

A CULTURE OF INNOVATION
INSIDER ACCOUNTS OF COMPUTING
AND LIFE AT BBN



DAVID WALDEN AND RAYMOND NICKERSON, EDITORS

WITH CHAPTERS BY

NINETEEN LONG-TIME BBN PEOPLE

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To the people of BBN, whose intelligence, curiosity, and determination over the years created the work environment and computing innovations that make the BBN story worth telling.

Contents

Preface and Acknowledgments	xiii
About the Authors	xvii
PART I: Founders and Early Days in Computing	1
1 Founding a Culture of Engineering Creativity	3
<i>Leo Beranek</i>	
1.1 Introduction	3
1.2 BBN's beginnings	3
1.3 Steady growth and expansion	6
1.4 Finances	9
1.5 New directions: Licklider and computers	10
1.6 Men and machines	12
1.7 New directions in psychology	14
1.8 ARPANET	15
1.9 Thoughts on managing BBN	15
2 A Sketch of the Life of Richard Henry Bolt (1911-2002)	21
<i>Compiled by Raymond Nickerson</i>	
3 The ABC's of BBN	23
<i>John Swets</i>	
3.1 Scope of discussion	23
3.2 Acoustics and psychology at Harvard	23
3.3 Harvard's psychology joins MIT's computers	24
3.4 From "A" to "B" at BBN	25
3.5 Psychology at BBN	26
3.6 From "B" to "C" at BBN	28
3.7 Computers and time-sharing at BBN	28
3.8 Licklider moves to ARPA	29
3.9 Psychology's influence on computers at BBN: 1958-1963	30
3.10 Libraries of the future	31
3.11 Program simplification	35
3.12 Automatic pattern recognition	35
3.13 Computer-based teaching and learning	36
3.14 A computer-based psychology laboratory	41
3.15 Conclusion	41

4	Early Years of Basic Computer and Software Engineering	51
	<i>Compiled by David Walden</i>	
4.1	The PDP-1s and PDP-1 time-sharing	51
4.2	Higher-level language work	59
	PART II: Culture, Business, and Management	69
5	The Way We Were: Aspects of the Culture of BBN	71
	<i>David Walden</i>	
5.1	The third university	71
5.2	Recruiting, developing, and keeping employees	73
5.3	University ties	79
5.4	Entrepreneurial urges	79
5.5	Extracurricular activities	81
5.6	Student protests	83
5.7	Alumni association	85
6	The History of Technology Transfer at BBN	89
	<i>Stephen Levy</i>	
6.1	Introduction	89
6.2	1948-1959: Early intellectual property transfer efforts	90
6.3	1960-1969: Licensing, investments, and “industrialization”	90
6.4	1970-1979: Computer and communications subsidiaries	99
6.5	1980-1989: Rapid growth and the end of the cold war	107
6.6	1990-1997: Emergence of the Internet and acquisition by GTE	113
6.7	Conclusions	119
7	Leading a Top Notch R&D Group	121
	<i>Frank Heart</i>	
7.1	MIT and Lincoln Laboratory	121
7.2	BBN in late 1966	122
7.3	BBN R&D environment	123
7.4	ARPANET and its impact on BBN	130
7.5	Commercial imperative	133
7.6	Diversions	134
7.7	Closing comments	136
	PART III: Applying Computer Technology	139
8	Psychology at BBN from the mid 1960s	141
	<i>Raymond Nickerson and Sanford Fidell</i>	
8.1	Introduction	141
8.2	Psychology in context at BBN	142
8.3	Overview of psychological studies at BBN	146
8.4	Intra-BBN connections	151
8.5	Facilities	152
8.6	Project descriptions	154
8.7	Concluding comment	177

9	Control Systems R&D at BBN	189
	<i>Sheldon Baron</i>	
9.1	Introduction	189
9.2	Human information processing and control	190
9.3	Advanced command and control systems	205
9.4	Applications not focused on human control or decision support	210
9.5	Concluding remarks	213
10	50 Years of Acoustic Signal Processing for Detection	219
	<i>Edward Starr and Richard Estrada</i>	
10.1	Coping with the digital revolution	219
10.2	1950s and early 1960s	220
10.3	1960s and early 1970s	220
10.4	Undersea surveillance signal and information processing basics	227
10.5	Early all-digital signal processing	228
10.6	Mid- and late 1980s	234
10.7	Summary	241
11	DataProbe and ADCAP	245
	<i>Thomas Fortmann</i>	
11.1	Torpedo data analysis	245
11.2	Technical challenges	247
11.3	Data caching and tape slavery	248
11.4	User interface and data display	251
11.5	Other applications and platforms	254
11.6	FDRS and Mark 661	255
11.7	Point Mugu	256
11.8	ButterProbe	257
11.9	FAES and patterns	259
11.10	Commercial sales	259
11.11	Epilogue	261
12	Medical Applications of Computers	265
	<i>Paul Castleman</i>	
12.1	Patient care	265
12.2	Clinical research	267
12.3	Biomedical research	268
12.4	Commercial software products	271
12.5	Impact of the BBN environment	273
12.6	Observations and conclusions	276
13	Educational Technology at BBN	281
	<i>Wallace Feurzeig</i>	
13.1	From drill-and-practice to “intelligent” CAI	281
13.2	Learning and teaching mathematics	290
13.3	Learning and teaching science	311
13.4	Learning and teaching language and reading	325
13.5	Training technology	332
13.6	Educational networking	343

14	Speech Processing at BBN	353
	<i>John Makhoul</i>	
14.1	Before 1971	353
14.2	ARPA Speech Understanding Research program, 1971-1976	355
14.3	Speech coding and compression, 1972-1991	359
14.4	Scrambling for work	361
14.5	Speech recognition, since 1984	365
14.6	Neural networks, OCR, and other research	370
14.7	Commercial activities	371
14.8	Looking forward	373
15	Natural-Language Understanding at BBN	381
	<i>Ralph Weischedel</i>	
15.1	The 1960s: Individuals and early concepts	381
15.2	The 1970s: Networks	383
15.3	The 1980s: Knowledge expands	388
15.4	The 1990s: Methods	390
15.5	The 2000s	393
15.6	Looking forward	395
16	Artificial Intelligence (AI) at BBN	401
	<i>Compiled by David Walden</i>	
16.1	Evolution of the AI group	401
16.2	AI techniques	407
16.3	Applying AI	408
	PART IV: Developing Computer Technology	415
17	Data Networking @ BBN	417
	<i>Steven Blumenthal, Alexander McKenzie, Craig Partridge, David Walden</i>	
17.1	ARPANET	417
17.2	On to the Internet	423
17.3	IP, Routers, and Routing Protocols	426
17.4	Satellite and radio	429
17.5	Secure networks	437
17.6	Network operations	438
17.7	What has BBN's role been?	441
18	Distributed Computing at BBN	451
	<i>Richard Schantz</i>	
18.1	Introduction	451
18.2	Early investigations: 1970-1973	452
18.3	Distributed computing infrastructure emerges and evolves: 1973-1995	457
18.4	Internet application focus: 1981-1995	481
18.5	Conclusion	486
19	Networked E-mail	493
	<i>Compiled by David Walden</i>	
19.1	Tomlinson's initial demonstration	493
19.2	A succession of e-mail programs	494
19.3	Codification of the e-mail standard	495
19.4	Other BBN e-mail systems	496

20	SIMNET: A Revolution in Distributed Team Training	501
	<i>Compiled by David Walden</i>	
20.1	Sketch of the basic technology	501
20.2	Evolution of the SIMNET project and BBN's participation	503
20.3	Key ideas and challenges	508
20.4	Demonstrations and applications of SIMNET technology	510
20.5	BBN's attempt to expand into the military training business	511
20.6	Non-BBN spin-offs and follow-ons of the SIMNET activity	514
21	Later Years of Basic Computer and Software Engineering	519
	<i>Compiled by David Walden</i>	
21.1	More high-level language work	519
21.2	More time sharing	522
21.3	Adapting existing computers to packet switching	525
21.4	Building complete computer systems	526
21.5	Computer devices	532
21.6	Parallel processors	534
22	Epilog	555
	<i>David Walden</i>	
22.1	Changes in ownership	555
22.2	The classic BBN culture and business	556
22.3	The evolution continues	558

Preface

Our purpose

Bolt Beranek and Newman (BBN) was originally a partnership and then a public corporation, Bolt Beranek and Newman Inc. As a public company, BBN went through several other organizational and name transitions. Starting in the 1990s, it became a part of a couple of big telephone companies; and then (2003–2009) it operated as BBN Technologies, a privately held corporation. Today (2011) it operates as Raytheon BBN Technologies. Throughout these incarnations, BBN has been a notable (we might claim renowned) science and engineering innovator in, first, the acoustics field and, later, the computer field. BBN's role in the development of the Internet may be its most widely known innovative involvement, but it has made equally important contributions to other, less widely known, areas of the application of computers.

This book covers BBN's history of work in the computer field,¹ as well as more general discussion of BBN's culture and management, told by people who were deeply involved in these activities for many years (some to the present day). Thus, we have titled this book *A Culture of Innovation: Insider Accounts of Computing and Life at BBN*.

The raw material for the book was originally pulled together mostly in the early- to mid-2000s, covering the period up to the early 1990s. Some, but not a lot, of more recent history has been added. Thus, *the coverage in this book of BBN's computer history is increasingly thin for the years moving forward from the mid-1990s*.

Organization and style of this volume

As can be seen from the Table of Contents, this volume is divided into several logical sections: one that is more about company history, one that is more about business and culture, one that is focused on a variety of areas of computer application, and one that focuses on the development of computer technology itself.

We mostly have attempted to use a consistent style throughout this book. However, for practical reasons of reducing editorial and keyboarding work, we have not forced a standard footnote and endnote style or bibliographic citation style on the separate chapters. For bibliographic entries for BBN reports, we also have taken a shortcut and left out the full company name and the location; the BBN library in Cambridge, Massachusetts, maintains the archive of BBN reports.

NB: While most of the chapters are told in the voices of their author or authors, Chapters 4, 16, 19, 20, and 21 were compiled by Walden and are based on extensive use of quotations from actual participants. It might have been stylistically better (and perhaps more readable) if Walden had written these chapters in his own words based on the history he learned from the quoted individuals; however, Walden judged it more

¹A significant part of BBN's acoustic history is reported in Deborah Melone and Eric W. Wood's 2005 book *Sound Ideas — Acoustical Consulting at BBN and Acentech* (Acentech Incorporated, 33 Moulton Street, Cambridge, MA 02138). The acoustic history of BBN is also covered to some extent in Leo Beranek's 2008 memoir, *Riding the Waves: A Life in sound, Science, and Industry* (MIT Press, Cambridge, MA).

important to make available the quotes of the people who were there and did the work rather than writing his own version of the history.

Website

We have created a website to go with this book:

www.walden-family.com/bbn

Posted on the website are color versions of some of the book's figures that show up better in color — from Chapters 8, 11, and 13.

Corrections and additional content will also be posted on the website.

Acknowledgments

As editors of this volume, we have many people to thank. First and foremost, thanks must go to our authors. Current BBN president Tad Elmer gave us access to BBN's archives. BBN librarian Jennie Connolly and her co-workers helped us in numerous ways, as did many other BBNers and ex-BBNers. We have dedicated this book to the people of BBN whose intelligence, curiosity, and determination over the years created the computing innovations and work environment that make the BBN story worth telling. Naturally we have in mind the managers, scientists, engineers and consultants; we also are thinking of the people in the numerous technical, administrative and other support functions that an organization like BBN requires.

Investigating the history of computing at BBN and pulling together the content of this volume was prompted by an invitation from Thomas (Tim) Bergin, then editor-in-chief of the *IEEE Annals of the History of Computing*, who invited us to edit a special issue of that journal on computing at BBN. We are grateful to Tim for his invitation and for shepherding that project through the production of approximately twenty draft papers. Later, David Grier became editor-in-chief of the *IEEE Annals of the History of Computing*, and he worked with us to shape twelve of our draft documents into finished papers, suitable for publication in two special issues of the journal (volume 27 number 2 April–June 2005 and volume 28 number 1 January–March 2006). Also supporting publication of those papers were the anonymous reviewers and IEEE Computer Society employees Robin Baldwin, Alkenia Winston, Louise O'Donald, and others whose names we never knew.

We are grateful to the IEEE Computer Society for permission to reuse content from those special issues, as follows:

- A shorter version of the chapter by Leo Beranek, "BBN's Earliest Days: Founding a Culture of Engineering Creativity," appeared in the *IEEE Annals of the History of Computing*, Volume 27, Number 2, April–June 2005, pp. 6–14.
- A shorter and somewhat different version of the chapter by John Swets, "The ABCs of BBN," appeared in the *IEEE Annals of the History of Computing*, Volume 27, Number 2, April–June 2005, pp. 15–29.
- A shorter version of the chapter by Stephen Levy, "History of Technology Transfer at BBN," appeared in the *IEEE Annals of the History of Computing*, Volume 27, Number 2, April–June 2005, pp. 30–38.
- A similar version of the chapter by Frank Heart, "Leading at Top-Notch R&D Group in the BBN Environment," appeared in the *IEEE Annals of the History of Computing*, Volume 27, Number 2, April–June 2005, pp. 39–51.

- A shorter and somewhat different version of the chapter by Sheldon Baron, “Control Systems R&D at BBN,” appeared in the *IEEE Annals of the History of Computing*, Volume 27, Number 2, April–June 2005, pp. 52–64.
- A shorter version of the chapter by Richard Estrada and Edward Starr, “50 Years of Acoustic Signal Processing for Detection: Coping with the Digital Revolution,” appeared in the *IEEE Annals of the History of Computing*, Volume 27, Number 2, April–June 2005, pp. 65–78.
- A similar version of the chapter by Paul Castleman, “Medical Applications of Computers at BBN,” appeared in the *IEEE Annals of the History of Computing*, Volume 28, Number 1, January–March 2006, pp. 6–16.
- A much shorter version of the chapter by Wallace Feurzeig, “Educational Technology at BBN,” appeared in the *IEEE Annals of the History of Computing*, Volume 28, Number 1, January–March 2006, pp. 18–31.
- A shorter version of the chapter by John Makhoul, “Speech Processing at BBN,” appeared in the *IEEE Annals of the History of Computing*, Volume 28, Number 1, January–March 2006, pp. 32–45.
- A shorter version of the chapter by Ralph Weischedel, “Natural-Language Understanding at BBN,” appeared in the *IEEE Annals of the History of Computing*, Volume 28, Number 1, January–March 2006, pp. 46–55.
- A somewhat different version of the chapter by Steven Blumenthal, Alexander McKenzie, Craig Partridge, and David Walden, “Data Networking @ BBN,” appeared in the *IEEE Annals of the History of Computing*, Volume 28, Number 1, January–March 2006, pp. 56–71.
- A shorter and somewhat different version of the chapter by Richard Schantz, “BBN’s Network Computing Software Infrastructure and Distributed Applications (1970–1990),” appeared in the *IEEE Annals of the History of Computing*, Volume 28, Number 1, January–March 2006, pp. 72–88.

Several previously unpublished chapters are also included, five of which benefitted from the review process of the *IEEE Annals* although the papers were eventually withdrawn from consideration for publication in the *Annals* because of space limitations in the two BBN special issues.

Karl Berry and Steve Peter provided guidance for the use of \LaTeX for typesetting this book, and Steve Peter provided font advice for the cover art and for denoting sidebars. Boris Veytsman helped with a key typesetting issue. Ulrike Fischer providing a helpful answer to a question posted to the `comp.text.tex` discussion group. Other members of the \TeX community provided other answers. Jay Howland provided editorial help to Dave Walden on chapters for which he was involved in the writing or compilation. All our authors reviewed the proof copies of their own chapters, while Alex McKenzie spotted errors in the proof copies of his chapter and all of the other chapters.

Our spouses have our great appreciation for putting up with, as they have done so often in the past, the long hours we have spent at the keyboard writing and editing.

David Walden, East Sandwich, Massachusetts
Raymond Nickerson, Bedford, Massachusetts
December 2011

About the Authors

All of the authors in this volume had or are having long careers at BBN. Among them they cover the entire history of BBN.

Beranek and Levy each served as chief executive officer of the company for a long period of time. Beranek, Swets, Levy, Walden, Heart, and Starr served at various times as leader of BBN's research, development, and consulting business, where most of the activity described in this volume took place. The other authors all held or still hold senior technical or management positions in the company.

Shelly Baron joined BBN in 1967 after a 10-year career with NASA and remained there until his retirement as a senior vice president in 1998. His technical contributions were varied and well-recognized; he also held a number of management positions in his tenure at BBN. Baron received a PhD in applied mathematics from Harvard University. A Life Fellow of the IEEE, he was secretary/treasurer of the IEEE Control Systems Society, a member of the administrative committee of the IEEE Systems, Man and Cybernetics Society. In 1984, Baron was a recipient of the IEEE Centennial Medal.

Leo Beranek, who cofounded BBN in 1948, was BBN's president and CEO from 1953 to 1969 and chief scientist from 1969 till mid-1971. Previously, he was an associate professor of electrical engineering at MIT (1947-1958) and a faculty instructor of physics and communication engineering at Harvard University (1943-1947). Beranek, a Fellow of the IEEE, served on the IRE Committee on Professional Groups (1947-1948) and was Charter Chairman of the first group, Professional Group on Audio, now the IEEE Signal Processing Society. He earned a DSc from Harvard in acoustics and is the recipient of numerous awards, including the 2003 U.S. Presidential National Medal of Science.

Steve Blumenthal is the CTO at BridgePort Networks, a venture-backed start-up developing systems to provide seamless roaming between wireless LANs and cellular carrier networks. Blumenthal was with BBN from 1977 through 1997, where he worked on and led DARPA projects in packet voice/video conferencing, satellite packet switching, and the engineering and buildout of IP networks for AOL and BBN Planet. Later, at GTE and Genuity, he led the engineering of GTE's nationwide fiber-optic backbone and the development of Internet services. He has a BS and an MS in electrical engineering and computer science from MIT.

Paul Castleman joined BBN in 1962 while finishing his AB degree in applied mathematics at Harvard College. For more than two decades he directed BBN's medical computer activities. Castleman then went on to help start—and serve as chairman of the board for—Belmont Research and, later, Lincoln Technologies, two medical/pharmaceutical software firms that were each eventually successfully sold.

Dick Estrada joined BBN in 1975 after working at Bell Labs for six years. He worked on acoustic signal and information processing for 20 years. He held numerous technical and management positions at BBN and is now a part-time consultant with the company. Estrada has a PhD from the University of California at Berkeley.

Wally Feurzeig, BBN Principal Scientist, is a mathematician and computer scientist who has worked in computer science research since 1950. The central focus of his work is the development of sophisticated systems for learning and teaching in the areas of artificial intelligence,

programming languages, and mathematics education. He holds an MS in mathematics from the Illinois Institute of Technology.

Sandy Fidell joined BBN shortly after receiving a PhD in experimental psychology from the University of Michigan in 1968. He was a member of the Psychoacoustics Department in Los Angeles (Van Nuys and Canoga Park), California for 33 years. For most of that time he was responsible for the computer system that supported the entire Los Angeles group and for his last 20 years at BBN was the manager of the Psychoacoustics Department. Throughout his tenure, he did research on numerous aspects of psychoacoustics. He left BBN in 2001 to found Fidell Associates, where he still serves as CEO.

Tom Fortmann received a BS in Physics from Stanford and a PhD in Electrical Engineering from MIT. After teaching at Newcastle University in Australia, he spent 1974–1997 at BBN Laboratories as an engineer, manager, and senior vice president. Since his retirement, he has taught mathematics as a volunteer in two Boston high schools, founded a math professional development program for elementary teachers, and served on the Massachusetts Board of Elementary and Secondary Education. He and his wife Carla live in a 215-year-old house on the Battle Green in Lexington, where they raise chickens and Navy SEALs.

Frank Heart, after spending 15 years at MIT's Lincoln Laboratory, joined BBN in late 1966, led the ARPANET team at BBN in the late 1960s and the 1970s, and retired in 1994 as president of BBN's Systems and Technology Division. Heart is a member of the IEEE and has been a member of the IEEE Boston Section executive committee. He was a member of the IEEE's predecessor IRE, and, representing the IRE, was a founding director and treasurer of the American Federation of Information Processing Societies. He led the BBN engineering team for which BBN received an IEEE Corporate Innovation Recognition award in 1999. Heart served two terms as a member of the USAF Scientific Advisory Board.

Steve Levy is the general partner of Levy Venture Partners. In 1995, he retired as chairman from BBN, which he joined in 1966. From 1976 to 1994, he was BBN's CEO. Levy, who has served on many corporate boards, is past chairman of the American Electronics Association (AEA), the Massachusetts High Technology Council, and the Massachusetts Telecommunications Council. He served on the U.S. Department of Defense's Policy Advisory Committee on Trade and the AEA's National Information Infrastructure Task Force. He holds a BBA in accounting and was awarded an honorary doctor of laws degree from the University of Massachusetts.

John Makhoul joined BBN in 1970. Currently, he is working on various aspects of speech and language processing, optical character recognition, and human-machine interaction using voice. He is also an adjunct professor at Northeastern University and Boston University. Originally from Lebanon, Makhoul received degrees in electrical engineering from the American University of Beirut, Ohio State University, and MIT. Makhoul is a Fellow of the IEEE and of the Acoustical Society of America. His awards include the IEEE's Third Millennium Medal.

Alex McKenzie worked at BBN from 1967 to 1996 in a variety of positions related to network design, implementation, and management. As a BBN manager he was responsible for 250 staff members and an annual budget over \$50 million. He helped develop communication protocols in the ARPANET/Internet Network Working Group, the IFIP working group on Computer Networks (chair 1979-1982), and the International Organization for Standardization (chair of Presentation Layer group). He was awarded the IFIP "Silver Core" for outstanding service in 1986. Alex received a BS from Stevens Institute of Technology, an MS from Stanford University, and a certificate from the Sloan School of Management at MIT.

Ray Nickerson joined BBN in 1966 and was with the company, in Cambridge, as a researcher and manager, for 25 years. He was director of the Behavioral Sciences Division (which became the Information Sciences Division in 1975) or deputy director of the Computer and Information

Sciences Division for most of the period covered by this chapter. He retired as a senior vice president of BBN Systems and Technologies in 1991 and is now a research professor at Tufts University.

Craig Partridge is Chief Scientist for Internetworking at BBN Technologies, where he has worked on data networking problems since 1983. He is best known for his work on email routing, TCP round-trip time estimation, and high-performance router design. He received an MSc and a PhD, both in computer science, from Harvard University. Partridge is the former editor in chief of IEEE Network Magazine and ACM Computer Communication Review and is an IEEE Fellow.

Rick Schantz is a principal scientist at BBN Technologies where he has been a key contributor to advanced distributed computing research since joining the company in 1973. His research has been instrumental in defining and evolving the concepts underlying middleware since the early days of the ARPANET and Internet. More recently, he has led research in developing and demonstrating the effectiveness of middleware support for adaptively managing real-time, end-to-end quality of service and system survivability. Schantz received a PhD in computer science from the State University of New York at Stony Brook. He is a Fellow of the ACM.

Ed Starr joined BBN in 1959. He initially worked in the physical sciences and moved to computer systems a decade or two later to work on the Butterfly Multiprocessor. He assembled excellent teams and led them to accomplish large, difficult programs such as the Defense Data Network (DDN) for the Defense Communications Agency and the Fixed Distributed System (FDS) for the Navy. He retired as General Manager and CEO of BBN in 2001.

John Swets is a healthcare policy lecturer at Harvard Medical School and a radiology research associate at Brigham and Women's Hospital. He retired in 1998 from BBN after serving as senior vice president; general manager of research, development, and consulting; and board of directors member (all from 1970-1974); and chief scientist for information sciences (1975-1998). Previously, he taught at MIT. He also taught at the University of Michigan, from which he earned a BA and a PhD in psychology. Swets is a member of the National Academy of Sciences and the American Academy of Arts and Sciences. His awards include the Warren Medal of the Society of Experimental Psychologists.

Dave Walden worked at BBN from 1967 to 1970 and from 1971 to 1995, serving in a variety of technical, management, and staff positions. Walden was a member of the engineering team for which BBN received an IEEE Corporate Innovation Recognition award in 1999: "For pioneering contributions to computer networking technology through the development of the first packet switches, the ARPANET Interface Message Processor (IMP) and Terminal Interface Message Processor (TIP)." He has written extensively on technical and management topics and on computing history.

Ralph Weischedel is a principal scientist and heads the natural language processing group in the Speech and Language Processing Department at BBN. He holds a PhD in computer and information sciences from the University of Pennsylvania. Prior to joining BBN in 1984, he was a tenured associate professor at the University of Delaware. Weischedel is a former president of the Association for Computational Linguistics.