduction

There often exists little agreement between the
self-perception of leaders and a description of that same
behavior by subordinates.[1] Leaders can perceive their
behavior in one way, while followers see the same behavior
quite differently. There is a correlation between the level
of perceptual agreement and leadership effectiveness. The
higher the level, the more effective the leader.[2]

But what causes leaders to be effective or ineffective?
Hersey and Blanchard identify education, experience, and
training as factors which help determine the leadership
style used and subsequent effectiveness of leaders.[3]
Leadership training is considered important in developing
leadership effectiveness.[4,5,6,7] Leadership experience is
also thought to enhance a persons ability to effectively
lead subordinates to goal accomplishment.[8] Consequently,
the effects of training and experience can be viewed as
crucial elements in the development of effective leaders.

The idea that training and experience lead to

effective officers is the general consensus in the USAF today. Officers are trained, directly and indirectly, on and off the job, to lead subordinate personnel, and then given a chance to experience the use of leadership. Direct training and experience is provided in professional military schools and in the unit of assignment. The exploration of professional military education and experience, as they relate to the leadership effectiveness of USAF security police officers is the goal of this study. This exploration will be accomplished by analyzing security police officers' professional military education and experience levels as they affect leadership effectiveness.

Subsequent subsections of this chapter specify the methods which are used in the gathering and analysis of data pertinent to this thesis.

Sample

The officers who participated in this study were purposely selected from security police squadrons at seven USAF installations in California. The installations were Mather, Beale, Mclellan, Travis, Castle, Vandenberg, and March Air Force Bases. Only data on officers whose primary duties and training are in the security police careef field was obtained. The 33 officers surveyed were male and

female security police officers with ranks ranging from
second lieutenant to lieutenant colonel. Their positions
ranged from shift supervisor to chief of security police.
The officers had from less than one year to over twenty
years of experience in the military. Ages ranged from 21 to
45 years. Data was not obtained as to how they were
commissioned (i.e., Reserve Officer Training Corps, Officer
Training School, or USAF Academy), nor was data concerning
race or socioeconomic background. This data was not
considered relevant to this study. The officers surveyed
were purposely selected from USAF installations in
California because of time and financial constraints.

There are approximately 1000 security police officers in
the USAF, ranging in rank from second lieutenant to brigider
general, with over half being majors or below.[a] They are
stationed throughout the free world on USAF installations or
on separate assignments. The officer sample used in this
study is representative of the security police officer
population.

Other security police personnel surveyed were
subordinate or superior to the sample officers. An average
of four people per sample officer was selected from this

----

[a] Provided by USAF Personnel Center, Randloph AFB, Texas.

group. One was a superior officer, the rest were
subordinate to the sample officers. The surveyed superior
officers were security police officers who normally
supervise the sample officer. No officers outside of the
security police squadrons were surveyed. Subordinate
personnel were randomly selected from personnel subordinate
to each sample officer. Where possible, a senior
noncommissioned officer, a noncommissioned officer, and an
airman were selected to give their perceptions of the
officer's leader behavior. This subsample of subordinate
and superior personnel provided cross-section perception of
the sample officers leadership behavior in given situations.

Measures

Three instruments were used to collect data. The first,
titled the Professional Military Education and Experience
Survey, hereafter referred to as the PMEES, was specifically
developed for this study (see Appendix 1). The second set
of instruments is the Leadership Effectiveness and
Adaptability Demensions (LEAD)-instruments developed by
Hersey and Blanchard.[9]

The PMEES measures the number of professional military
education courses completed and the experience level of
security police officers both in the military and in the

security police career field. The focus is on those
positions at the squadron level. These two areas, profes-
sional military education course completion rates and expe-
rience the independent variables used in this study.

The PMEES was pretested on five security police
officers and found very reliable in obtaining the desired
data. The instrument collects all possible data on
professional military education and experience in the
security police career field. The PMEES is estimated to be
very reliable in accurately collecting this data.

The Leadership Effectiveness and Adaptability
Dimensions (LEAD) instruments contains twelve work related
situations, each representing three instances of the four
maturity states of the followers. Four alternative
leadership styles are presented on the survey. The
LEAD-Self requires the sample officer to select the one
style which best describes his/her leadership behavior in
the situation.[10] The LEAD-Other is the same instrument as
the LEAD-Self but written for a subordinate or superior to
complete.[11]

The LEAD-Self was designed to measure self-perception
of three aspects of leader behavior: (1) style; (2) style
range; and, (3) style adaptability.[12] Primarily the
LEAD-Self provides a picture of how the officer perceives
he/she behaves (or would lead) in given situations. The

LEAD-Other indicates how others perceive an officer's leadership behavior in the same situations.

Hersey and Blanchard indicate that the higher the level of agreement between the leader and others in the twelve situations the greater the effectiveness of the leader.[13] Thus the leadership effectiveness of an officer can be determined by comparing the way others perceive his/her behavior in given situations with the officer's own perceptions.

Leadership effectiveness is also determined by obtaining the effectiveness score from the LEAD-Self. This score is obtained through the Style Adaptability Score achieved by the officer.[14] This effectiveness score is determined by adding the score given to each alternative selected and then totaling them. Combined effectiveness scores for the LEAD instruments serve as the dependent variable for this study, i.e. leadership effectiveness.

When pretested on security police personnel the LEAD instruments were found to be excellent survey intruments. Post questioning of pretested officers and subordinates revealed the twelve situations presented on the LEAD instruments were closely related to everyday leadership problems encountered by security police managers. Subordinate personnel reported the situations and responses selected were within situations encountered in the course of

the job and reflected normal leader responses seen.
Because the situations presented were so general and the
fact that pretested individual found the situations very
similar to ones encountered, the instruments are viewed as
reliable in determining the leadership style and
effectiveness of USAF effectivenss of USAF security police
officers.

USAF security police officers are considered a fairly
homogenous group, especially in the areas being studied.
Each officer faces similar types of experiences,
professional military education, and training, at different
points in his/her career. The sample used in this study is
representative of the entire career field--they are shift
commanders, operations officers, chiefs of security police,
and commanders. Because of their similarity to other USAF
security police officers, the responses obtained in this
study are considered representative of the entire security
police officer corps.

Design

This study is designed to explore and then describe the
effect of professional military education and experience on
the leadership effectiveness of those USAF security police
officers surveyed. Specifically, this study explores the

correlation between the number of professional military education courses completed, the experience level of security police officers, and their leadership effectiveness. It also contains a description of the leadership styles and effectiveness of the security police officers surveyed.

Describing security police officer leadership effectiveness and exploring the relationship between variables required that the following procedures be followed.

After the nature of the problem was ascertained, suitable survey instruments were created or found. Next, the number of officers and others to be surveyed was determined. The Personnel Survey Branch at Headquarters, Military Personnel Center, Randloph Air Force Base, Texas, suggested a reduction in the number of other personnel to be surveyed. This recommendation was followed. With the numbers of sample officers determined, each chief of security police was contacted and tentative dates established for the collection of data.

Pretesting of the PMEES and LEAD instruments indicated a need to organize the instruments before-hand as well as to practice the verbal instructions to be given to the individuals surveyed.

Each officer packet contained one PMEES, one LEAD-Self and one or more LEAD-Other instruments, depending upon the officer's position in the organization (i.e., operations

officers and chiefs of security police filled out several
LEAD-Other instruments on subordinate officers; subordinate
personnel packets contained one LEAD-Other instrument.)

Subordinate personnel were selected from personnel
serving under each sample officer. Senior noncommissioned
officers, noncommissioned officers, and airmen were selected
from those personnel on duty on the day of the survey. Not
using totally random selection procedures is viewed as less
problematic than the impact of other variables, such as time
in the current leadership position and subordinate
experience and maturity, on the accuracy of the data
collected.

Using people from different pay grades, experience
levels, and ages to input their perception of the leadership
behavior of the security police officer provides a excellent
cross-sectional view of the officers. This provided a more
accurate perspective of the officers' leadership
effectiveness.

Data from the instrument was placed on work sheets.
From each work sheet officers were rank ordered on
professional military education, experience, and leadership
effectiveness. Once the rank orders were determined
correlations between the variables were obtained using the
Spearman rank order correlation coefficent.

Research Questions and Analysis

The problem in this study posed four research questions. The questions were stated in a general nature in Chapter 1. Each question is expanded so detailed analytical procedures could be presented.

Question One: Are USAF security police officers effective leaders?

This question is composed of several parts. First, there is the question of determining effectiveness, which is determined from the adaptability scores obtained from the LEAD-Self and Others.[16] The scores are totalled and divided by the number of instruments completed on each officer. The scores establish the effectiveness of the officer from varying perspectives. The scores place an officer on a scale of -24 to +24, with scores below 0 being Ineffective scores and those above 0 being Effective scores. Effectiveness for all officers is also determined by the number of leadership styles used and the appropriateness of the style to the situation.

Question Two: How much agreement exists between

officers and their followers and superiors concerning and
officer's behavior in given leadership situations?

The answer to this question will be presented in a
table showing the mean response of officers in each
situation on the LEAD instruments, and the mean response for
the others in the same situations. The table will show the
variance between how officers perceive themselves as
behaving and how others perceive their behavior in the same
situations. Agreement will be determined significant if the
t-score obtained from the comparison of means is equal to or
less than .05. Significance between intergroup means will
be determined as will significance for intragroup means.

Question Three and Four:

(3). Is securtiy police officer leader effectiveness
associated with the number of professional military
education courses completed?

(4). Is security police officer leadership
effectiveness associcated with the level of experience as a
security police officer?

A shift in analytical methodology takes place in
analyzing these last two questions. The shift is to a

statistical analysis of the interplay between the variables.
A correlation is found by applying the Spearman Rank Order
Correlation Coefficent (Spearman$_{rho}$) to the variables.[17]
This technique results in a correlation between professional
military education courses completed and leadership
effectiveness, and experience and leadership effectiveness.
Rank orders are determined by responses on the PMEES, on
education and experience, and effectiveness scores obtained
from the LEAD instruments.

It is anticipated that each correlation will be
positive indicating there is a direct relationship between
variables.

Summary

Exploring the level and causes of USAF security police
officer leadership effectiveness requires two analytical
approaches. First, the level of leadership effectiveness is
determined through the use of the effectiveness scores
obtained from the LEAD instruments. The overall leadership
effectiveness is determined from the effectiveness scores.
The level of agreement between others and the officer on
leadership behavior in given situations is also determined.
Officers are rank ordered by these effectiveness scores.
These scores are the dependent variable.

Secondly, statistical correlations between the variables are obtained. Each officer is rank ordered by the number of professional military education courses completed, by the level of experience at the security police squadron level, and leadership effectiveness. Once the rank orders are obtained they are correlated using the Spearman Rank Order Correlation Coefficent. Positive correlations are expected to be found in each case.

The exploratory design used in this study determines the effectivenss of USAF security police officers, and then determines if professional military education and experience have a causal effect on leadership effectiveness. The four research questions funnel the data toward this goal.

The need to determine the causal relationship between the variables, as stated in the problem, is to find out what makes security police officers effective leaders. Effective leadership allows the activities of peacetime security police units, with their wartime role, to be carried out to maximum capabilities. The goal of this study is to explore officer leadership effectiveness and determine ways to increase security police officers leadership effectiveness.

Notes

[1] Martin G. Evans, Leadership Behavior: Demographic Factors and Agreement Between Subordinates and Self-Description," Personnel Psychology 25 (1972): 649.

[2] Paul Hersey and Ken Blanchard, Management of Organizational Behavior, 2nd ed. (Englewood Cliffs: Prentice-Hall, 1982), p. 127.

[3] Hersey and Blanchard, p. 126.

[4] Myra W. Isenhart, "An Investigation of the Interface Between Corporate Leadership Needs and the Outward Bound Experience," Communications Education 32 (January 1983): 126.

[5] Beverly M. Alban Metcalfe, "Leadership: Extrapolating From Theory and Research to Practical Skills Training," Journal of Management Studies 19, no. 3 (1982): 300.

[6] Victor H. Vroom, "Can Leaders Learn to Lead?" Organizational Dynamics 3-4 (Winter 1976):   28.

[7] Marsha Sinetar, "Developing Leadership Potential," Personnel Journal (March 1981): 195.

[8] General Sir John Hackett, The Profession of Arms (New York: McMillian, 1983), pp. 218-219.

[9] Hersey and Blanchard, pp. 99-100.

[10] Hersey and Blanchard, pp. 243-245.

[11] Hersey and Blanchard, p. 264.

[12] Hersey and Blanchard, p. 100.

[13] Hersey and Blanchard, p. 245.

[14] Paul Hersey and Ken Blanchard, "So You Want To Know Your Leadership Style?" Training and Development Journal (February 1974): 28.

[15] Hersey and Blanchard, So You Want To Know?, p. 28.

[16] Hersey and Blanchard, So You Want To Know?, p. 28.

[17] Richard P. Runyon and Audrey Haber, Fundamentals of Behaviorial Statistics, 2nd ed. (Menlo Park: Addison-Wesley, 1972), pp. 102-104.

Chapter 4

Results

Introduction

Data used to answer the research questions was gathered from security police officers, their subordinates or superior officers, in eight security police squadrons located at Mather, Beale, Mclellan, Travis, Castle, Vandenberg, and March Air Force Bases in June 1984. The results are divided into four areas: (1) general descriptive data of the sample; (2) answers to the research questions; (3) a discussion section; and (4) a summary of the findings.

Sample Descriptive Data

Thirty-three security police officers were surveyed. They ranged in rank from second lieutenant to lieutenant colonel. Table 4.1 presents the distribution of the sample officers by rank. Table 4.2 provides the experience level of the officers by years of commissioned service in the security police career field. Table 4.3 lists the number of officers with prior experience as a USAF enlisted person.

Table 4.4 indicates security police officer attendance at
in-residence professional military education courses by
school, rank, and number, while Table 4.5 shows the number
of officers, by rank and school, who have completed
professional military education correspondence courses.

Table 4.1
Security Police Officer Distribution

Rank	Number	Percent
Second Lieutenant (0-1)	8	24
First Lieutenant (0-2)	7	21
Captain (0-3)	13	40
Major (0-4)	3	9
Lieutenant Colonel (0-5)	2	6
Totals	33	100

Table 4.2
Security Police Officer
Experience Level by Years

Years	Number	Percent
< 5	20	61
6-10	10	30
11-15	1	3
16-20	2	6
Totals	33	100

Table 4.3
Security Police Officers
With Prior
Enlisted Experience

Years	Number	Percent
< 1	1	3
2-4	3	9
5-7	5	15
8-10	2	6
11-13	2	6
14-16	1	3
≥ 17	1	3
Totals	15	45

Table 4.4
Security Police Officer Attendance
at In-Residence Professional
Military Education Courses

Course	Rank	Number	Percent
Squadron Officers School	O-1		
	O-2		
	O-3	3	9
	O-4	2	6
	O-5		
	Total	5	15
Air Command and Staff College	O-4	1	3
	O-5		
	Total	1	3

Table 4.5
Officer Completion Level of
Professional Military Education
Correspondence Courses

Course	Rank	Number	Percent
Squadron Officers School	O-1		
	O-2	1	3
	O-3	5	15
	O-4	3	9
	O-5	2	6
Totals		11	33
Air Command and Staff College	O-3	3	9
	O-4	4	12
	O-5	2	6
Totals		9	27
Air War College	O-4		
	O-5	2	6
Totals		2	6
Others	O-4		
	O-5	2	6
Totals		2	6

The descriptive data in Tables 4.1 through 4.5 relates general aspects of the officer sample. These tables further delineate the sample as described in Chapter Three and reinforce the homogeneity of this sample with the security police officer population.

General Research Questions

Data was gathered to answer four research questions. The four questions are specifically restated and the analyzed data presented.

Question One: Are USAF Security Police Officers Effective Leaders?

This question was answered through the effectiveness scores obtained from the LEAD-Self administered to each officer and the effectiveness scores obtained from the LEAD-Other given to the subordinates and superiors of each officer. The effectiveness scores were totalled for each officer, then divided by the number of people, i.e., the officer and the others. This score provided an across-the-board view of the leadership effectiveness of each officer. The effectiveness scores of the officers are presented in Table 4.6. Score ranges are divided in to effectiveness levels. These levels are based on prior studies, and may be arranged in other ways.[1] The arrangement used here is based on the range of scores obtained.

Table 4.7 presents data on the dominant leadership styles reported by the security police officers surveyed. Dominant styles were determined by totalling the number of

Table 4.6
Security Police Officer Effectiveness Range

Range	Number	Percent
Very Ineffective (-24 to -13)	1	3
Ineffective (-12 to -1)	2	6
Effective (0 to 6)	20	61
More Effective (7 to 12)	10	30
Very Effective (13 to 24)		
Totals	33	100

times each officer selected one of the four styles from the
LEAD-Self. If one style was selected more than fifty per-
cent of the time (six times or more), it was considered the
dominant style. If no one style was selected more than fif-
ty percent of the time then no style was considered dominant.

Table 4.7
Dominant Leadership Styles Reported

Style	Number	Percent
Telling	3	10
Selling	15	45
Participating		
Delegating		
No Dominant Style Reported	15	45
Total	33	100

Leadership flexibility was also determined from the LEAD-Self. Officers reporting one style more than twice were considered as being flexible in their leadership styles. Table 4.8 shows the number of styles reportedly used by the sample officers.

Table 4.8
Style Flexibility

Styles Used	Number	Percent
4	5	15
3	21	64
2	6	18
1	1	31
Total	33	100

Table 4.9
Officer Responses by Style and Situation

Situation	S-1	S-2	S-3	S-4
1	8	25		
2	1	17	15	
3	3	18	12	
4		31	2	
5	27	6		
6	1	20	11	1
7	8	22	3	
8	10	14	1	8
9	29	4		
10	9	19	5	
11		11	18	3
12	4	9	9	10
Totals	100	196	76	22

Question Two: How much agreement is there between
officers and their subordinates and superiors on an
officer's leadership behavior is a given situation?

The level of agreement sought in Question Two was
answered by totaling the officers responses on the LEAD-Self
for each style and totalling the others responses on the
LEAD-Other for each style. The resulting combined data was
compared and found significant (p<.05). Table 4.9 presents
officer responses by situation and style for each of the
twelve situations presented. Table 4.10 presents the
subordinate and superiors perception of the officers'

Table 4.10
Others Response by Style and Situation

Situation	S-1	S-2	S-3	S-4
1	34	57	33	2
2	17	62	32	15
3	29	32	54	11
4	37	68	12	9
5	71	40	10	5
6	18	56	34	18
7	28	72	20	6
8	37	49	22	18
9	85	22	11	8
10	54	59	7	6
11	23	42	38	23
12	23	11	35	22
Totals	461	570	308	143

Table 4.11
Comparison of Mean Leadership Style Scores of Officers
and Mean Scores of Others for the Same Style

Group	Style	Mean	SD	t-score
Officers	Telling	8.3	9.87	t= 2.44
Others		36.75	20.58	p<.05
Officers	Selling	16.33	7.93	t=3.95
Others		50	14.99	p<.05
Officers	Participating	6.33	6.41	t=2.45
Others		25.66	14.29	p<.05
Officers	Delegating	1.83	3.48	t=2.59
Others		11.91	7.06	p<.05

behavior in the twelve situations. Table 4.11 compares the
means and standard deviations for each leadership style by
officer and others.

The three preceding tables show that the Selling style
of leadership is reported by officers (X = 16.33) and others
(X = 50) as being the primary leadership style used, with
both significantly agreeing (t=2.44, p<.05) that Telling is
the second most used leadership style.

The results indicates that the officers use of the
Selling Style is significantly dominant (t=3.58, p<.05) over
the use of the Telling style. Similar results were found
between the Other's perception of the use of the Selling
versus Telling style (t=6.133, p<.05).

Question Three: Is USAF security police officer
leadership effectiveness associated with the number of
professional military education schools completed?

Data relative to this question was gathered on the
Professional Military Education and Experience Survey
instrument and from the leadership effectiveness scores
obtained when answering Question One. Each officer was rank
ordered by the number of professional military education
courses completed. In-residence courses were double
weighted because the actual leadership training received in
these courses is thought to increase leadership
effectiveness. No single course was weighted any heavier
than another. Correspondence courses were given a single
score for each one completed.

Each officer was then rank ordered by his/her
leadership effectiveness score. The Spearman rank order
correlation coefficent (r_{rho}) was applied to the resulting
ranks. A r_{rho} of -.054 was obtained for the correlation
between professional military education and leadership
effectiveness. This is not a significant correlation ($p <$.
05).

Question Four: Is USAF security police officer leadership effectiveness related to the officers leadership experience?

The same process used in answering Question Three was used in answering this question. Officers were rank ordered by the number of years of commissioned service at the security police squadron level. When the r_{rho} was applied to the rank orders a correlation of .20 was obtained. This coefficent is not significant ($p>.05$).

Discussion

The results obtained for this study of USAF security police officer leadership effectiveness is discussed in the following subsections. The first briefly deals with the descriptive data, with the last four analyzing the results of the research questions just presented.

Thirty-three USAF security police officers from the rank of second lieutenant to lieutenant colonel were surveyed. Eighty-five percent of these officers were captains or below, with the majority of the officers (40%) being captains. Sixty-one percent of the officers had five or less years of commissioned officer experience with

ninty-one percent (30) of the officers having less than ten
years of commissioned experience. Forty-five percent of the
officers had prior enlisted experience in the USAF.

Only fifteen percent of the officers had completed
Squadron Officers School in-residence. Only one major had
attended Air Command and Staff College in-residence.

As shown in Table 4.5 thirty-six percent of the
officers had completed Squadron Officers school by
correspondence, thirty percent Air Command and Staff College,
six percent Air War College, and nine percent had completed
other forms of professional military education.

This appears to be a very low percentage of officers
attending in-residence or completing professional military
education courses by correspondence. Table 4.5 indicates
that majors and lieutenant colonels (0-4 and 0-5) have a
higher completion rate in correspondence courses than do
captains of below.

This is partially explainable. Only captains with over
seven years of commissioned time are permitted to take
advanced professional military education courses by
correspondence. However this study anticipated much higher
rates of completion for correspondence courses and
in-residence attendence at professional military education
courses at the lower ranks, especially in captains. Only
twenty-three percent of the captains had attended Squadron

Officers School, and only thirty-five percent had completed
the course by correspondence. Only one lieutenant had
completed Squadron Officers School by correspondence and
only five reported being enrolled. This is believed to have
adversely affected the correlation found in Question Three.
Such low completion rates for professional military
education courses may cause the findings not to be capable
of generalization to the larger population.

The security police officers surveyed are
representative of the security police officer population.
Eighty-five percent were captains or below. While this is
slightly above the average for the entire population it is
not unusual for security police squadrons where the majority
of officers are captains or below. Only two squadrons
surveyed had fewer than three officers, while the average
for the remainder was five. Security police officer
leadership effectiveness was determined by obtaining an
average effectiveness score from the LEAD instruments. Only
three officers were found Ineffective (see Table 4.6), two
were in the Ineffective range, with only one being Very
Ineffective. Thirty officers were found to be effective
leaders. Sixty percent (20) were in the Effective range and
thirty percent were More Effective. The combined
percentages were slightly higher than those found by
Kuykendall and Unsinger in their study of civilian police

leaders.[2] Security police officers were found to be
effective leaders.

Table 4.7 further shows the leadership styles used by
security police officers. Forty-five percent report the
Selling style as their dominant style of leadership, ten
percent report Telling as the dominant style, while forty-
five percent report having no dominant style. Kuykendall
and Unsinger and Rees and O'Karma also reported Selling as
the dominant style in their studies.[3,4] Kuykendall and
Unsinger found fifty-one percent of police managers used a
Selling style and forty-five percent had no dominant leader-
ship style.[5] Rees and O'Karma found that subordinates and
superiors perceived the same dominant leadership style.[6]

The number of leadership styles reportedly used by the
sample officers reinforces the other findings concerning
their leadership effectiveness. Sixty-four percent of the
officers surveyed reported using three leadership styles,
eighteen percent reported using two styles, fifteen percent
four styles, while only three percent reported using only
one. This indicates that the majority of the officers
surveyed adapt their leadership styles to the situations
they encounter. Similar results were found in civilian
police managers.[7]

Question Two addressed the issue of how correctly do
officers, their subordinates and superiors, perceive the

officers leadership behavior in given situations. The
perceptual agreements were determined from the LEAD
instruments. Table 4.9 shows the number of actual responses
for each style and situation reported by the officers. In
fifty percent of the situations the Selling style of
leadership was reported by the officers, while the Others
reported it being used thirty-eight percent of the time. In
each case Selling was the dominant style reported. Table 4.
11 compares the mean scores for the Styles reported by the
officers and the others. The comparison was significant at
the .05 level in each case. Comparison of the means between
styles in groups shows a significant (p<.05) difference for
both the officers and others between the Selling and Telling
styles. Each group perceived the dominant leadership style
being used. Rees and O'Karma found similar results when
studying supervisors and subordinates.[8]

Agreement between officers, their subordinates and
superiors, on the officers behavior in given leadership
situations is high. Each group agreed on the styles used,
from the least to the dominant. In each case the agreement
was significant (p<.05).

The answers to Questions Three and Four were not
significant (p>.05). The correlation found between
professional military education and leadership effectiveness
(-.054), and the correlation found between experience and

leadership effectiveness (.20) did not show these two areas as significant factors in determining leadership effectiveness. Each question and the results are dealt with individually. After each has been covered a summary of the findings is presented.

Professional military education was not found to be a significant factor in determining leadership effectiveness ($r_{rho}=-.054$, $p>.05$). The results are believed to have been affected by the low number of officers who have attended professional military education courses in-residence (only 18%). However, a review of individual cases indicates that those with higher levels of professional military education did not score higher on leadership effectiveness; in some cases the opposite was true. This does not negate the value of professional military education; it does, however, question its value in affecting leadership effectiveness in the officers surveyed.

As with professional military education, officer experience at the squadron level was not found to be a significant factor in determining leadership effectiveness ($r_{rho}=.20$, $p>.05$) in the officers surveyed. Experience in security police squadrons, where a significant level of leadership occurs, was not found to significantly affect the leadership effectiveness of the security police officers surveyed. Inherent in the question was the assumption that

experience at the squadron level would cause officers to be more effective leaders. It was believed that the more experience an officer had leading people the more effective he/she would be. This was not proven. As with professional military education, in individual cases the extreme reverse was true. (See Appendix 2)

The answers to Questions Three and Four reinforce Fiedler's contentions that the leader's personality and the situation tend to be more important in leadership than does experience and training.[9]

Summary

Four questions on USAF security police officer leadership effectiveness were researched in this study. The findings provided positive answers to the first two: (1) Security police officers are effective leaders; and, (2) There is a significant level of agreement between leaders, their followers and superiors, on the leader's behavior in given leadership situations. However, the answers to Questions Three and Four were not significant. Higher levels of professional military education did not positively affect leadership effectiveness, nor did higher levels of leadership experience. Neither area was found to be significant factors in determining the leadership

effectiveness of the security police officers surveyed.

Using the Spearman rank order correlation coefficent, insignificant correlations of -.054 and .20 were found in the relationships between professional military education and experience, and leadership effectiveness.

The descriptive data collected on the security police office: sample reinforced the homogeneity of the sample to the population and helped answer and clarify the findings. The mixed results are by no means dismaying; they only point to the need for further research.

Notes

[1] Jack Kuykendall and Peter C. Unsinger, "The Leadership Styles of Police Managers," Journal of Criminal Justice 10 (1982): 311-321.

[2] Kuykendall and Unsinger, p. 314.

[3] Kuykendall and Unsinger, p. 314.

[4] Richard T. Rees and James G. O'Karma, "Perception of Supervisor Leadership Style in a Formal Organization," Group and Organizational Studies 5, no. 1 (March 1980): p. 67.

[5] Kuykendall and Unsinger, p. 314.

[6] Rees and O'Karma, p. 67.

[7] Kuykendall and Unsinger, p. 314.

[8] Rees and O'Karma, p. 67.

[9] Fred E. Fiedler, "LeaderShip Effectiveness," American Behavioral Scientist 24, no. 5 (May/June 1981): 619-632.

Chapter 5

Summary

Introduction

The effects of education and experience on leadership are at best disputed. In the USAF both are viewed as primary methods of creating more effective leaders. Professional military education is used to teach officers to be more effective leaders while experience in leading subordinates is believed to increase a leader's ability to lead effectively. Other writers have put forth similar views regarding education and experience.[1,2,3,4,5]

This study asked four general research questions concerning: (1) The leadership effectiveness of security police officers; (2) The level of agreement between security police officers, their subordinates and superiors, on an officer's behavior in given situations; (3) The relationship between professional military education and leadership effectiveness; and, (4) The relationship between security police leader experience and leadership effectiveness.

Thirty-three security police officers and 126 of their subordinates and superiors in eight security police squadrons in California were surveyed. Data was gathered

by A Professional Military Education and Experience Survey
(PMEES) and Hersey and Blanchard's Leadership Effectiveness
and Adaptability Dimensions (LEAD) instruments, Self and
Others.[6] The findings indicate that security police
officers are effective leaders and that there is a
significant level of agreement between officers, their
subordinates and superiors, on officer behavior in given
leadership situations. A correlation of -.054 was found
between professional military education and leadership
effectiveness, and one of .20 was found between experience
and leadership effectiveness, using the Spearman rank order
correlation coefficent. Neither correlation was significant
at the .05 level.

Conclusions

The following conclusions are drawn from this study:

(1) The majority of security police officers are
effective leaders. Most officers use a variety of
leadership styles depending upon the situational
requirements. Subordinates view their superior officers as
effective leaders.

(2) Security police officers, their subordinates and
superiors, correctly perceive the leadership sty being
used by an officer in leadership situations. While the

style may not always be the most appropriate for the situation, the style being used is perceived properly.

(3) Professional military education was not a significant factor in determining the leadership effectiveness of the security police officers surveyed. The low level of professional military education found may have contributed to the lack of significance in this area, or professional military education may truly not be a significant factor in causing officers to be more effective leaders.

(4) Experience was not found to be a significant factor in determining leadership effectiveness in the security police officers surveyed. The leadership positions which security police officers fill are varied. No two positions are exactly the same. However, nearly all positions officers fill at the squadron level require the use of leadership techniques. It would appear that either (1) the officers do not learn from the situations, or (2) they learn the wrong response. In either case, experience does not appear to have significantly affected the leadership effectiveness of the officers surveyed.

Discussion

The literature reviewed in Chapter 2 pointed to a
problem encountered in this study: namely, there is little
empirical research on the effects of training or experience
on leadership effectiveness. The literature on training was
mainly theoretical.[7,8,9,10]

Each put forth ideas or theories that people can be
trained to lead others. However, their ideas were not
supported by data. This study indicated that USAF
professional military education has no significant effect on
security police officer leadership effectiveness. The
findings may have been skewed by the low levels of
in-residence attendance at professional military education
courses, or may point to a significant problem in the USAF
profession . military education courses. This latter
contention would require further research before the
significance of the courses can be determined. Caution must
be exercised because individual cases found in this stud·
which are directly contrary to the assumption that
professional military education creates effective leaders,
may be isolated cases.

Basically the same results were found in correlating
experience with leadership effectiveness. The lack of a
significant relationship tends to reinforce Fiedler's

contention that the relationship between superior and subordinate leaders tends to impact directly on the subordinate leaders behavior in leadership situations.[11]

This study replicated the findings of two other empirical studies.[12,13] However because this study ventured into an area with little empirical data available the findings of insignificance in the relationship of professional military education, experience, and leadership effectiveness are difficult to judge.

Implications for Further Research

The scope of this study was rather broad, yet sufficiently narrow to allow research into the desired areas. Future research should either replicate this study or parts of it attempting to provide a better understanding of each area.

First, it is recommended that this study be replicated on security police noncommissioned officers. A study of noncommissioned officers should reveal similar data, and provide a comparison group in the same career field. Noncommissioned officers attend more professional military education than do officers. They typically spend far greater amounts of time in security police squadrons and are required to use leadership techniques more often.

Replicating this study on noncommissioned officers might clairify the areas of insignificance found by this study, while comparing the noncommissioned officers leadership abilities to those of the commissioned officer.

Secondly, if only parts of this study are replicated then more detailed results might be obtained. Different or better instruments could be designed or found which gather data relevant to education, experience, and leadership.

Further study into the area of USAF security police leadership is necessary. The potential conflict role of security police requires a clear understanding of how USAF security police are lead, how they follow, and how each area can be improved. Police functions are required in our society. In other societies, where USAF personnel are forced to be assigned, police services are an absolute must just to ensure security of costly resources and human lives. Security police have to maintain combat effectiveness in case of war. This requires experienced and effective leadership. Unless we understand how we lead, and more importantly, how our leadership affects our followers ability to carry out their assignments, we may face dismal failure in the future.

Notes

[1] Robert R. Blake and Jane S. Mouton, "How to Choose a Leadership Style," Training and Development Journal, (February 1982): 39-47.

[2] Myra W. Isenhart, "An Investigation of the Interface Between Corporate Leadership Needs and The Outward Bound Experience," Communication Education 32 (January 1983): 123-129.

[3] Beverly M. Alban Metcalfe, "Leadership: Extrapolating From Theory and Research to Practical Skills Training," Journal of Management Studies 19, no. 3 (1982): 295-304.

[4] Marsha Sinetar, "Developing Leadership Potential," Personnel Journal (March 1981): 193-196.

[5] Victor H. Vroom, "Can Leaders Learn to Lead?" Organizational Dynamics 3-4 (Winter 1976): 17-28.

[6] Paul Hersey and Ken Blanchard, Management of Organizational Behavior (Englewood Cliffs: Prentice-Hall, 1982), pp. 233-237.

[7] William Litzinger and Thomas Schaefer, "Leadership Through Followership," Business Horizons 2, no. 5 (1982): 78-81.

[8] Isenhart, pp. 123-129.

[9] Metcalfe, pp. 295-304.

[10] Vroom, pp. 17-28.

[11] Fred E. Fiedler, "Leadership Effectiveness," American Behavioral Scientist 24, no. 5 (May/June 1981): 619-632.

[12] Jack Kuydendall and Peter C. Unsinger, "The Leadership Styles of Police Manager," Journal of Criminal Justice 10 (1982): 311-321.

[13] Richard T. Rees and James G. O'Karma, "Perception of Supervisor Leadership Styles in a Formal Organization," Group and Organizational Studies 5, no. 1 (March 1980): 65-69.

Appendix A

USAF SECURITY POLICE OFFICER
PROFESSIONAL MILITARY EDCUATION
and
EXPERIENCE SURVEY

The following questions pertain to certain aspects of your military experience. Please answer each question fully and according to the instructions provided.

1. Fill in the blanks for the following questions.

    a. How many years have you been in the USAF?_____

    b. How many years have you been in Security Police?____

_____c. If you were in another career field, or another branch of the military service please indicate career field, branch and years._____

2. Please check the positions you have held at the squadron level and the number of years in each.

POSITION   NUMBER OF YEARS

Shift Supervisor   1 2 3 4 5 6 7 8 9 10 More_____

Operations Officer 1 2 3 4 5 6 7 8 9 10 More_____

CSP   1 2 3 4 5 6 7 8 9 10 More_____

Commander   1 2 3 4 5 6 7 8 9 10 More_____

Other(specify)_____

3. Please complete the following questions on Professional Military Education.

    a. Indicate the courses attended in-residence:

        SOS_____
        ACSC_____
        AWC_____
        Other(specify)_____

b. Indicate the courses completed by correspondence:

SOS____
ACSC____
AWC____
Other(specify)_____

4. Please complete the following information:

Rank____Age____Sex   M   F

Appendix B

Officers Rank, Experience Level, Professional Military
Education Level, and Effectiveness Scores.

Rank	Years Experience	PME Level	Effectiveness
O-1	.2	0	5.6
O-1	.1	0	5.8
O-1	.5	0	3.6
O-1	.25	0	7
O-1	.2	0	3.6
O-1	1	0	6.25
O-1	1	0	6.6
O-1	.5	0	2
O-2	1	0	6.25
O-2	2	0	3.3
O-2	3.5	0	.5
O-2	2	0	-1
O-2	2	1	4
O-3	4	0	4
O-3	3	1	8
O-3	7.5	2	4
O-3	2	0	4.4
O-3	6	0	2.8
O-3	4.5	1	2.2
O-3	10.5	2	.2
O-3	6	0	7.4
O-3	9	2	6.4
O-3	9	2	6.5
O-3	6	1	9
O-3	8	1	4.75
O-3	9	2	-3
O-3	5	1	4.4
O-4	9	4	1.6
O-4	13	2	2.4
O-4	7	3	11.75
O-5	17	5	3.25
O-5	19	4	-14

Bibliography

Blake, Robert R. and Jane S. Mouton. "How to Choose a
    Leadership Style." Training and Development Journal
    (February 1982): 39-47.

Barrow, Jeffery C.. "Worker Performance and Task Complex-
    ity As Causal Determinants Of Leader Behavior Style
    And Flexibility." Journal of Applied Psychology 61
    no. 4 (1976): 433-440.

Bass, Bernard M., et al. "Management Styles Associated with
    Organizational, Task, Personal, and Interpersonal
    Contigencies." Journal of Applied Psychology 60, No.
    6 (1975): 720-729.

Bleda, Paul, et al. "Enlisted Men's Perception of Leader
    Attributes and Satisfaction with Military Life."
    Journal of Applied Psychology 62, no. 1 (1977): 43-49.

Evans, Martin G.. "Leadership Behavior: Demographic
    Factors and Agreement Between Subordinate and Self-
    Description." Personnel Psychology 25 (1972): 643-649.

Ferris, Gerald R.. "The Influence of Leadership on Per-
    ceptions of Job Autonomy." The Journal of Psychology
    114 (1983): 253-258.

Fiedler, Fred E.. "Organizational Determinants of Manage-
     ial Incompetence." In Crosscurrents in Leadership.
     Eds. James G. Hunt and Lars L. Larsen. Carbondale:
     Southern Illinois University Press, 1979.

------------. "Leadership Effectiveness." American Behav-
     ioral Scientist 24, no. 5 (May/June 1981): 619-612.

Gabriel, Richard A. and Paul L. Savage. Crisis In Command:
     Mismanagement in the Army. New York: Hill and Wang,
     1978.

Gosnell, Wayne L. "The Air Force is Making Occupational-
     ist of Its Junior Officers." Research Report to the
     USAF Air War College, Air University, 1980.

Greene, Charles N. "The Reciproral Nature of Influence
     Between Leader and Suboedinate." Journal of Applied
     Psychology 60, no. 2 (1975): 187-193.

Grunstad, Norman. "Overview: USAWC Study of Leadership
     for the 1970's." In A Study of Organizational
     Leadership. Eds. Office of Military leadership,
     United States Military Academy. Harrisbury: Stock-
     pole, 1976.

Hackett, General Sir John. The Profession of Arms.
     New York: McMillian, 1983.

Hauser, William L. "The Will to Fight." In Combat
     Effectiveness. Ed. Sam C. Sarkesian. Beverly Hills:
     Sage, 1980.

Hersey, Paul and Ken Blanchard. Management of Organizational Behavior. 2d. ed. Englewood Cliffs: Prentice-Hall, 1982.

----------. "So You Want To Know Your Leadership Style?" Training and Development Journal (February 1974): 22-37.

----------. "Leadership Style: Attributes and Behaviors." Training and Development Journal (May 1982): 50-52.

Isenhart, Myra W. "An Investigation of the Interface Between Corporate Leadership Needs and the Outward Bound Experience." Communication Education 32 (January 1983): 123-129.

Jones, Allan P., et al. "Perceived Leadership Behavior and Employee Confidence in the Leader as Moderated by Job Involvement." Journal of Applied Psychology 60, no. 1 (1975): 146-149.

Kuykendall, Jack and Peter C. Unsinger. "The Leadership Styles of Police Managers." Journal of Criminal Justice 10 (1982): 311-321.

Likert, Rensis. The Human Organization. New York: McGraw-Hill, 1967.

Litzinger, William and Thomas Schaefer. "Leadership Through Followership." Business Horizons 2, no. 5 (1982): 78-81.

Metcalfe. Beverly M. Alban. "Leadership: Extrapolating
From Theory and Research to Practical Skills Train-
ing." Journal of Management Studies 19 no. 3 (1982):
295-304.

Office of Military Leadership, United States Military
Academy. A Study of Organizational Leadership.
Harrisburg: Stockpole, 1976.

Rees, Richard T. and James G. O'Karma. "Perceptions of
Supervisor Leadership Style in a Formal Organization."
Group and Organizational Studies 5, no. 1 (March 1980):
65-69.

Runyon, Richard P. and Audrey Harber. Fundamentals of
Behavioral Statistics, 2d. ed. Menlo Park:
Addison-Wesley, 1972.

Sarkesian, Sam C. ed. Combat Effectiveness. Beverly Hills:
Sage, 1980.

Sims, Henry P. and Andrew D. Szilagyi. "Leader Reward
Behavior and Subordinate Satisfaction and Perform-
ance." Organizational Behavior and Human Perform-
ance 14 (1975): 426-438.

Sinetar, Marsha. "Developing Leadership Potential."
Personnel Journal (March 1981): 193-196.

Stogdill, Ralph M. Handbook of Leadership. New York:
Free Press, 1974.

$$S \Rightarrow -a \overset{b}{\frown} A -$$

$$S \Rightarrow -a \overset{b-b}{\frown} A -$$

$$A \Rightarrow \overset{\longrightarrow}{-b} c -$$

$$A \Rightarrow \overset{-b}{-b} > c -$$

$$-a_1 \overset{b_1 - b_2}{\diagdown_{b_3}} \overset{|e_5}{\diagup_{/e_3}} c_1 -$$
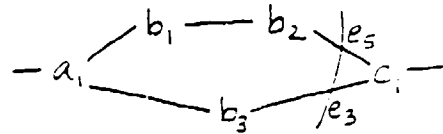
(node read: b_2)

$$[dead]_3$$

$$\left[A \Rightarrow \overset{-b | e_5}{\underset{-b | e_3}{\ulcorner} c -} \;, \; nil, \; \{1\} \right]_4$$

$$\left[S \Rightarrow -a \overset{b - b \times [e_5]}{\frown} A - \;, \; ((A \; 5 \; 6)), \; \phi \right]_2$$

$$\left[A \Rightarrow \overset{ \times | e_5}{\underset{-b | e_3}{} c -} \;, \; nil, \; \{2\} \right]_5$$

$$\left[A \Rightarrow \overset{e_5}{\underset{-b \times e_3}{\ulcorner b - c -}} \;, \; nil, \; \{2\} \right]_6$$

Example 2, list 4.

We read node b_2. Item 3 dies expecting a c. and item 4 makes a normal state transition. Item 2 moves into a state containing its A-node's other input; this input can be passed down to items 5 and 6 without p-splitting them because they have no other callers.

$$S \Rightarrow -a \overset{b}{\frown} A-$$

$$S \Rightarrow -a \overset{b-b}{\frown} A-$$

$$A \Rightarrow \overset{}{\underset{-b}{\rightharpoondown}} c-$$

$$A \Rightarrow \overset{-b}{\underset{-b}{\rightharpoondown}} c-$$
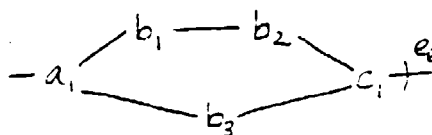
(node read: C_1)

$$[dead]_6$$

$$\left[A \Rightarrow \overset{-b}{\underset{-b}{\rightharpoondown}} c \overset{[e_6]}{+} , \ nil , \ \{1\} \right]_4$$

$$\left[S \Rightarrow -a \overset{b}{\frown} A \overset{e_6}{+} , \ nil , \ \phi \right]_1$$

$$\left[A \Rightarrow \overset{}{\underset{-b}{\rightharpoondown}} c \overset{[e_6]}{+} , \ nil , \ \{23\} \right]_5$$

$$\left[S \Rightarrow -a \overset{b-b}{\frown} A \overset{e_6}{+} , \ nil , \ \phi \right]_2$$

Example 2, list 5.

We read the final *c*. Item 6 dies expecting a *b*, while items 4 and 5 move into accepting states. They then return to items 1 and 2, both of which accept.

$S \Rightarrow -A\;\overset{b}{\frown}\;c-$

$S \Rightarrow -A\;\overset{b-b}{\frown}\;c-$

$A \Rightarrow -a\;\overset{b-}{\underset{b-}{\frown}}$
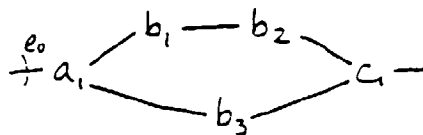
$A \Rightarrow -a\;\underset{b-}{\frown}$ (node read: NONE)

$$\left[S \Rightarrow \overset{[e_0]}{\longmapsto} A\;\overset{b}{\frown}\;c- \;,\; ((A\; 3\; 4)) \;,\; \emptyset \right]_1$$

$$\left[S \Rightarrow \overset{[e_0]}{\longmapsto} A\;\overset{b-b}{\frown}\;c- \;,\; ((A\; 3\; 4)) \;,\; \emptyset \right]_2$$

$$\left[A \Rightarrow \overset{e_0}{\longmapsto} a\;\overset{b-}{\underset{b-}{\frown}} \;,\; nil \;,\; \{1,2\} \right]_3$$

$$\left[A \Rightarrow \overset{e_0}{\longmapsto} a\;\underset{b-}{\frown} \;,\; nil \;,\; \{1,2\} \right]_4$$

Example 3, list C.

Example 3.

This example demonstrates staggered reduction. No new operations are introduced.

The first list starts with items for two alternate S-recognizers. Both of these recognizers expect an A at the same point in the input, so two A-recognizers are invoked and both will return to both S-recognizers.

$$S \Rightarrow -A \overset{b}{\frown} c -$$

$$S \Rightarrow -A \overset{b-b}{\frown} c -$$

$$A \Rightarrow -a \overset{b-}{\underset{b-}{\langle}}$$

$$A \Rightarrow -a \overset{\frown}{\underset{b-}{\smile}}$$

$$-a_1 \overset{e_1 \; b_1 \; --- \; b_2}{\underset{/e_2 \qquad b_3}{\bigg\langle}} c_1 -$$
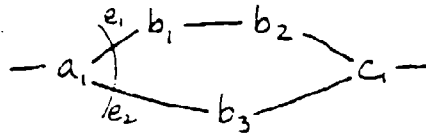
(node read: a_1)

$$\left[A \Rightarrow -a \overset{[e_1]}{\underset{e_2}{\big|}} b - \;, \; nil \;, \; \{1, 2\} \right]_4$$

$$\left[S \Rightarrow -A \overset{b}{\smile} c - \;, \; ((A \; 3)) \;, \; \phi \right]_5$$

$$\left[S \Rightarrow -A \overset{e_1}{\mathrel{+}} b \overset{\frown}{\frown} c - \;, \; ((A \; 4)) \;, \; \phi \right]_1$$

$$\left[S \Rightarrow -A \overset{b-b}{\smile} c - \;, \; ((A \; 3)) \;, \; \phi \right]_6$$

$$\left[S \Rightarrow -A \overset{e_1}{\mathrel{+}} b - b \overset{\frown}{\frown} c - \;, \; ((A \; 4)) \;, \; \phi \right]_2$$

$$\left[A \Rightarrow -a \overset{e_1}{\underset{e_2}{\big|}} \overset{b-}{\underset{b-}{}} \;, \; nil \;, \; \{5, 6\} \right]_3$$

Example 3, list 1.

Node a_1 is read. leading item 4 into an accepting state for the edge e_1. Its return causes items 1 and 2 to ϵ-split into items 5 and 6. Notice that, although item 4 has returned one of its outputs, it remains in the call lists of its callers. It will be removed only when it returns all of its outputs.

$$S \Rightarrow -A \overset{b}{\underset{\smile}{\frown}} c -$$

$$S \Rightarrow -A \overset{b-b}{\underset{\smile}{\frown}} c -$$

$$A \Rightarrow -a \overset{b-}{\underset{b-}{\frown}}$$
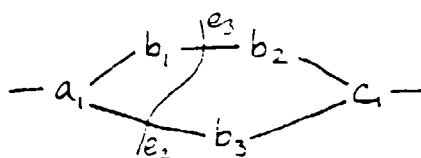
$$A \Rightarrow -a \underset{b-}{\frown}$$ (node read b_1)

$$\left[A \Rightarrow -a \overset{b \;\, [e_1]}{\underset{e_2 \, o-}{\frown}} , \; nil , \; \{5,6\} \right]_3$$

$$\left[S \Rightarrow -A \overset{e_3}{\underset{\smile}{+o}} c - , \; ((A \; 3)) , \; \phi \right]_5$$

$$\left[S \Rightarrow -A \overset{e_3}{\underset{\smile}{+ b-b}} c - , \; ((A \; 3)) , \; \phi \right]_6$$

$$\left[S \Rightarrow -A \overset{b \times e_3}{\underset{\smile}{\frown}} c - , \; ((A \; 4)) , \; \phi \right]_1$$

$$\left[S \Rightarrow -A \overset{b \overset{e_3}{+} b}{\underset{\smile}{\frown}} c - , \; ((A \; 4)) , \; \phi \right]_2$$

$$\left[A \Rightarrow -a \underset{e_2}{\overset{\frown}{+ b-}} , \; nil , \; \{1,2\} \right]_4$$

Example 3, list 2.

Node b_1 is read. leading item 3 into an accepting state of the edge e_3. Items 5 and 6 need not be ϵ-split since they have no other calls pending for their A-node. Item 4 is active and unchanged.

$S \Rightarrow_{?} -A \overset{b}{\frown} c -$
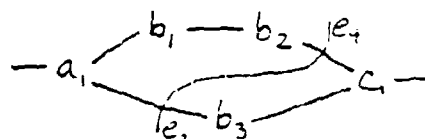
$S \Rightarrow -A \overset{b-b}{\frown} c -$

$A \Rightarrow -a \overset{b--}{\underset{b-}{\frown}}$

$A \Rightarrow -a \overset{}{\underset{b-}{\frown}}$

$-a_1 \overset{b_1 - b_2 \ \ |e_4}{\underset{|e_2 \ \ b_3}{\diamond}} c_1 -$

(node read b_2)

$[dead]_1$

$\left[S \Rightarrow -A \overset{b-b}{\underset{\frown}{\frown}} \overset{e_4}{\times} c - , ((A +)), \phi \right]_2$

$\left[S \Rightarrow -A \overset{-b \times^{e_4}}{\underset{\frown}{\frown}} c - , ((A \ 3)), \phi \right]_5$

$\left[S \Rightarrow -A \overset{b \overset{e_4}{\mp} b}{\frown} c - , ((A \ 3)), \phi \right]_6$

$\left[A \Rightarrow -a \overset{b-}{\underset{e_2}{\frown} b-} , nil , \{5,6\} \right]_3$

$\left[A \Rightarrow -a \overset{}{\underset{e_2}{\frown} b-} , nil , \{1,2\} \right]_4$

Example 3, list 3.

Node b_2 is read, killing item 1 which was expecting a c. Items 2, 5, and 6 all make state transitions; items 3 and 4 are unchanged.

$S \Rightarrow -A \overset{b}{\frown} c -$
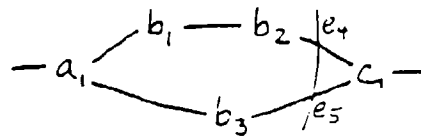
$S \Rightarrow -A \overset{b-b}{\frown} c -$

$A \Rightarrow -a \overset{b-}{\underset{b-}{\diagdown}}$

$A \Rightarrow -a \underset{b-}{\frown}$ (node read: b_3)

$-a_1 \overset{b_1 - b_2 |e_4}{\underset{b_3 \quad /e_5}{\diagup}} c_1 -$

$$\left[A \Rightarrow -a \overset{b-}{\underset{b \underset{[e_5]}{\dashv}}{\diagdown}} , \; nil , \; \{5,6\} \right]_3$$

$$\left[S \Rightarrow -A \overset{b \;|e_4}{\underset{/e_5}{\frown}} c - , \; nil , \; \phi \right]_5$$

$$\left[S \Rightarrow -A \overset{b \overset{a}{\mp} o}{\underset{/e_5}{\frown}} c - , \; nil , \; \phi \right]_6$$

$$\left[A \Rightarrow -a \underset{b \underset{[e_5]}{\dashv}}{\frown} , \; nil , \; \{1,2\} \right]_4$$

$$\left[S \Rightarrow -A \overset{b - b \; |e_4}{\underset{/e_5}{\frown}} c - , \; nil , \; \phi \right]_2$$

Example 3, list 4.

Node b_3 is read. leading both items 3 and 4 into accepting states. Their returns are uneventful.

$$S \Rrightarrow -A \overset{b}{\frown} c -$$

$$S \Rrightarrow -A \overset{b-b}{\frown} c -$$

$$A \Rrightarrow -a \overset{b-}{\underset{b-}{\diagdown}}$$

$$A \Rrightarrow -a \overset{\frown}{b} - \qquad \text{(node read: } C_1 \text{)}$$

$$-a_1 \overset{b_1 \;-\!-\; b_2}{\underset{b_3}{\diagup}} C_1 \overset{e_*}{\underset{}{\mp}}$$

$$\left[S \Rrightarrow -A \overset{b}{\frown} c \overset{e_*}{\mp} , \; nil, \; \phi \right]_5$$
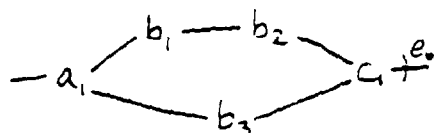
$$\left[dead \right]_6$$

$$\left[S \Rrightarrow -A \overset{b-b}{\frown} c - , \; nil, \; \phi \right]_2$$

Example 3, list 5.

Node c_1 is read. The results are straightforward.

$$S \Rightarrow -A\overbrace{}_{b}-$$

$$A \Rightarrow -a\overbrace{}_{b}-$$

$$A \Rightarrow -a\overbrace{}_{b-b}-$$

$$\frac{\cdot}{i e_0} \, a_1 \overbrace{} -b_1-b_2-$$

(node read: NONE)

$$\left[S \Rightarrow \overset{[e_0]}{+} A\overbrace{}_{b}- \;,\; ((A\,23)) ,\; \emptyset \right]_1$$

$$\left[A \Rightarrow \overset{e_0}{+} a\overbrace{}_{b}- \;,\; nil ,\; \{1\} \right]_2$$

$$\left[A \Rightarrow \overset{e_0}{+} a\overbrace{}_{b-b}- \;,\; nil ,\; \{1\} \right]_3$$

Example 4, list 0.

Example 4

This example explores an interaction between staggered reduction and duplicate-item merging which the reader may have anticipated after seeing the previous example. No new operations are introduced.

We start by predicting the *A*-node in the *S*-recognizer in all possible ways.

$$S \Rightarrow -A\underset{b}{\overset{\diagup}{\diagdown}}-$$

$$A \Rightarrow -a\underset{b}{\overset{\diagup}{\diagdown}}-$$

$$A \Rightarrow -a\underset{b-b}{\overset{\diagup}{\diagdown}}-$$

$$-a_1\underset{/e_2}{\overset{e_1}{\diagdown}}b_1-b_2-$$

(node read: a_1)

$$\left[A \Rightarrow -a\frac{\overset{[e_1]}{}}{/e_2 b-} \ , \ nil, \ \{1\} \right]_2$$

$$\left[S \Rightarrow -A\frac{\overset{e_1}{}}{-b-} \ , \ ((A \ 2 \ 3)), \phi \right]_1$$

$$\left[dead \ (merged) \right]_4$$

$$\left[A \Rightarrow -a\frac{\overset{[e_1]}{}}{e_2 b-b-} \ , \ nil, \ \{1\} \right]_3$$

Example 4, list 1.

Upon reading node a_1, both the a-recognizers are ready to accept edge e_1. The return of item 2 causes item 1 to ϵ-split into item 4, but then the return of item 3 moves item 4 into the same state as item 1, so it is merged into that item.

A point worth noting here is that only items which were originally ϵ-splits of each other can ever be merged. This is because ϵ-splitting is the only way to get two items which represent the same recognizer started at the same input position.

$S \Rightarrow -A\underset{b}{\frown}-$

$A \Rightarrow -a\underset{b}{\frown}-$

$A \Rightarrow -a\underset{b-b}{\frown}-$

$-a_1\underset{b_1 \overline{|e_2|} b_2}{\overset{e_1}{\frown}}-$

(node read: b_1)

$$\left[A \Rightarrow -a\underset{b+\overline{[e_3]}}{\frown}, \ nil, \ \{1\} \right]_2$$

$$\left[S \Rightarrow -A\underset{b-}{\overset{e_1}{\leftarrow}}, \ ((A\ 3)), \ \phi \right]_5$$
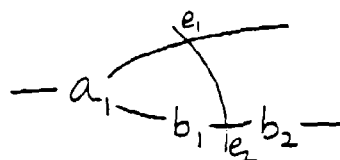
$$\left[S \Rightarrow -A\underset{e_3}{\overset{e_1}{\leftarrow}}b-, \ nil, \ \phi \right]_1$$

$$\left[A \Rightarrow -a\underset{b+\overline{e_3}b}{\frown}-, \ nil, \ \{5\} \right]_3$$

Example 4, list 2.

Reading node b_1 moves item 2 (but not item 3) into a state accepting c_3. This causes item 1 to be ϵ-split once again, this time into item 5.

$$S \Rightarrow -A \overset{\diagup}{\underset{b}{-}}-$$

$$A \Rightarrow -a \overset{\diagup}{\underset{b}{-}}-$$

$$A \Rightarrow -a \overset{\diagup}{\underset{b-b-}{}}$$
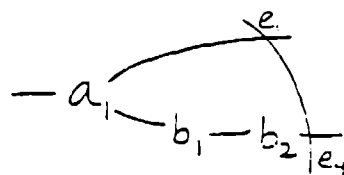
$$-a_1 \overset{e_.}{\underset{b_1 - b_2}{\diagup}} \Big|_{e_+}$$

(node read: b_2)

$$\left[S \Rightarrow -A \overset{e_.}{\underset{b}{\frown}} \Big|_{e_+} , \text{ nil} , \phi \right]_1$$

$$\left[A \Rightarrow -a \overset{\frown}{\underset{b-b}{}} \Big|_{[e_+]} , \text{ nil}, \{5\} \right]_3$$

$$\left[S \Rightarrow -A \overset{e_.}{\underset{b}{\frown}} \Big|_{e_+} , \text{ nil}, \phi \right]_5$$

Example 4, list 3.

Node b_2 is read. The results are straightforward.

$$S \Rightarrow -a \overset{b}{\frown} A \prec$$

$$A \Rightarrow \begin{matrix} -c \\ -b - a - \end{matrix}$$

$$A \Rightarrow > A \overset{c}{\underset{b-a-}{<}}$$
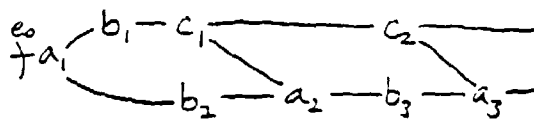
(node read: NONE)

$$\left[S \Rightarrow \overset{e_0}{\mp} a \overset{b}{\frown} A \prec , \; nil , \; \phi \right],$$

Example 5, list 0.

Example 5

Our last example is our most complex one. It demonstrates left recursion, and introduces the *r-split* operation. Staggered invocations and reductions are thrown in for good measure.

Things start out simply enough, as we invoke a recognizer for *s*.
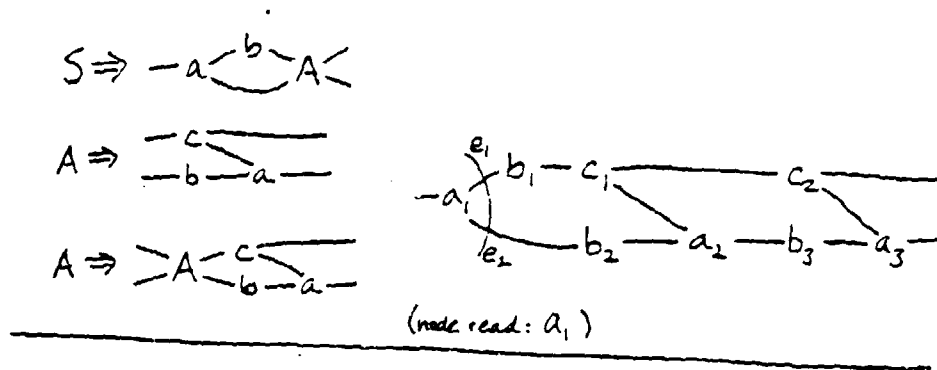
$$S \Rightarrow -a \overset{b}{\frown} A<$$

$$A \Rightarrow \overset{-c}{\underset{-b-a-}{}}$$

$$-a_1 \overset{e_1}{\underset{e_2}{\bigg\langle}} \overset{b_1-c_1}{\underset{b_2-a_2-b_3-a_3-}{}} \overset{c_2}{}$$

$$A \Rightarrow >A< \overset{c}{\underset{b-a-}{}}$$

$$(\text{node read}: a_1)$$

$$\left[S \Rightarrow -a \overset{e_1, b}{\underset{[e_2]}{\bigg\langle}} A< , ((A\ 2\ 3)), \emptyset \right]_1$$

$$\left[A \Rightarrow \overset{-c}{\underset{+e_2 b - a -}{}}, nil, \{1,3\} \right]_2$$

$$\left[A \Rightarrow \overset{}{\underset{[e_2]}{} }A< \overset{c}{\underset{b-a-}{}}, ((A\ 2)), \{1\} \right]_3^R$$

Example 5, list 1.

Reading node a_1 moves the S-recognizer into a state where it must predict one of the S-node's inputs. Multiple-call collapsing happens as it did in the string case, with both items 1 and 3 calling item 2 for the non-recursive expansion of A. Unlike the string case, however, item 3 does not explicitly call itself recursively; instead, it is marked with the R-flag.

Here are the intuitions behind this marker: If we encode by 'S' an S-recognizer, by A_n a non-recursive A-recognizer, and by A_r a recursive A-recognizer, then the simulation is currently representing an infinite number of parsers, each with one of the following call structures:

$$S \rightarrow A_n$$
$$S \rightarrow A_r \rightarrow A_n$$
$$S \rightarrow A_r \rightarrow A_r \rightarrow A_n$$
$$\vdots$$
$$S \rightarrow A_r \rightarrow \ldots \rightarrow A_r \rightarrow A_n.$$
$$\vdots$$

The simulation does this by keeping just the two structures

$$S \rightarrow A_n$$
$$S \rightarrow A_r \rightarrow A_n$$

(and it shares the A and A_n between the two). The the R-flag on item 3 indicates that it is the recursive A-recognizer which is being used to encode the infinite sequence of such recognizers present in the unoptimized case.

$$S \Rightarrow -a \overset{b}{\frown} A <$$

$$A \Rightarrow \begin{array}{c} -c \\ -b \frown a - \end{array}$$
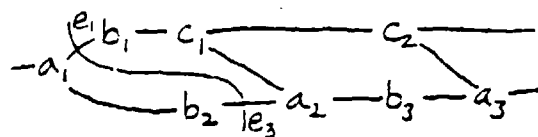
$$A \Rightarrow > A < \begin{array}{c} c \\ b \frown a - \end{array}$$

(node read: b_2)

$$\left[A \Rightarrow \begin{array}{c} -c \\ -b \underset{e_3}{\frown} a - \end{array}, \ nil, \ \{1,3\} \right]_2$$

$$\left[S \Rightarrow -a \overset{e_1}{\frown} \overset{b}{\frown} A < , \ ((A \ 2 \ 3)), \ \phi \right]_1$$

Example 5, list 2.

Node b_3 is read, causing the non-recursive A-recognizer to make a state transition.

$S \Rightarrow -a \overset{b}{\frown} A <$

$A \Rightarrow \genfrac{}{}{0pt}{}{-c}{-b-a-}$

$A \Rightarrow > A < \genfrac{}{}{0pt}{}{c}{b-a-}$

$-a_1 \overset{b_1 \overset{e_4}{} c_1}{\underset{b_2 \overset{e_3}{} a_2 - b_3 - a_3 -}{}} \genfrac{}{}{0pt}{}{c_2}{}$

(node read: b_1)
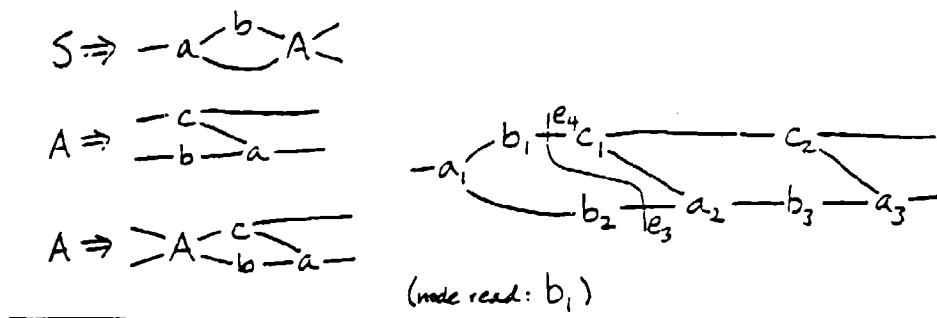
$\left[S \Rightarrow -a \overset{b}{\frown} \times^{[e_1?]} A < , ((A\ 2\ 3)), \emptyset \right]_1$

$\left[\text{dead (multiple-call collapsing)} \right]_4$

$\left[A \Rightarrow \genfrac{}{}{0pt}{}{\overset{e_4}{} c}{-b \overset{}{e_3} a-} , \text{nil}, \{1,3\} \right]_2$

$\left[A \Rightarrow \overset{[e_1]}{\times} > A < \genfrac{}{}{0pt}{}{c}{b-a-} , ((A\ 2)), \{1\} \right]_3^R$

Example 5, list 3.

This is a cute one. Node b_1 is read. allowing item 1 to pass down the other input of its *A*-node to items 2 and 3. This first p-splits item 2 into item 4. because item 2 is also called by item 3 and the decision to p-split is made solely on the basis of number of callers. not on whether they agree as to added inputs. But when item 1 passes the new input to item 3 and item 3 goes to pass it on to item 4, such an action would make item 4 and item 2 calls on the same recognizer at the same point. so multiple-call collapsing acts by redirecting item 3's call to item 2 instead of item 4. This in turn removes the last return pointer from item 4. so it is marked as dead. The net effect is to (correctly) keep item 1 and item 3 both calling item 2 for the non-recursive expansion of their *A*-nodes.

$$S \Rightarrow -a \overset{b}{\smile} A \prec$$

$$A \Rightarrow \overset{-c}{\underset{-b-a-}{}}$$

$$A \Rightarrow \succ A \overset{c}{\underset{b-a-}{\prec}}$$

$$-a_1 \overset{b_1 - c_1}{\underset{b_2}{\frown}} \overset{|e_5}{\underset{e_3}{}} \overset{c_2}{\underset{a_2 - b_3 - a_3 -}{}}$$

(node read: C_1)

$$\left[A \Rightarrow \overset{-c \frac{|[e_5]}{|e_5|}}{-b \frac{}{|e_3|} a -} \quad , \quad nil \quad , \quad \{1, 3\} \right]_1$$

$$\left[S \Rightarrow -a \overset{b}{\smile} A \prec \ , \ ((A\ 3\ 6)) \ , \ \phi \right]_5$$

$$\left[S \Rightarrow -a \overset{b}{\smile} A \overset{e_5}{=} \ , \ ((A\ 2)) \ , \ \phi \right]_1$$

$$\left[A \Rightarrow \succ A \overset{c}{\underset{b-a-}{\prec}} \ , \ ((A\ 3)) \ , \ \{5\} \right]_6^R$$

$$\left[A \Rightarrow \succ A \overset{e_3}{\underset{b-a-}{\not{x}\,c}} \ , \ ((A\ 2)) \ , \ \{5, 6\} \right]_3$$

Example 5, list 4.

Reading node c_1 moves the non-recursive recognizer for A (item 2) into an accepting state. This causes item 1 to c-split as usual into item 5. Item 3, however, does an *r-split* into item 6, which means it does a normal c-split but then loses its r-flag and picks up its split image as a caller.

Once again, let us look at the intuition underlying this action. If we flag a recognizer that has returned with an asterisk, and a recognizer that has made a state transition as the result of a return with a prime, then the parsers being simulated now have one of the following call structures:

$$S' \rightarrow A_n^*$$
$$S \rightarrow A_r' \rightarrow A_n^*$$
$$S \rightarrow A_r \rightarrow A_r' \rightarrow A_n^*$$
$$\vdots$$
$$S \rightarrow A_r \rightarrow \ldots \rightarrow A_r \rightarrow A_r' \rightarrow A_n^*.$$
$$\vdots$$

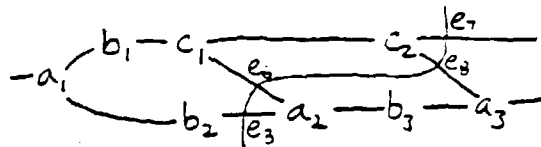The simulator now represents these structures using the following three structures

$$S' \rightarrow A_n^*$$
$$S \rightarrow A_r' \rightarrow A_n^*$$
$$S \rightarrow A_r \rightarrow A_r' \rightarrow A_n^*$$

where item 1 is S', item 2 is A_n^*, item 5 is S, item 3 is A_r', and item 6—the r-split of item 3—is the A_r recognizer flagged as the representative of the infinite chain. A simple c-split of item 3 would have been insufficient to build this new structure because it would have made items 3 and 6 siblings, instead of child and parent. In addition, it would not have correctly marked item 6 as the A_r recognizer instead of item 3.

$$S \Rightarrow -a \overbrace{}^{b} A <$$

$$A \Rightarrow \begin{array}{c} -c \overline{} \\ -b - a - \end{array}$$

$$A \Rightarrow > A < \begin{array}{c} c \overline{} \\ -b - a - \end{array}$$

(node read: C_2)

$$[dead]_1$$

$$\left[A \Rightarrow > A < {}_b^{c} \overset{|e_7|}{\underset{\times e_3}{}} a - \; , \; ((A\ 2)), \; \{5,6\} \right]_3$$

$$\left[S \Rightarrow -a \overbrace{}^{b} > A < \; , \; ((A\ 6\ 8)), \; \phi \right]_7$$

$$\left[S \Rightarrow -a \overbrace{}^{b} > A \overset{e_7}{\underset{}{<}} \; , \; ((A\ 3)), \; \phi \right]_5$$

$$\left[A \Rightarrow > A < {}_b^{c} \overline{} a - \; , \; ((A\ 6)), \; \{7\} \right]_8^R$$

$$\left[A \Rightarrow > A \overset{e_7}{\underset{-b-a-}{+c \overline{}}} \; , \; ((A\ 3)), \; \{7, 8\} \right]_6$$

$$\left[A \Rightarrow {}_{-b}^{-c \overline{}} \overset{e_*}{\underset{e_3}{}} a - \; , \; nil, \; \{1, 3\} \right]_2$$

Example 5, list 5.

After reading the next c-node, the whole r-split process happens again. The simulation is now keeping the following structure:
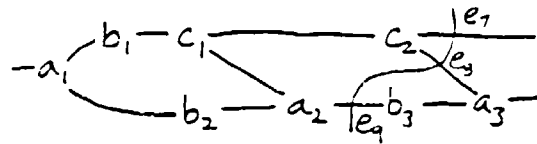
$$
\begin{aligned}
S' &\to A_n^* \\
S' &\to A_r'^* \to A_n^* \\
S &\to A_r' \to A_r'^* \to A_n^* \\
S &\to A_r \to A_r' \to A_r'^* \to A_n^*.
\end{aligned}
$$

The reader should be sure he understands how this structure was attained!

$S \Rightarrow -a \overset{b}{\frown} A <$

$A \Rightarrow \overset{c}{-} \underset{b-a}{\smile} -$

$A \Rightarrow > A < \overset{c}{\underset{b-a}{\smile}} -$

(node read: a_2)

$$\left[A \Rightarrow \overset{-c}{\underset{b \smile a}{\quad}}_{[e_4]} , \quad nil , \{1,3\} \right]_2$$

$$\left[A \Rightarrow > A \overset{c}{\underset{b-a}{\overset{e_8}{\smile}}} , \quad nil , \{5,6\} \right]_3$$

$$\left[A \Rightarrow > A \overset{e_7}{\underset{b \smile a}{c}} , \quad ((A\ 3)) , \{7,8\} \right]_6$$

$$\left[S \Rightarrow -a \overset{b}{\frown} A \overset{e_7}{<} , \quad ((A\ 3)) , \phi \right]_5$$

Example 5, list 6.

With the reading of node a_2, the bottom finally begins to come off the stack. The simulation now contains the following structure
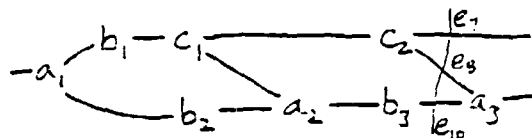
$$S' \rightarrow A_r'^*$$
$$S \rightarrow A_r' \rightarrow A_r'^*$$
$$S \rightarrow A_r \rightarrow A_r' \rightarrow A_r'^*.$$

which differs from that of the last list in that all the non-recursive A-recognizers have gone away. The reader should consider what the structure would have been if we had read another c node and started another level of recursion.

$$S \Rightarrow -a \overset{b}{\frown} A <$$

$$A \Rightarrow \overset{=c}{\underset{-b-a-}{=}}$$

$$A \Rightarrow >A < \overset{c}{\underset{b-a-}{=}}$$

(node read: b_3)

$$\left[A \Rightarrow >A < \overset{c}{\underset{b \frac{e_8}{e_{10}} a}{=}} \; , \; nil \; , \; \{5,6\} \right]_3$$

$$\left[A \Rightarrow >A \overset{e_7}{\underset{b-a-}{\times}} < \; , \; ((A\;3)) \; , \; \{7,8\} \right]_6$$

$$\left[S \Rightarrow -a \overset{b}{\frown} A \overset{e_7}{\times} < \; , \; ((A\;3)) \; , \; \phi \right]_5$$

Example 5, list 7.

The $A_7^{\prime\prime}$ recognizer on the bottom of the stack makes a transition on b_3.

$$S \Rightarrow -a \overset{b}{\smile} A <$$

$$A \Rightarrow \overset{-c}{\underset{-b-a-}{}}$$
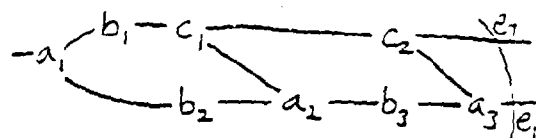
$$A \Rightarrow > A \overset{c}{\underset{b-a-}{\smile}}$$

(node read: a_3)

$$\left[A \Rightarrow > A \overset{c}{\underset{b-a}{\smile}}_{[e_{11}]} , \; nil, \; \{5, 6\} \right]_3$$

$$\left[S \Rightarrow -a \overset{b}{\smile} A \overset{e_7}{\underset{e_{11}}{\gtrless}} , \; nil, \; \phi \right]_5$$

$$\left[A \Rightarrow > A \overset{e_7}{\underset{e_{11}}{\gtrless}} \overset{c}{\underset{b-a-}{}} , \; nil, \; \{7, 8\} \right]_6$$

Example 5, list 8.

The stack unwinds another level. The final configuration kept by the simulator is:

$$S'^\bullet$$

$$S \;\to A_r' \qquad\qquad \text{(item 7} \to \text{item 6)}$$

$$S \;\to A_r \to A_r' \qquad \text{(item 7} \to \text{item 8} \to \text{item 6)}.$$

4.2.4. Algorithm Description

We are now ready to state our flow graph parsing algorithm. The algorithm takes as input a flow grammar and a flow graph; it determines whether the graph is generated by the grammar. As with our version of Earley's algorithm, the output of the algorithm is a sequence of item lists—one for each node in the input—which represent all the possible configurations of a non-deterministic graph parser when run on that input. The algorithm does not output a parse tree for the input, although it can be modified to do so in a manner similar to that presented in the last chapter.

The algorithm operates by using a list of items I_i to keep track of all the configurations a parser might be in after reading the first i nodes it chooses to read. Given lists $I_0, \ldots, I_{i-1}$, the algorithm constructs list I_i by using three operations: a *scanner* operation, a *predictor* operation, and a *completer* operation. These operations in turn use three sub-operations: the *p-split*, the *c-split*, and the *r-split*. We first describe the nature of all these operations, and then how the algorithm uses them to construct the lists $I_0, I_1, \ldots, I_n$.

The P-Split Operation

The p-split operation takes as input an item i, a non-terminal node n which i is deriving, a item c which has called i, and a list I_j. It performs the following actions:

1. It creates a new item i' whose state part is that of i, whose call list is that of i, and whose return set is that of i except that c is removed.

2. It adds i' to I_j.

3. It goes through the live callees of i and adds i' to each of their return sets.

4. It goes through all the live callers of i except c and replaces their calls to i by calls to i'.

5. It changes i's return set to be the singleton $\{c\}$.

Items i and i' are said to be p_j-*splits* of each other. This relation is transitive—any other p_j-splits of i are p_j-splits of i' (and vice versa)—but does not persist across lists: a p_j-split of i is not a p_k-split of i for $i \neq j$.

The C-Split Operation

The c-split operation takes as input an item i, a non-terminal node n in i's target graph, an item c which i has called to derive n, and a list I_j. It performs the following actions:

1. It creates a new item i' whose state part is that of i, whose return list is that of i, and whose call list that of i except that c is removed from the callees for n.
2. It adds i' to I_j.
3. It goes through the live callers of i and adds i' to any call list on which i appears.
4. It goes through all the live callees that i has pending for nodes other than n and adds i' to each of their return sets.
5. It goes through all the live callees other than c that i has pending for n and replaces i by i' in their return sets.
6. It makes c the only callee for n in i.

The items i and i' are said to be *c-splits* of each other. This relation is transitive—any other c-splits of i are c-splits of i' and vice versa—and it persists across lists: a c-split of i created on a list I_j a c-split of all those created on other lists.

The R-Split Operation

The r-split operation takes the same inputs i, n, c, I_j as the c-split. It first performs a c-split operation to produce an item i' on list I_j, and then takes the following actions:

1. It marks i' with the R-flag.
2. It removes the R-flag from i.
3. It adds i to the call list of n in i', and adds i' to the return set of i.

The Scanner Operation

The scanner operation takes as input an item i from list I_{j-1} and the j-th input node to be read n_j. Let s be the state part of i. If s is empty (i is suspended), the scanner does nothing. If s is non-empty, but none of its pairs contain edges which are inputs of n_j, then the scanner adds i unchanged to

list I_j. If s does contain inputs of n_j, but n_j is determined to be *unacceptable* as described in section 4.1.4. the scanner marks i as *dead* and adds it to list I_j. Finally. if n_j is acceptable to s. the scanner (i) computes a new state s' as described in section 4.1.4. changes the state part of i to s'. and adds i to list I_j.

The Predictor

The *predictor* operation takes as input an item i from list I_j. Let s be the state part of i. If none of the target edges of s are inputs to non-terminals, the predictor does nothing. Otherwise. for each non-terminal node n which has one or more input edges in s, the predictor distinguishes two cases:

Case (i) The item i already has calls pending for n.

Let $i_1, \dots, i_m$ be the live items i has called for n. Then for each i_k, the predictor does the following:

1. If i_k has callers besides i. the predictor invokes the p-split operation on i_k, n, i, and I_j.

2. Let s_k be the state gotten by augmenting i_k's current state in accordance with the calling conventions of section 4.1.5. If the predictor has already added a p_j-split i' of i_k with state-part s_k to I_j, then the predictor adds i to the call list of i' and replaces i_k by i' on the call list for n in i. Otherwise. the predictor changes the state of i_k to be s_k and adds it to list I_j.

   (*N.B.* The item i' referred to above may not still be in state s_k when its return list is modified, since predictions occurring between this one and the one that added i' may have modified the state of i'. In such a case, the predictor still reuses i' rather than create a new item.)

Case (ii) The item i has no calls pending for n.

Let N be the type of n, let $R_1^n, R_2^n, \dots, R_m^n$ be all the recognizers for grammar rules which derive N, and let $s_1^n, s_2^n, \dots, s_m^n$ be the initial states of those recognizers computed as per section 4.1.5. For each s_k^n, if the predictor has already added a new item i' with state part s_k^n to list I_j, the predictor adds i' to the call list for n in i and adds i to the return set of i'. Otherwise, the predictor creates an item with state part s_k^n, empty call list, and return set $\{i\}$; if this item is for a left-recursive rule the predictor marks it with the R-flag. The predictor then adds this item to

I_j and to the call list for n in i.

(*N.B.* The point made above about possible changes in the state of the items i' also applies in this case.)

The Completer

The completer operation takes as input an item i on list I_j. Let s be the state part of i. If none of the target edges in s are trailing edges, the completer operation does nothing. Otherwise, let $i_1, \ldots, i_m$ be the live members of i's return set. Let n_k be the non-terminal in i_k whose call list contains i, and let c_k be that call list. Finally, let s_k be the state of i_k induced by i's return as per section 4.1.5. The completer performs the following actions for each i_k:

1. If i_k is marked with the R-flag, the completer invokes the r-split operation on i_k, n, i, and I_j.
2. If i_k has calls other than the one to i pending for node n, the completer invokes the c-split operation on i_k, n, i, and I_j.
3. If the completer has already added to I_k a c-split i' of i_k whose state part is s_k and who has calls outstanding for the same nodes as i_k does,[2] the completer marks i_k as dead (from a merge) and adds it to I_j. Otherwise, the completer changes the state of i_k to be s_k and adds it to I_j.

   (*N.B.* As in the predictor, the item i' mentioned above may not still be in state s_k at the time of the current completion. Intervening completions may have changed i''s state, but the completer still marks i_k as dead.)

The Algorithm

First, we construct I_0 as follows:

1. For each rule P_k in the grammar which derives S, let s_k be the initial state of a recognizer for that rule computed in accordance with section 4.1.5 and the initial linkage information specified in the input. Add an item

---

[2] This restriction on calls merely reflects the fact that, unlike the state of string items, the state of graph items does not reflect which non-terminals are being derived. Thus, when considering whether to merge graph items, this part of their 'state' must be checked separately. Note that only which nodes have outstanding calls matters here, not the items to which those calls were made.

to I_0 whose state part is s_k, whose call list is empty, and whose return set is empty.

2. Run the predictor on every item in I_0. If this adds new items to I_0, run the predictor on them, and repeat this process until no new items are added.

Next, we successively construct $I_1, \ldots, I_n$. Given $I_0, \ldots, I_{j-1}$, we construct I_j as follows:

3. Choose an input node n_j to read next. (This node must be in the right fringe of the current read head.)

4. Run the scanner over every item in I_{j-1}.

5. Run the completer over every item in I_j. If this adds new items to I_j, run the completer over them, and repeat this until no new items are added.

6. Run the predictor over every item in I_j. If this adds new items to I_j, run the predictor over them, and repeat this until no new items are added.

A little thought will convince the reader that this algorithm produces the lists given in the examples above. A graph is accepted by this algorithm if I_n contains an item whose call lists and return set are empty and whose state part is an accepting state of a recognizer for a rule deriving S.

This algorithm can be converted to produce a parse using techniques exactly like those presented in the last chapter.

Chapter 5.

Discussion

In this chapter, we discuss a variety of issues related to flow graphs, flow grammars, and our parsing algorithm. We include a complexity analysis of the algorithm and some suggestions for related research.

5.1. Flow Graphs and Grammars

As was mentioned in the introduction, flow graphs were abstracted from program descriptions called *plans*. The goal of the abstraction was to preserve two structural features of plans: (i) the partial ordering of operations, and (ii) the naming of inputs and outputs. There were a number of structural features of plans that were left out of flow graphs, most notably "fan out" — the use of an operation's single output as the input of more than one other operation. The criteria used to determine which features of plans would be preserved in flow graphs grew out of the author's work in program analysis and are not germane here; however, we say more below about how graphic representations which include other features may be usefully manipulated by our parsing algorithm.

It should be quite clear from the above that the structure of flow graphs and flow grammars were developed without much regard for graph-theoretic concerns. This does not necessarily mean, however, that they are devoid of theoretical interest. If we view flow grammars as generalizations of string grammars which generate partially- as opposed to totally-ordered sentences, then the following sorts of questions naturally arise:

- Is there a natural definition of a "finite-state flow-graph automaton"? Is it possible to develop a hierarchy of such automata analogous to the

135

string-automata hierarchy? What is the relationship between this hier-
archy and the string hierarchy?

- Is is possible to develop a hierarchy of flow grammars analogous to
  Chomsky's type 0–3 string-grammar hierarchy? In particular. are there
  canonical-form results for flow grammars, and do the sets of languages
  generated by such grammars satisfy any interesting closure properties?

- If the answers to the above questions are affirmative, can we relate the
  automaton and grammar hierarchies in a manner reminiscent of the string
  case?

Our research into flow-graph parsing, as might be surmised from the refer-
ences mentioned in chapter 1, was initially concerned with questions such
as these. We hoped initially that flow-graph parsing might be reducible to
context-free string parsing. While we eventually gave up on achieving such
a direct connection between the two—we now believe that flow grammars
have a strictly greater generative capacity than string grammars—the intu-
itions we developed in the course of this research seem to indicated strongly
that the answers to the questions given above are generally affirmative.

5.2. Applicability of the Algorithm

One of the most interesting features of our parsing algorithm is its amenabil-
ity to 'advice' from outside sources of knowledge. Since the algorithm's con-
trol mechanism works by consulting and updating and explicit agenda—the
current item list—it is a relatively easy matter for external agents to control
or influence the algorithm's behavior: they need only make alterations in
this list.

For example, let us consider the fan-out problem mentioned above. Fig-
ure 5.1 shows a grammar fragment and a pseudo-flow graph which contains
fan-out. This figure represents the result of a typical program optimization
and may be read as follows:

> A and B are high-level operations. A may be implemented
> by operation a followed by operation b, while B may be im-
> plemented by operation a followed by operation c. If I have
> a program which performs both A and B, I can optimize this
> program by performing a just once and then using its output
> as the input of both b and c.

$$A \Rightarrow -a-b-$$
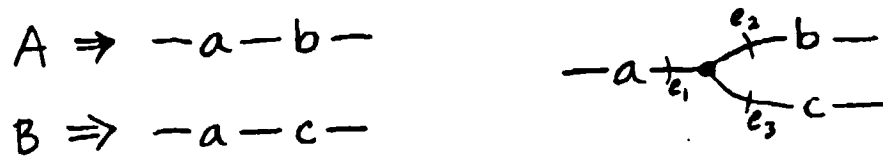
$$B \Rightarrow -a-c-$$

Figure 5.1. Flow grammar fragment and pseudo-flow graph. The graph displays fan-out and can be considered an optimization of the two flow graphs generated by the grammar fragment.

We cannot recover this analysis simply by parsing, because the flow graph which represents the optimized program can not be read all the way through by our read-head mechanism. But consider the state of the parser at the point where its read head encounters the fan-out. The grammar fragment shown in figure 5.1 will have given rise to the following two item skeletons:

$$\left[A \Rightarrow -a \overset{e_1}{+} b-, \; \ldots \right]$$

$$\left[B \Rightarrow -a \overset{e_1}{+} c-, \; \ldots \right]$$

input:

$$-a \overset{e_1}{+} ??$$

A fan-out handler invoked at this point, basing its actions on a theory of program optimization through shared operations, might (i) replace e_1 in the parser's head position by e_2 and e_3, and (ii) change these item fragments to read:

$$\left[A \Rightarrow -a \overset{e_2}{+} b-, \; \ldots \right]$$

$$\left[B \Rightarrow -a \overset{e_3}{+} c-, \; \ldots \right]$$

input.

$$-a \; ??$$

These actions would allow the parser, using the rules of figure 5.1, to recover both the desired analyses for the input.

Readers may be dismayed by the seeming informality of such a solution.[1] The point here is that our parsing algorithm embeds a notion of input structure which does not take into account anomalies due to sharing. A domain expert which understands such structural anomalies can show the parser how to proceed in these cases by altering its state in the aforementioned way; the operations themselves may seem low-level but the theory underlying them is not.

To put it another way. it is important here not to confuse "representation-level" with "low-level". Because the algorithm's representations fairly directly reflect the state of the parsers being simulated, a wide range of grammar- and graph-theoretic operations can be implemented directly via simple representation-level operations. In fact, it is precisely this closeness between the theoretic and representational levels that makes this algorithm so easy to advise.

5.3. Correctness

We have done no substantive work on a correctness proof for our parsing algorithm. For one thing. such a proof would ideally require definitions of flow graphs, flow grammars. and the graph-derivation process which are a great deal more rigorous than those presented here. For another, the algorithm itself would have to be stated quite a bit more precisely than we have stated it. To readers who might be interested in constructing a correctness proof, we recommend the proof of correctness of Earley's algorithm contained in [Aho and Ullman 1972]. The structure of that proof would probably serve as a good model for a correctness proof in this case.

5.4. Complexity Analysis

We conclude by considering the running time of our simulation algorithm. In our analysis, we will be concerned entirely with obtaining a loose upper bound on worst-case time complexity as a function of the number of nodes and edges in the input graph. paying only cursory attention to space complexity or time/space complexity as a function of the input grammar. The

---

[1] In fact, we expect that readers are screaming "Ouch! What a hack!"

point of this focus is twofold: (i) we are interested primarily in exposing intuitions about the relative cost of the algorithm's operations, and (ii) we will be satisfied to show that the algorithm displays polynomial rather than exponential time growth with the size of the input.

The algorithm spends all its time, except for a constant amount at the beginning, running the scanner, predictor, and completer over each constructed item. Thus, the total running time of the algorithm is the product of the number of constructed items and the sum of the times needed to run each of these three operations on an item. We will consider each factor separately.[2]

In what follows, we will be using the following definitions:

p = the number of rules in the grammar,
w = the maximum number of inputs to a grammar rule,
t = the maximum number of pairs in the state of a recognizer,
h = the maximum number of edges in a head position,
e = the number of edges in the input graph, and
n = the number of nodes in the input graph.

In addition, we will often be making an ordered choice of k items from among m items. There are

$$m \times m - 1 \times \ldots \times m - (k - 1) = k! \times \binom{m}{k}$$

ways of making such a choice; we will denote this number by $\left[{}^{k}_{m} \right]$.

The algorithm constructs $n + 1$ lists. On each list, any two items must differ in one of (i) the rule they were invoked for, (ii) where in the input they were invoked, or (iii) their state. Each start position is an ordered choice of at most w edges from the e in the input, and each state is determined by an ordered choice of at most t edges from the current head position; thus, the number of items a single list is bounded above by

$$p \times \begin{bmatrix} w \\ e \end{bmatrix} \times \begin{bmatrix} t \\ h \end{bmatrix}$$

.

---

[2]This analysis is patterned directly after that given by Earley in [1969].

Both the predictor and the completer need to know whether they have already added a particular item to the current list. If we are concerned only with running time (and not space requirements), we can optimize this operation to take constant time by keeping a table of all such items which is indexed by the the three factors mentioned above.[3] We will assume that such an optimization is used in the following analysis.

Now we wish to bound the time it takes to run each of the three basic operations on a given item i from list I_j. In this analysis, we will use an augmented predictor operation that also attaches to each created item a unique integer identifier. When the c-split operation splits such an item, this identifier will be copied to the split item, allowing the predictor to tell in constant time whether two items are c-splits of each other.

The scanner either copies i or simulates a state transition for the recognizer represented by i. This takes constant time. In addition, the scanner has to check each of up to t pairs in the item's state part to determine whether the item is active on the node read. This also requires time independent of the size of the input graph.

When the predictor considers an item i on I_j whose state contains inputs to target non-terminal(s), it tries to add to I_j up to tp items: one for each rule which derives each of the non-terminals whose inputs have been reached. In addition, it may p-split the up to $\left[\frac{t-1}{phw}\right]$ members of its call list: a figure derived below. Given the optimization described above, checking whether each of the resulting items has already been added to the list takes constant time, so the predictor takes up to $\left[\frac{t-1}{phw}\right]$ time on each item.

When the completer considers an item i on I_j whose state part contains trailing edges of its target graph, it must process every item in i's return set. Thus, the amount of time taken by the completer is the product of the maximum number of items in a return set and the amount of time it takes to process each such item.

Return pointers in an item arise from two sources. Originally, an item has one return pointer for each of its calling items. However, as the parser runs and its callers split, an item may contain several return pointers to different splits of one original caller. We consider first how many original callers an item can have, and then how many splits each can turn into.

---

[3]Such a table, of course, will tend to be very sparse; the author's actual implementation of the algorithm used a more compact, time-consuming representation.

A given sub-recognizer R can only have been originally called from recognizers at one of w head positions (one for each of its inputs). This, its original calling recognizers must have been in one of at most $\begin{bmatrix} t \\ wh \end{bmatrix}$ states, so there can have been at most

$$p \times \begin{bmatrix} t \\ wh \end{bmatrix} \times \begin{bmatrix} w \\ e \end{bmatrix}$$

original calling items.

Suppose an instance of a recognizer r (which was called at some specific input position) calls an item i to derive a node n. Every state transition on a node other than n that the calling recognizer takes while i is running might split the caller and add up to p return pointers to i. Since at least one input of n can not appear in the state led to by such a transition, there are at most $\begin{bmatrix} t-1 \\ e \end{bmatrix}$ possible states which contribute splits, leading to a total return set membership of

$$\left(p \times \begin{bmatrix} t \\ wh \end{bmatrix} \times \begin{bmatrix} w \\ e \end{bmatrix} \right) \times \left(1 + \begin{bmatrix} t-1 \\ e \end{bmatrix} \right)$$

When a calling item i c- or r-splits as the result of a callee's return, we must add the split-off item to the call lists of i's callers and the return lists of i's callees. This will take as much time as there are callers and callees. We saw above that how may callers there are; a similar argument (utilizing the symmetry of creation of call and return pointers) shows that there are up to $\begin{bmatrix} t-1 \\ phw \end{bmatrix}$ callees. Thus, splitting an item may take up to the sum of these figures, leading to a total cost for the completer of

$$\left[\left(p \times \begin{bmatrix} t \\ wh \end{bmatrix} \times \begin{bmatrix} w \\ e \end{bmatrix} \right) \times \left(1 + \begin{bmatrix} t-1 \\ e \end{bmatrix} \right) \right]$$
$$\times \left[\left(p \times \begin{bmatrix} t \\ wh \end{bmatrix} \times \begin{bmatrix} w \\ e \end{bmatrix} \right) \times \left(1 + \begin{bmatrix} t-1 \\ e \end{bmatrix} \right) + \begin{bmatrix} t-1 \\ e \end{bmatrix} \right]$$

When we add the costs of the three operations together, we find that the completer dominates the cost of the other operations, so the cost of the entire algorithm is bounded by the product of the completer cost and the total number of items. This product is polynomial in e; in the string case it reduces to $e^3 = n^3$ which is the cost of Earley's algorithm.

References

Aho, Alfred V., and Jeffrey D. Ullman, *The Theory of Parsing, Translation, and Compiling*, volume 1, Prentice Hall, 1972.

Brotsky, Daniel C., "Program Understanding through Cliché Recognition," (M.S. Proposal), MIT-AI-WP-224, December 1981.

Earley, J., "An Efficient Context-Free Parsing Algorithm," (Ph.D. Thesis), Computer Science Department, Carnegie Mellon University, 1968.

Knuth, Donald E., "On the Translation of Languages from Left to Right," *Information and Control* 8:12, December 1965, pp. 607-639.

Montanari, U.G., "Separable Graphs, Planar Graphs, and Web Grammars," *Information and Control* 16:3, March 1970, pp. 243-267.

Pavlidis, T., "Linear and Context-Free Graph Grammars," *Journal of the ACM* 19:1, January 1972, pp. 11-23.

Pfaltz, J.L., and A. Rosenfeld, "Web Grammars," *Proceedings of the IJCAI*, Washington, D.C., 1969, pp. 609-619.

Rich, Charles, "Inspection Methods in Programming," (Ph.D. Thesis), MIT-AI-TR-604, December 1980.

Rich, Charles, and Richard C. Waters. "Abstraction, Inspection, and Debugging in Programming," MIT-AIM-634, June 1981.