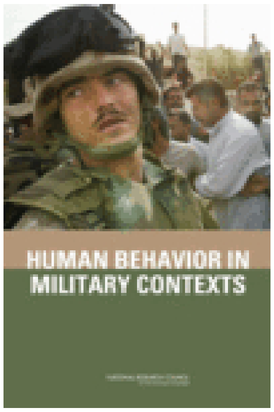

Human Behavior in Military Contexts

Committee on Opportunities in Basic Research in the Behavioral and Social Sciences for the U.S. Military, James J. Blascovich and Christine R. Hartel, Editors, National Research Council

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HUMAN BEHAVIOR IN MILITARY CONTEXTS

Committee on Opportunities in Basic Research
in the Behavioral and Social Sciences for the U.S. Military

James J. Blascovich and Christine R. Hartel, *Editors*

Board on Behavioral, Cognitive, and Sensory Sciences

Division of Behavioral and Social Sciences and Education

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COMMITTEE ON OPPORTUNITIES IN BASIC RESEARCH IN THE BEHAVIORAL AND SOCIAL SCIENCES FOR THE U.S. MILITARY

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Preface

Late in 2005, staff of the Research and Advanced Concepts Office of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) asked the National Research Council (NRC) to explore research opportunities in the basic behavioral and social sciences in order to assist ARI in developing a long-term research agenda in these areas. The NRC, through the Board on Behavioral, Cognitive, and Sensory Sciences, created the Committee on Opportunities in Basic Research in the Behavioral and Social Sciences for the U.S. Military to undertake this task.

On behalf of the committee, I would like to express my appreciation to the many people who contributed to this project. The lead contact at ARI, Paul Gade, provided guidance and enthusiastic support for the project. Ably assisting him—and the committee—were Peter Legree and Jonathan Kaplan.

Members of the study committee, volunteers selected from many academic specialties and several having extensive experience in research for the military, found the project an interesting and stimulating opportunity for interdisciplinary collaboration. They cooperated in work groups, learned each other's technical languages, and exemplified in their work the collegial qualities that are among the National Academies' unique strengths. The Academies are grateful to them for their hard work, expertise, and good humor.

The committee held three meetings, at which it identified a variety of possible research opportunities in the behavioral sciences and considered the promise of each. As the committee considered priorities, it invited the input of a number of other specialists in vital research areas at a committee-sponsored workshop in October 2006. This workshop made possible an even deeper discussion of the promising areas of opportunity. Through such consultation and private deliberation, the committee arrived at a consensus on recommendations to ARI. The committee believes it has identified key areas of research that, with additional investment, will yield useful results for the U.S. military. Those investments will also reveal enormous potential of behavioral and social research to meet military needs.

The committee owes special thanks to several experts from outside the committee who prepared papers that were especially valuable: Lisa Feldman Barrett, Boston College; Michele Gelfand, University of Maryland; Arthur Graesser and Brandon King, The University of Memphis; Todd Heatherton, Anne C. Krendl, and Dylan D. Wagner, Dartmouth College; Nicole Krämer, University Duisburg-Essen; Judith Kroll, Pennsylvania State University; and Jiajie Zhang, University of Texas, Houston. The commissioned papers, which were presented at the committee's workshop, provided detailed accounts of the current state of research in fields that the committee thought would be likely to lead to exciting advances in knowledge and have possible applications to military needs.

The second part of this report consists of six of those papers. Although they are not the work of the committee, we consider them to be useful aids in our consideration of investments for the U.S. military's research portfolio. The papers represent the opinions of their authors, and they do not necessarily map directly onto either the recommendations or the research areas recommended by the committee.

We also benefited considerably from the presentations and comments at the workshop of several other experts: Robert Atkinson, Arizona State University; Heidi Byrnes, Georgetown University; Turhan Canli, State University of New York at Stony Brook; Peter Carnevale, New York University; Gerald Clore, University of Virginia; Catherine Cramton, George Mason University; and Marianne LaFrance, Yale University. All of them contributed to the committee's thinking in important ways, and we thank them.

At the NRC, Janet Garton was the study director for the first 8 months, getting the study off to a very successful start. Subsequently, Christine R. Hartel, director of the Board on Behavioral, Cognitive, and Sensory Sciences, took over as study director. In both roles, she provided critical expertise and guidance for the project. Senior program assistant Matthew D. McDonough provided skillful administrative and logistic support over the course of the project. Donna L. Randall saw to it that every organizational requirement was fulfilled. Julie Schuck and Matthew Von Hendy assisted with research for the report; Kristen A. Butler helped out in many emergencies. The executive office reports staff of the Division of Behavioral and Social Sciences and Education, especially Eugenia Grohman and Yvonne

Wise, provided invaluable help with editing and production of the report. Kirsten Sampson-Snyder managed the report review process.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We thank the following individuals for their review of this report: Robert Atkinson, Division of Psychology in Education, Arizona State University; Richard Brislin, Shidler College of Business, University of Hawaii; Keith Brown, Watson Institute for International Studies, Brown University; Susan T. Fiske, Department of Psychology, Princeton University; Larry G. Lehowicz, Experimentation, Test and Training Sector Group, Quantum Research International, Arlington, VA; Alan M. Lesgold, School of Education, University of Pittsburgh; Kevin R. Murphy, Department of Psychology, Pennsylvania State University; and William Revelle, Department of Psychology, Northwestern University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Neil J. Smelser, University of California, Berkeley. Appointed by the NRC, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

James J. Blascovich, *Chair*
Committee on Opportunities in Basic Research in the
Behavioral and Social Sciences for the U.S. Military

Contents

PART II: PAPERS

Executive Summary

People are the heart of all military efforts. People operate the available weaponry and technology, and they constitute a complex military system composed of teams and groups at multiple levels. Scientific research on human behavior is crucial to the military because it provides knowledge about how people work together and use weapons and technology to extend and amplify their forces.

The military has long recognized the role of research in furthering its mission. In that vein, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) asked the National Research Council to provide an agenda for basic behavioral and social research focused on applications in both the near (5-10 years) and far (more than 10 years) terms. This request was made in the context of limited funds: for fiscal 2007, the U.S. Department of Defense budget for behavioral and social science is $37.6 million, its lowest level in 4 years, and for basic behavioral research at ARI it is approximately $4 million, including $1 million earmarked for "network science."

The committee considered a wide range of topics in the behavioral sciences and a smaller number in the social sciences, focusing on their applicability to military needs. Both historically and currently, those needs are in the areas of personnel, training and learning, leadership, and organization. The committee's distillation resulted in six research topics with an emphasis on ones that are likely to be applicable to military needs in the relatively near future.

The committee found that there are sufficient ideas and capability in the scientific community to support new work in each of the recommended areas. The committee also judged that significantly increased funding for the behavioral and social sciences is necessary if the military is to take advantage of the opportunities for major research contributions to its mission.

> **The committee recommends six areas of research on the basis of their relevance, potential impact, and timeliness for military needs: intercultural competence, including second-language learning; teams in complex environments; technology-based training; nonverbal behavior; emotion; and behavioral neurophysiology.**

These recommended areas were selected because of their potential impact, particularly in the near term; military needs and relevance; and likelihood of transfer from basic to applied research. The intersection of military needs and research areas is depicted in Table ES-1.

The recommended research areas represent topics of particular importance to the military.

- Intercultural competence—the ability to navigate and adapt to different cultures—is critical at every level of the military, from field operations to strategic planning. Within the field, the two areas of particular importance for the military are learning a second language and cross-cultural negotiation.
- Teams are ubiquitous and critical to the military, as they are in all organizations. Understanding team behavior and functioning, their dynamic nature, and leaders' behaviors in them are key issues for the military.
- The use of technology is an increasing feature of military training. It is critical that the use of technology is based on evidence-based knowledge about learning and not simply driven by the available technology.
- Nonverbal communication is a key aspect of people's reactions and behavior. In the military, nonverbal communication directly affects leadership, persuasion, negotiation, cultural fluency, training, and learning.
- Emotion affects almost every aspect of people's behavior and performance. In the military, troops are subject not only to intense emotions in stressful situations, such as euphoria and grief, but also to long-term effects on their health and functioning, both in their families and military units.
- Behavioral neurophysiology holds great promise for understanding the interplay among the biological underpinnings of motivational, affective, and cognitive processes, and new noninvasive techniques make possible research on human behavior that has not previously

TABLE ES-1 Research Topics and Areas of Military Concern

	Leadership	Training	Personnel	Social Interactions	Organizational Structures
Intercultural Competence	x	x	x	x	x
Teams in Complex Environments	x	x	x	x	x
Technology and Training	x	x	x	x	x
Nonverbal Behavior	x	x	x	x	x
Emotion	x	x	x	x	x
Neurophysiology	x	x	x	x	

been observable. Such research can make critical contributions to military procedures for personnel selection, training, and performance evaluation.

The committee recommends a doubling or more of the current budget for basic (6.1) research for the behavioral and social sciences across U.S. military research agencies. This level of funding can support approximately 40 new projects per year across the committee's recommended research areas. Funding should be significant enough to establish a scientific foundation in basic behavioral and social research from which important specific applications addressed to military needs can be developed.

An expanded military budget for basic research in the behavioral and social sciences of about $75 million will support both new and continued work on important research topics with likely application in the near future and longer term, as well. Although the recommended additional funding will support only a small number of projects in each of the recommended fields, it will allow a sufficient number of large and small new grants to support viable fields of research that are relevant to military needs. Without such support, basic behavioral and social science research is not likely to meet those needs.

More than 15 years ago, the former commander of the Vietnamese forces against both the French and American armies, General Vo Nguyen Giap, said: "In war there are the two factors—human beings and weapons. Ultimately, though, human beings are the decisive factor. Human beings! Human beings!'' (*New York Times*, 1990, p. 36).

PART I

COMMITTEE REPORT

1

Overview

PEOPLE AND SYSTEMS

That human behavior forms the nucleus of military effectiveness is unquestioned. Regardless of technological advances, the military is and always will be a complex system composed of human and technical elements that must work together effectively in a wide variety of contexts over time. Humans embedded in the complex military system must possess the knowledge, skills, abilities, aptitudes, and temperament to perform their roles effectively in a reliable and predictable manner, and effective military management requires understanding of how these qualities can be best provided and assessed. Furthermore, the technical and social contexts in which people operate can either facilitate or inhibit system effectiveness.

Key factors in the design of organizations and humans' role in them are the identification, recruitment, and placement of individuals in an organization and the creation of leadership and social and learning environments that foster the behaviors that are needed to accomplish the goals and objectives of the organization. In the military, where the first goal is effective warfighting, these factors are often clustered under the terms personnel, training, leadership, and organization.

Personnel As military systems become more complex and demands on team members become greater, getting and keeping the best people remains a constant and critical need. The military needs individuals who are culturally aware, technologically sophisticated, and behaviorally flexible and who can learn new languages and skills, and withstand new stressors. Assessment, selection, placement, and job design—always key features of large organizations—become even more important as complexity increases.

Training and Learning Training has always been a critical aspect of military success. Important issues are appropriate training content and effective and efficient delivery systems. The role of technology in training appears to have tremendous potential. However, the goal of training is learning, so it is not enough to build good training systems: it is also important to understand how those systems interact with learners' proclivities and limitations.

Leadership Leadership is a process of influence, so one demand on a leader is establishing credibility to provide the basis for influence. Research over the past 100 years has shown that the key elements of credibility are task-relevant competence and trustworthiness. Leaders need to develop relationships with followers, both individually and as team members, which motivate and enable them to contribute maximally to mission accomplishment. At the core of any leader-follower relationship is communication. Effective communication requires understanding others. The tremendous diversity of communication targets for modern military officers dramatically complicates the issue. Finally, leaders who have established credibility and built motivated and highly functioning teams must deploy those resources for mission accomplishment. Leader self-efficacy and team collective efficacy allow for the full utilization of leader and follower resources. Environmental (situational) analysis, information processing, and decision making bring those resources to bear. Very frequently, military situations are highly demanding and stressful, so leaders must also have self-awareness, emotional control, coolness under pressure, and resilience.

Organizational Functioning Organizational tasks call for teams that can provide multiple perspectives and collective resources. Coordination of teams requires communication structures and practices, distribution and integration of task-relevant information, information analysis and decision making, and harnessing collective effort. Coordination decrements are generic to all teams, but as teams become more functionally and demographically diverse and physically more distributed over time and space, coordination becomes increasingly difficult. As the size of an organization increases, the organizational research imperatives become ever greater: in the military, the coordination of squads, crews, companies, and larger forces becomes increasingly complicated. Developing technologies offer great potential for improving communication under these circumstances, but also carry the potential for even greater coordination difficulties and possible mission failure.

THE ROLE OF RESEARCH

In December 2006, there were proposals for 40,000 U.S. troops as strategic, tactical, and weapons trainers for the nascent Iraqi army. The situation was perceived as urgent. Yet there was little discussion of whether the U.S. military could provide 40,000 *effective* trainers in 6-8 weeks or of the types of jobs they would be expected to do.

Basic research programs are not intended to resolve such immediate crises. But the December 2006 Iraqi situation will not be the last time that U.S. troops are called on to train others in warfighting and to assist the operations of troops of other countries. In many, perhaps most, cases the foreign nationals will not be from Western countries, and there will likely be a need for rapid action. What sort of training do the trainers need for their mission? What kinds of support do troops need for such assignments?

The answers to these questions can be found by research in the behavioral and social sciences. Developments in various technologies will help, and new technologies will contribute to training and joint operations, but, fundamentally, the way the U.S. personnel behave will determine the success of such missions.

Once military personnel are embedded in such situations, they are subjected to a variety of stresses that differ in important ways from the stressors of engagement encountered by troops serving in conventional, U.S.-only, units. This includes lack of social support, the continuing stress of having to deal with a foreign language and culture on a 24/7 basis, and the possible lack of contact with the usual military command and support structure. Again, behavioral and social research, from behavioral neurophysiology to sociology, is critical to understanding these kinds of stresses and developing ways to monitor, reduce, or counteract them.

Other issues for troops in such theaters as Afghanistan and Iraq arise because of the often lengthy tours of duty for largely noncombat situations. What effects do such assignments have on the cognitive and emotional capacities of embedded troops on a continuous basis? How long they are fit for duty? Again, these critical questions for the military in the 21st century need behavioral and social science research.

BASIC AND APPLIED RESEARCH

An important question in considering what kinds of research must be conducted has to do with the distinction between basic and applied research. Circular A-11 of the U.S. Office of Management and Budget defines basic and applied research and development in what seem to be very definite terms:

> Basic research is defined as systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.
>
> Applied research is defined as systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.

Nevertheless, the distinction between basic and applied research is not always clear, even among the scientists conducting it, especially as basic research begins to make some applications more apparent. Hence, U.S. government funding data for basic research frequently includes amounts for applied research as well. This is particularly true for basic behavioral and social science research funded by the military because it is constrained to fund research likely to be close to its own interests, and the closer research comes to being applied, the more obvious its military relevance. Basic research is called 6.1 by the U.S. Department of Defense (DOD) and applied is called 6.2. However, in this report, applied research refers to that which is closer to basic research (6.1) than it is to advanced development (6.3). As Nobel Laureate George Smootz has said, "People cannot foresee the future well enough to predict what's going to develop from basic research. If we only did applied research, we would still be making better spears."[1]

FUNDING CONTEXT

Funding for basic research in the behavioral and social sciences has varied widely throughout all the military services over the last several decades. In fiscal 2007, total DOD funding for behavioral and social sciences research will be $37.6 million, its lowest level in 4 years (see Table 1-1). Funding for cognitive and neural science will be at its lowest level since 2002, despite a DOD basic research review that described cognitive and neural sciences as a key area that should be strengthened. These figures make it clear that investments in behavioral and social research and development must be carefully targeted to achieve the maximum possible returns.

[1]See http://www.lbl.gov/Education/ELSI/Frames/research-basic-defined-f.html [accessed July 2007].

TABLE 1-1 Behavioral and Social Sciences Funding, Fiscal 2004-2007 (in $ million)

Service	Fiscal Year 2004	2005	2006	2007
Army	12.5	15.5	13.8	13.3*
Navy	17.0	15.5	14.5	10.4
Air Force	14.5	12.8	13.5	13.9
Total	44.0	43.8	41.8	37.6

*Includes $1 million for network science.

CHARGE TO THE COMMITTEE

In order to fund the most promising research in the face of an ever-tightening budget constraints, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) asked the National Research Council to provide an agenda for basic research in the behavioral and social sciences with an eye to the possibility of applications in both the near (5-10 years) and far (over 10 years) terms.

Specifically, the charge from ARI requested that:

> A study committee, established under the auspices of the Board on Behavioral, Cognitive, and Sensory Sciences, address the range of interactions among social settings and behavioral patterns, seeking areas of scientific opportunity where significant investment is most likely to improve the military's effectiveness and efficiency in the new roles it is assuming.
>
> The committee will explore opportunities in basic research in the behavioral and social sciences to assist the U.S. military in formulating new directions for its basic research portfolios and to develop a long-term research agenda in these areas. Through a workshop and other information gathering activities, the study committee would identify research opportunities that draw on the most recent developments in the behavioral and social sciences—including behavioral, cognitive, and social neurosciences—that cross multiple levels of analysis, and that are poised to contribute quickly and significantly to the military's basic and applied research needs.

THE COMMITTEE'S APPROACH

To meet ARI's charge, the committee first and foremost decided that the research areas selected must be relevant to current military interests. Two types of research might fit in this category: basic research at the cusp of readiness for application to military needs and basic research with long-term potential for such application. The research must already be feasible and demonstrate potential not only for payoff in the next 5 to 10 years, but also for transformation to applied (6.2 funding) research. Recognizing the tension between the desire for practical payoffs from research in the near future and the creation of the groundwork for basic research with long-term potential, the committee's response is to recommend research that responds to near-term needs without neglecting longer term opportunities.

The committee also recognized that, like all organizations, military agencies engaged in funding behavioral and social science research operate under a variety of constraints. Each agency has its specific mission, which may preclude it from investing in research in specific areas. All operate under limited—sometimes extremely limited—budgets, making cost-effective investments imperative.

The committee met three times; its members brought a mixture of expertise in the behavioral and social sciences to their discussions. However, because of time and resource constraints, the committee could not be constituted to include all social science disciplines. Furthermore, in the course of its deliberations, the committee unexpectedly lost two committee members because of schedule conflicts; they would have supplied needed expertise in some of those areas. These circumstances led the committee to focus principally, though not solely, on the behavioral sciences, with much less attention to the relevant work now ongoing in related social science disciplines.

The committee expanded its knowledge base by commissioning papers from experts in a number of research areas, particularly ones that did not overlap with the expertise of the committee members themselves. The papers were presented at a public workshop on October 24-25, 2006, and discussed by the authors, other scientists, committee members, and other participants, including the report sponsors, representatives of other military research funding agencies, military personnel, and the public. Six of the background papers form the second part of this report. The papers represent the opinions of individual authors, not those of the committee, and the papers and their authors' recommendations do not necessarily map directly onto the research areas recommended by the committee. However, the papers do detail the kinds of findings that make these areas of research rich in potential for military investment.

The committee considered a wide range of established and promising research fields and specialties within the behavioral sciences. The committee also recognized that much cutting-edge work is happening at the intersection of technology and the traditional areas of behavioral and the social sciences and included this knowledge in making its recommendations.

RECOMMENDED RESEARCH AREAS

The committee recommends six areas of research on the basis of their relevance, potential impact, and timeliness for military needs: intercultural competence, including second-language learning; teams in complex environments; technology-based training; nonverbal behavior; emotion; and behavioral neurophysiology.

These recommended research topics clearly intersect with each of the major foci of the military: the best personnel, leaders, training, and organizations to carry out first its warfighting mission and then its many other diverse missions. We note that the list of research areas proceeds from external cultural influences to internal physiological states, not in any order of priority. Several research areas fit the selection criteria described above (i.e., relevance, impact, and timeliness). The multiplicity of inherent relationships among and between these promising areas and military needs (e.g., personnel, leadership) led the committee to organize these relationships in a matrix of research opportunities and military needs as depicted in Table 1-2.

In fact, real-world military problems rarely occur within a single scientific discipline or a single level of analysis. One can easily imagine higher-order relationships among these components. For example, integrating research on neurophysiology and emotion may well be important in order to advance our understanding of the performance of military personnel in threatening or stressful situations. Or, research integrating nonverbal behavior and intercultural competence may be essential in training for social interactions with noncombatant populations.

Military research agencies are already addressing some of these areas. For example, at this time, ARI is funding basic research on leadership, training, and personnel assessment, some of it in traditional areas of psychological research, and also in social science areas, such as anthropology and sociology. In 2006, ARI released a broad agency announcement calling for research in the broad area of network science, with a focus on cognitive and social domains; on training and learning; leadership; human resource practices; social systems; and the role of affect (emotion) in calibrating behavioral action and cognition. Clearly, ARI recognizes the relevance of these basic research issues to current military needs and modern, asymmetric conflicts.

Very shortly after the committee concluded its deliberations, the Defense Science Board released a report on its 2006 summer study, *21st Century Strategic Technology Vectors* (Defense Science Board, 2007). The cover memorandum from the task force cochairs says:

TABLE 1-2 Research Topics and Areas of Military Concern

	Leadership	Training	Personnel	Social Interactions	Organizational Structures
Intercultural Competence	x	x	x	x	x
Teams in Complex Environments	x	x	x	x	x
Technology and Training	x	x	x	x	x
Nonverbal Behavior	x	x	x	x	x
Emotion	x	x	x	x	x
Neurophysiology	x	x	x	x	

> The report of the Defense Science Board 2006 Summer Study on 21st Century Strategic Technology Vectors identifies a set of four operational capabilities and their enabling technologies that can support the range of future military missions. . . . Perhaps most central is to gain deeper understanding of how individuals, groups, societies and nations behave and then use this information to (1) improve the performance of U.S. forces through continuous education and training and (2) shape behaviors of others in pre-, intra-, and post-conflict situations.

On page 13, the report states:

> The third of the human terrain enabling technology area—human, social, cultural, and behavioral (HSCB) modeling—is the one that pushes the boundaries of DOD's comfort zone the farthest. However, it is an area that DOD cannot afford to ignore. The DOD needs to become much more familiar with the theories, methods, and models from psychology, sociology, cultural anthropology, cognitive science, political science, and economics in order to be able to identify those with real potential to add value to DOD's tool kit. . . A formidable challenge in modeling social and behavioral phenomena is to integrate and make coherent micro-macro models at multiple levels of data, granularity, and analysis, and across multiple disciplines of the social sciences, and to acquire and structure data that can be used to guide and test the models.

To accomplish this vision, the Undersecretary of Defense for Science and Technology proposes new 6.2 (applied research) funding of $7.3 million in fiscal year 2008 and increases over the next 5 years for a total of $51.4 million.[2] Note that this is called applied (6.2) research by the DOD, yet the funding justification also includes the basic research needed to make the modeling possible.

It seems, then, that this report is extraordinarily timely in its recommendations. The text below briefly describes the committee's recommended areas of research in the behavioral and social sciences. The next six chapters of the report discuss them in depth.

Intercultural Competence The ability to navigate and adapt to different cultures is known as intercultural competence or cultural intelligence. The latter term includes cognitive (knowledge of language, customs, beliefs), physical (body language, gestures), and emotional (confidence, adaptability, openness) components. Thus, a key issue for the military is to select, train, and deploy individuals who possess these qualities and are able to function in multiple cultures. Two areas of research are particularly important for

[2]See http://www.dtic.mil/descriptivesum/Y2008/OSD/0602670D8Z.pdf [accessed September 2007].

the military: learning a second language and cross-cultural negotiation. Research in these areas must come from many fields, including linguistics, cultural and social anthropology, sociology, history, and political science, as well as cognitive and educational psychology.

Teams Teams are ubiquitous in today's organizations—including the military—and their effectiveness is absolutely critical to the performance and viability of the organizations in which they are embedded, as well as to the well-being of the people who staff them. A large scientific literature focuses on understanding team behavior and functioning: it informs the design of organizations, leaders' behaviors in them, and policies and practices related to staffing teams. The complexities of teams as dynamic systems nested in organizations and changing over time present major challenges for future research that are just beginning to be addressed theoretically, methodologically, and technologically.

Technology and Training The goal of basic behavioral research on technology and training is to create a science of learning that is relevant to issues in military training, guides instructional design of technology-based training in the military, and identifies and assesses instructional methods that have large effects on learning. Basic behavioral research on technology and training will enable military trainers to take advantage of an evidence-based approach to designing training for individuals and for teams.

Nonverbal Communication Research has rigorously validated that people rapidly, even if unconsciously and automatically, perceive and become influenced by the nonverbal signals of those around them. Whether in a job interview, a first date, or the first meeting with a local warlord, first impressions, formed mainly on the basis of nonverbal cues, can determine outcomes. The nature of nonverbal communication has been a thorny problem for its study and analysis. Nonverbal communication research directly affects several areas of military relevance: leadership, persuasion, negotiation, cultural fluency, training, and learning. The area is rich with technological opportunities and challenges for research.

Emotion Emotion represents a universal and intrinsic aspect of human consciousness, which functions as an evaluative representation of the environment to the person experiencing the emotion. Emotion moderates important cognitive, behavioral, and physiological phenomenon. Emotions produce effects at every level of cognition and influence many social behaviors. Moreover, reliable and important individual differences can be found in these effects. In a military context, it is natural and common to experience intense emotions in anticipation of and during operations, and intense feelings of euphoria, regret, grief, anger, or disgust afterwards. However, over longer periods, the failure to regulate emotional responses can lead to poor long-term performance (e.g., decision making) and health declines (e.g., posttraumatic stress disorder), as well as disruptions to social units (e.g., family, military unit).

Behavioral Neurophysiology Basic knowledge of human behavior, as well as practical knowledge important to the military, could greatly benefit from research using validated neurophysiological markers—such as cardiovascular, endocrine, and central nervous system markers—to examine the interplay among motivational, affective, and cognitive processes. Such research is likely to increase the effectiveness of military procedures for the selection, training, and performance evaluation of personnel for specific leadership and operational duties in ways not subject to the biases of subjective evaluations.

RECOMMENDED RESEARCH FUNDING

It is clear to the committee that behavioral and social science research critical to the military remains insufficiently funded. The situation is serious because if these deficiencies continue, the military will lack sufficient understanding of human behavior in social and cultural contexts pertinent to their needs, and fall behind military forces of other nations and groups in this regard. Military funding must match the urgency and the nature of the challenges that the military faces.

The committee recommends a doubling or more of the current budget for basic (6.1) research for the behavioral and social sciences across U.S. military research agencies. This level of funding can support approximately 40 new projects per year across the committee's recommended research areas. Funding should be significant enough to establish a scientific foundation in basic behavioral and social research from which important specific applications addressed to military needs can be developed.

Doubling the current funding of $37.6 million to a total of about $75 million will allow the continuation of current work, as well as new basic research projects in the recommended areas. The committee found that there are sufficient ideas and capability in the scientific community to justify the recommended funding increase and number of new projects. This recommended additional funding will allow a sufficient number of new grants, ranging from large to small, in each recommended research area.

The recommended increased funding represents a very small portfolio of projects in any given area, yet the committee is convinced it is enough to sustain research interest in each of them and to begin to provide the necessary research base for military applications. These efforts should be coordinated by mechanisms such as annual research meetings, center grants and contracts, and joint funding from various agencies. Moreover, $37.5 million in new funding is less than two-thirds of 1 percent of the fiscal 2005 DOD research budget of $5.7 billion. In 2005, psychology and the social sciences were allotted 3 percent of that research budget, in comparison with 53 percent for engineering and 15 percent for mathematics and computer science. The committee believes that these kinds of disparities in spending result in important disparities in results for military effectiveness.

CONCLUSION

This report and the papers clearly demonstrate that there are many bodies of stimulating, ongoing research in the behavioral and social sciences that can enrich the military's ability to recruit, train, and enhance the performance of its personnel, both organizationally and in its many roles in other cultures. Such research may sometimes be carried out in established scientific fields; sometimes it is the product of older disciplines merging ideas and techniques to generate new areas of research. Much of this basic research is not, and cannot be, immediately targeted to military applications. But military research agencies cannot afford to neglect nurturing it. By supporting a vigorous program of research, the U.S. military can ensure that its key issues will be addressed by the best scientists in this country and around the world.

The research areas emphasized in this report are not all new. More than a decade ago, a National Research Council (1994) report—known as STAR 21—by the Board on Army Science and Technology concluded

> The Army of the future will have to be able to deal with foreign allies and indigenous populations. Such dealings will often be at the small unit level. The Army needs to develop ways to train U.S. soldiers to interact with groups in other cultures (Personnel Systems, p. 44) . . . . There is insufficient understanding of: (1) the learning that occurs on a job and the kind of technology that can make this learning more efficient; (2) how social interactions among workers promote or inhibit learning; and (3) the ways that training prepares people to become effective learners and contributing members of a working group. (Personnel Systems, p. 35)

Yet, since the STAR 21 report was published, military support for basic research in the behavioral and social sciences has steadily decreased, despite the obvious need for more support, not less. It is necessary to understand in a profound way that equipment and technology always have a behavioral component, and not always a predictable one. Technology is used to amplify human behavior, both its effectiveness and its errors. No Roman legionnaire could do much as damage in error as could one of today's fighter pilots or artillery commanders.

Only through research on human beings can knowledge be gained about the basis of people's behavior and how best to enhance it, whether they are negotiating in the field with foreign nationals or performing as part of a large team in a complex technological environment.

Recently, Mario Mancuso, deputy assistant secretary of defense for special operations and combating terrorism, spoke about intelligence gathering and cultural skills: "Being able to develop and maintain and nurture relationships with groups in other societies . . . that is how we are going to be in a position to have a global sensor network. . . . It has nothing to do with satellites—it has to do with people."[3]

The investment must match the nature and urgency of the need.

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[3]See http://poky.atpco.com/atp/login.aspx?pubCode=ARM&forward=www.armytimes.com/pastissues/&query= [accessed July 2007].

2

Intercultural Competence

When Kentucky Fried Chicken first tried to make inroads into the Chinese market it ran into difficulties because, when translated into Chinese, its traditional slogan "finger lickin' good" suggested "eat your fingers off" (Ricks, 1999). In many countries, the gesture that in the United States signifies "OK" is actually an offensive gesture. Holding hands among men does not carry the same meaning in the Middle East as it does in other parts of the world. A former U.S. President was embarrassed when he gave the U.S. and British sign for "victory" while in Australia, where the sign has a very different, indeed obscene, connotation. Unfortunately, such cultural ignorance can have serious consequences.

Recent U.S. interventions in the Middle East have been rife with cultural misunderstandings. In Mogadishu, in the 1990s, American commanders underestimated the intensity of loyalty to clans and, after command was yielded to the United Nations, also did not understand the level of reliability and professionalism in allied units that were supposed to back up U.S. forces. The result was a disaster, culminating in the "Black Hawk Down" incident, which led to the withdrawal of U.S. forces. This outcome repeated what happened when Americans withdrew from Lebanon in the 1980s, after sustaining many casualties. Such withdrawals led to a widespread perception that Americans do not have the sense of honor and revenge that pervades many Middle Eastern cultures. This perception seems to have emboldened both Saddam Hussein and Osama Bin Laden. They could not have succeeded without the belief by many of their followers that the United States was a "paper tiger."

These examples illistrate a tremendous dilemma for the American military. There is no sense in taking needless casualties in a mission doomed to failure. Yet the consequences of withdrawal after casualties must be considered, not only in the tactical and strategic sense, but also in the cultural context.

A significant aspect of functioning in society involves interpreting others' behavior and acting accordingly. A shared understanding of appropriate and expected behaviors allows one to make predictions about the reactions and future behavior of others. In fact, a large part of the education process involves socializing children into the cultural norms and expectations of their societies. The situations described above demonstrate what happens when expectations are not shared and result in behaviors that are misinterpreted and misunderstood. Anthropologists have long identified this pattern of shared meaning, or culture, and have documented both the enormous and the subtle differences among societies (see, e.g., Beattie, 1964; Marcus and Fischer, 1999).

Cultures are perpetuated and transmitted through stories, rituals, symbols, laws, values, and social norms. They evolve out of the shared experience of group members as they struggle to adapt to external demands and attempt to integrate group members (Schein, 2004). Fundamentally, cultures develop to help humans fulfill their need for stability, consistency, and meaning. Problems arise when people try to apply their cultural lenses to understand a society or group with a different culture. Intercultural interactions often result in misunderstanding because individuals are using different rules to interpret the same behavior or situation.

Given that most military conflicts occur between countries, intercultural encounters have always been part of the military experience. However, modern conflicts such as the one in Iraq often involve more protracted engagement with local inhabitants and are rife with opportunities for intercultural misunderstandings. In addition, the military itself is becoming more diverse with recruits who come from different racial, ethnic, religious, and socioeconomic backgrounds. These different groups can have different subcultures with different sets of shared meaning and interpretative schemas.

DEFINITIONS

The ability to navigate and adapt to different cultures is known as intercultural competence (Martin and Hammer, 1989) or cultural intelligence (Earley and Mosakowski, 2004). The latter term includes three components: cognitive (knowledge of language, customs, beliefs), physical (body language, gestures), and emotional (confidence, adaptability, openness). A key issue for the military is to select, train, and deploy individuals who possess these qualities and are able to function in multiple cultures. Within the broad field, two areas of research are particularly important for the military: learning a second language and cross-cultural negotiation. The committee recommends that the military fund research in these areas as aspects of intercultural competence. Each of them is discussed in more detail below.

Identifying the dimensions that underlie cultural differences has been the subject of a large body of research. Perhaps the most current and widely used framework for understanding differences among cultures was proposed by Hofstede (2001). In this framework, cultures are differentiated along the dimensions of power distance, uncertainty avoidance, individualism/collectivism, masculinity/femininity, and long-/short-term orientation. Of these, individualism/collectivism has been the most widely studied (Earley and Gibson, 1998). As fruitful as Hofstede's framework has been, researchers have called for an expansion of the framework to include such dimensions as cultural fatalism (Aycan, Kanungo, Mendonca, Yu, Deller, Stahl, and Kurshid, 2000), cultural tightness-looseness (Gelfand, 2006), and cultural cynicism (Bond, Leung, Au, Tong, de Carrasquel et al., 2004). Even though these dimensions appear to explain most differences among cultures, the field is still evolving towards a commonly accepted framework that adequately explains cultural differences. The military should continue to monitor developments in theoretically motivated frameworks that could provide a basis for cross-cultural training.

SECOND-LANGUAGE LEARNING

The ability to communicate in the native tongue of a country is central to the development of cultural competence, and military history bears out its importance. The U.S. military has been heavily involved with non-English-speaking peoples since the clearing of Native Americans from their traditional lands in the 1800s, the Spanish-American War of 1898, and the Philippine insurrection of the early 1900s. During World Wars I and II, it was important to have U.S. liaison officers who spoke French and intelligence personnel who spoke German or, in the later war, Japanese (Devers, 1948; Counter Intelligence Corps School, 1951). The intensity of involvement is much greater when military forces are engaged in asymmetric warfare than when they are engaged in the field with an overt foe. In asymmetric warfare, it would be of unquestionable value if every patrol contained a person capable of communicating in the local language; for example, in modern-day engagements in Vietnam (Vietnamese, Yue Chinese, and Hmong), Iraq (Arabic, Farsi), and Afghanistan (Pashtu and Afghan Farsi). Such competence is required for two reasons. First, there is the obvious need to communicate with people who speak little or no English. The alternative is to use interpreters: however, some of them cannot be relied on either for competence in English or, more dangerously, for their loyalty to the U.S. mission. The second reason is the more general issue of cultural awareness. Acquiring some competence in a language is the single most important thing a person can do in order to become aware of the customs and attitudes of another culture. Except in a very few cases, it is not necessary to acquire the second language at the level that one can blend in without being noticed. The current governor of California, Arnold Schwarzenegger, and a past Secretary of State, Henry Kissinger, both speak German-accented English. Their successes clearly show that they understand our culture. They could not have acquired such understanding without an ability to communicate to monolingual English speakers.

The level of bilingualism required by military personnel varies greatly with the job. When a mission involves asymmetric warfare and nation building, some commanders may at times have to act as diplomats. Intelligence officers will have to deal with subtleties. At the platoon and squad levels, the communication problem is different, although the stakes might also be very high. A good analogy here is the sophisticated tourist: one who can speak enough of the language to get around in a city without a tour guide, even if he or she sticks out like a sore thumb when speaking. It may take months or even years to acquire the level of language that an intelligence officer needs, but the level of proficiency needed by lieutenants and sergeants may take only weeks or a few months. The short time needed at the field level is fortunate because what language will be required for a military operation is rarely known in advance. In the year 2000, how many people realized that the Army would have a need for Pashtu speakers in order to operate in Afghanistan? Or in 1990 that it would be helpful to have speakers of Somali and Maay, as well as Arabic, to operate in Somalia?

It is useful therefore to break the second-language learning issue into two parts. One is the training of a relatively few individuals to substantial proficiency; the other is rapid training of many people to a level of adequacy. This is the useful approach that the military has already taken. We note, however, that it is likely that some people who are trained only to the "adequate" level will reach substantial proficiency on the job, as they interact with the local population. This occurred with the British Army in India in the nineteenth century—an experience that might be consulted for guidance on policies that encourage noncommissioned officers and junior officers to learn a language.

The United States is not well suited, either educationally or culturally, for the production of second-language speakers. In spite of the fact that the country has traditionally received immigrant speakers of many languages, English dominates communication. Although Spanish is spoken by significant subgroups, English competence is both sufficient and necessary to participate fully in the U.S. society. This monolinguism contrasts with most of the world, where different languages exist on a more equal footing. In the United States, both high school and college standards for second-language learning are lax by international standards. Therefore, the military services have to take on the burden of language training largely on their own. They have already done so for training people who need to be proficient, in the Defense Language Institute at Monterey, California. Cooperative programs with colleges and universities are certainly a possibility. However, these programs require extensive time commitments, and speed may be important. Consequently, the military needs to know (a) who is a good candidate for second-language training for high levels of competency, and (b) what inexpensive training programs can be developed to produce adequate communicators, in the sense of "advanced tourist proficiency" described above. These topics are discussed in detail in the paper by Kroll in Part II of this volume. Here we present a summary of the main findings and issues in her paper.

Who Should Be Selected? During the 1950s, the Air Force used a simple model for selection. Candidates were given the first lesson of a year-long program in spoken Mandarin, and then examined. The highest scoring candidates were then sent to Yale University for a year-long traditional course in Mandarin. This is a specific example of a more general paradigm, in which candidates are given minimal, inexpensive training, tested, and then selected on the basis of the test. Even within this paradigm, however, not everyone in the military is tested. The Air Force participants, for instance, were recruits who had high scores in English competency on standard instruments, such as the Armed Services Vocational Aptitude Battery (ASVAB). Findings since then have suggested that better methods for selection could be developed.

Second-language learning is an area in which a relatively small investment of resources might provide considerable benefit to the military, in terms of identifying individuals who have a knack for learning second and third languages. Several research projects have developed promising ideas for the identification of people with the potential to learn second or third languages. The first line fits into the paradigm used by the Air Force in the 1950s: giving large numbers of people a small amount of training and then testing them to see who should be offered more extensive training. One of the ways to do this is to do what the Air Force did—develop a test to see who does well after the initial training, assuming an appropriate test can be developed.

There are interesting alternative techniques that could be the subject of longer term research (10-20 years). One of these involves the event-related potential (ERP), the brain's electrical response to an event. Early findings indicate that the ERP in response to syntactic or semantic anomalies, spoken in the language being instructed, can differentiate between people who have grasped the language to a higher or lower level of skill. Appropriate recordings can be obtained from electrodes placed on the surface of the skull, obviating the need for expensive imaging techniques. Those techniques have recently yielded information that might in time and with much development be useful for personnel selection. Researchers recently discovered that subjects who were the least successful in learning an artificial tonal language (most of the world's languages are tonal) had a brain structure (the left Heschl's gyrus, which includes primary auditory areas) that was significantly smaller than that of those who were more successful (Wong et al., 2007).

Another line of research is trying to determine who can best understand small artificial languages, using computers. It is possible that tests of the ability to learn an artificial language might identify people who have the capability of learning second languages in general, which may be much less expensive than offering instruction in a natural language, and then testing the learning. This could be tested in the very near term, 1-5 years. Yet another approach to selection is to examine the language learning skills of individuals who already speak two languages. This is attractive to the military because many service personnel are bilingual in English and some other language, predominantly but not exclusively Spanish. Would such bilingual men and women be more adept at learning a third language than someone who has yet to learn a second one?

As Kroll points out, the answer to this question depends on the answer to a basic research question about language learning. If second and third languages are essentially learned by a transfer-of-skills method, then the individuals selected for training should ideally already be familiar with a language similar to the target language. If transfer is the issue, an English-Spanish bilingual person would be better prepared to learn a language similar to Spanish (e.g., Italian or Romanian) than a comparably talented English monolingual person would be; however, an English-Spanish bilingual person would have no advantage over the English-only speaker in learning Farsi or Indonesian. In contrast, if learning a second language involves the acquisition of skills required for adult language learning in general, then an English-Spanish bilingual person would have an advantage over a monolingual person regardless of the target language. This unresolved issue is one for which a modest research investment could have high payoff for the military in the near term, 5-10 years.

How Should a Second Language Be Taught? It appears to be generally agreed that becoming truly proficient in a second or third language almost always requires a full-time experience of immersion, an approach in which only the target language is spoken. Such training may require months. This approach is cost-effective only for those individuals who will be in key positions in the military, such as intelligence or liaison officers. The Defense Language Institute has an excellent reputation for doing this well.

How to train rapidly for minimal competency is much less clear, although the Peace Corps has had some success with its methods in teaching competence in 2 months. The classic method used to teach business-level language is to offer in-class instruction by instructors who are both fluent in the target language and trained in language instruction, for roughly 2 hours a day, 2-3 days a week. This approach assumes that there are enough instructors available, and it seems clear that such a method of instruction is not feasible in the case of a rapid deployment of forces to an area outside of Europe, Latin America, or Northeast Asia. For example, suppose that the U.S. military was planning a deployment to Uzbekistan in 3 months. Are there enough language instructors fluent in Uzbek in the United States to train the captains, lieutenants, and sergeants in a division needed for that mission? Over the next 10 years, no one can be confident about where or when U.S. forces will have to be deployed.

Faced with this situation, considerable commercial and military efforts have been directed toward development of computer-presented instruction, which often involves trainees' conversing with realistic avatars of native speakers or playing serious training games like Alelo Inc.'s Tactical Iraqi™ Language and Culture Training System. Although these programs are impressive as feats in computer science, their effectiveness in training to a relatively low but appropriate level of proficiency has not been scientifically validated (see Chapter 4). Both the effectiveness of the existing programs and the principles by which such programs ought to be designed are topics for research that is both feasible now and very necessary.

In conclusion, we reiterate that the best single way to achieve "cultural awareness" is to learn to speak the language of the culture. Reliance on translators is at best a clumsy alternative and, at worst, risky because communication between U.S. forces and local residents is then controlled by individuals who may have their own agendas. The military should consider funding studies of a two-tier training system for second-language learning, in which the first tier would require a substantial mastery of a second language and cultural practices, and the second tier would train basic proficiency akin to the level of "advanced tourist."

CROSS-CULTURAL NEGOTIATION

The situations that call for military intervention are, almost by definition, conflict situations. Although one might think that force is the only strategy used by the military to deal with conflict situations, troops on the ground often find themselves negotiating with the local population and even mediating disputes among locals. Thus, a promising avenue of research for the military concerns the role of culture in the management of conflict situations. Anthropologists and political scientists at the U.S. Institute of

Peace study the impact of cultural differences on international negotiation and provide convincing arguments that culture is a primary factor in communal conflicts. This school of thought is represented in the works of Avruch (1998) on the nature of culture and its role in negotiation, Cohen (1997) on cross-cultural negotiation, and Solomon (1999) on negotiations between high-level American and Chinese officials. Gelfand (in this volume) presents a thorough discussion of this topic from a cultural psychologist's viewpoint. An outline of the critical issues is presented below.

Although the field of conflict and negotiation has made tremendous strides in recent years, most of the research has been conducted in Western and, in particular, U.S. populations (Triandis, 1994). However, recent research clearly demonstrates that cultural perspectives directly affect how conflict situations are perceived and acted on. For example, in the United States, conflict situations are typically perceived as being about finding out who is to blame; in Japan, a more typical approach is to achieve compromise. In fact, Gelfand, Nishii, Holcombe, Dyer, Ohbuchi, and Fukuno (2001) argue that intercultural conflict is particularly difficult to resolve because the very definition of conflict itself is often in dispute. Clearly, more research is needed across a wider variety of cultures to understand the cultural "conflict frames" that exist and to help interpret conflict situations. This research could yield results in the mid-term 5-10 years.

How one seeks to resolve conflicts through negotiation is also influenced by culture. It influences the extent to which information is directly shared among disputing parties, the specific tactics used to negotiate, and even the metaphors that guide the process itself. Research suggests that when negotiators adopt similar goals and perceptions of the negotiating task itself, the outcomes of the negotiation are much higher. Gelfand, Nishii, Godfrey, and colleagues (2003) have argued that, when conducting negotiations across cultures, it is critical to first "negotiate the negotiation." However, what is not known is which negotiation metaphors are relatively easy to adopt, are more likely to be embraced by different cultures, and are more likely to lead to effective outcomes.

A related finding is that culture affects how individuals respond to social pressure during the negotiation process. For example, negotiators from individualist cultures assume that their constituents expect them to be competitive; in contrast, negotiators from collectivist cultures assume they should cooperate during a negotiation. This effect is present when the negotiators expect to be held accountable for the outcome of the negotiation (Gelfand and Realo, 1999). When accountability is not an issue, negotiators are, in a sense, "released" from normative pressures to do what the culture dictates, as Gelfand points out. Military forces on the ground can be much more effective negotiators if they understand the nuanced role that social pressure plays in a particular culture.

What triggers conflict in the first place is of fundamental importance to the military, and research suggests that culture plays a role in how events are interpreted in this context. For example, violations of face and the ensuing shame that results is a powerful motivator of conflict within collectivist cultures; in contrast, while in individualistic cultures, conflict is often triggered by violation of personal rights. Gelfand, Bell, and Shteynberg (2005) found that shame is more contagious among collectivist cultures than in individualistic ones and often leads to actions aimed at seeking revenge. Interestingly, even witnessing another person experiencing shame is enough to trigger revenge seeking among collectivist individuals, according to Gelfand. Given these findings, research on the cultural basis of events that spark conflict is critical to the military, as are historical analyses (see, e.g., Mahoney and Rueschemeyer, 2003) and sociological analyses (see, e.g., Moskos, Williams, and Segal, 2000) of the interpretations of those events.

Finally, it is lamentable that little is known about the effectiveness of various strategies for reducing conflict across cultures. For example, Gelfand notes that researchers have documented the effectiveness of apologies for reducing aggression, fostering forgiveness, and repairing trust, but they have failed to examine the role that apologies play in reducing intercultural conflicts (Tavuchis, 1991). Other strategies that may be even more effective in reducing aggression and building trust need to be identified and studied. A systematic effort to document the prevalence of various conflict reduction strategies across cultures as well as their effectiveness when applied in different cultures warrants research attention by the military.

3

Teams in Complex Environments

THE CENTRALITY OF TEAMS

Throughout history, teams have been the fundamental unit of organization in the military. Wars are fought and won or lost by people working together in small groups located at every level of the command hierarchy: the infantry squad in the field, the aircraft mechanics in the hanger, the technicians in the engine room of a nuclear submarine, and the Joint Chiefs of Staff in the boardroom. Team effectiveness has always been and continues to be essential to the success of military missions.

Given the centrality of teams, it is not surprising that the behavior of teams has been studied for a long time. Recently, major strides have been made in understanding of team effectiveness. At least seven major reviews of the research on teams were conducted between 1990 and 2000 (see Kozlowski and Ilgen, 2006). In addition, there has been comprehensive and quantitatively focused research on team decision making under stress by Salas and his colleagues (Cannon-Bowers and Salas, 1998) and qualitatively focused work of Hackman and his students across multiple types of teams (Hackman, 1990). Recent reviews (Ilgen, Hollenbeck, Johnson, and Jundt, 2005; Kerr and Tindale, 2004; Kozlowski and Ilgen, 2006; Salas, Stagl, and Burke, 2004) document the continued advances in understanding team behavior.

The interest and research activity is due, in part, to a shift in the way work is organized in civilian as well to military organizations—away from the isomorphic linking of individuals to jobs to that of defining jobs at the team level. This shift was brought about by increasing workplace complexity and its consequences: demands for expertise, flexibility, and adaptability. Furthermore, military teams are increasingly composed of people who differ in culture, ethnicity, gender, age, and other externally apparent individual characteristics. Consider, for example, American infantry soldiers who receive combat training in small units that are relatively homogeneous in age and language and who have been both raised and trained in the United States. Then these soldiers suddenly find themselves in teams of Iraqi police trainees, patrolling the streets of Baghdad with teammates who cannot speak their language and have little or no shared experiences, either culturally or in tactical training. The mix of technical and interpersonal skills, along with those of temperament and adaptability needed to perform in such teams is critical to soldiers' survival as well as the success of the mission.

From a technical rather than a social perspective, teams are increasingly imbedded in technological systems in which the boundaries between human and nonhuman functions are inextricably confounded. Cockpit crews believe that they fly aircraft; designers and engineers believe that the technology flies aircraft. Both are right and both are wrong. Given the complexity of interacting systems in today's aircraft, precisely assigning the percentage of responsibility to humans or machines is impossible.

DEFINITION

Definitions of teams most similar to those in the military typically assume that they are composed of two or more individuals who interact socially; possess one or more common goals; perform tasks valued by the organization in which the team is embedded; possess some interdependencies with respect to workflow, goals, and outcomes; have roles in the team that may or may not differ in status and responsibilities; and are embedded in a larger organizational system. Similar characteristics were articulated by Salas, Dickenson, Converse, and Tannenbaum (1992) and appear in much of the research literature on work teams (e.g., Alderfer, 1977; Argote and McGrath, 1993; Hackman, 1992; Hollenbeck et al., 1995; Ilgen, 1999; Kozlowski and Bell, 2003; Kozlowski, Gully, McHugh, Salas, and Cannon-Bowers, 1996; Kozlowski, Gully, Nason, and Smith, 1999; and Kozlowski and Ilgen, 2006). This definition of teams includes important contextual conditions. Specifically, the teams exist to perform tasks, and they are rarely free-standing units but are embedded in larger organizational systems.

Implicit in the inclusion of task performance as a defining characteristic of teams is the fact that teams exist to serve some purpose and that the effectiveness of the team is important. The model that has guided research on team effectiveness for the last 30 years is the input-process-output (I-P-O) heuristic model usually attributed to McGrath (1964). Inputs are resources available to the team from its members (e.g., their skills and abilities), technological assets, and other factors in the team's environment. Processes are the activities of the team that convert the inputs into outcomes (e.g., coordinated effort of team members). Hackman (1987) defined the outcomes domain through partitioning into three relatively independent categories: performance, which is measured in task-relevant units; factors that affect team member needs (e.g., status, feelings of accomplishment, income); and team viability, the factors that hold the team together. Most research questions fit within a framework of investigating the effects of some factors that can be seen as inputs on team processes and, in turn, on one or more of the three output criteria of performance.

Today the I-P-O paradigm still dominates research on team effectiveness. However, this theoretical structure has been expanded in two important and critical ways: by time and by levels of analysis. In terms of time, process is, by definition, dynamic. Team process constructs are the result of team member cognitions, emotions, and behaviors that occur in the life of the team. Marks, Mathieu, and Zaccaro (2001) made explicit the dynamic nature of many of the constructs classified as "process" by introducing "emergent states" as a way of differentiating dynamic elements in the link between inputs and outcomes. Kozlowski et al. (1999) raised similar ideas in the framework of developmental cycles in the life of teams. With respect to levels of analysis, the well-accepted notion that people (human systems) are nested within teams and that teams are, in turn, nested within organizational and technical systems (Olson and Olson, 2003) is now not only simply acknowledged: the implications of this nesting are being more clearly articulated both theoretically and methodologically.

One immediate result of adopting a levels-of-analysis perspective is more careful scrutiny of the implications of within-team variances. Before researchers adopted a levels-of-analysis perspective, such team-level constructs as self-efficacy were typically defined as the sum or average across team members; within-team variance was assessed primarily for purposes of evaluating the accuracy of the team score. Now, however, researchers consider more carefully whether or not the construct itself requires convergence across members in order to be valid.

For example, team self-efficacy is the extent to which the members of a team believe the team is efficacious performing its task. The agreement of the team members is typically assessed only to decide whether the mean represents the team members' beliefs. Yet, in considering the most extreme responses of team members, a bimodal distribution of some other configuration might be of interest in determining team self-efficacy. Theoretically meaningful algorithms for indexing team self-efficacy are getting more attention as multiple levels of analysis are taken into account.

BASIC TEAM PROCESS AND EMERGING STATES

Given that teams are themselves multilevel systems of people and their environments, it should not be surprising that the team literature addresses constructs at multiple levels. Researchers have taken the constructs of cognitive, emotional/motivational, and behavioral processes of individuals and raised them to the team level.

Two team-level cognitive analogs are mental models and transitive memory. The former refers to team members' shared mental representation of knowledge or beliefs relevant to key elements of the team's task environment (Klimoski and Mohammed, 1994). Transitive memory is shared information about team members' knowledge, roles, skills, and abilities (Wegner, 1995). Mental models have been shown to have a positive effect on team performance, and they can be influenced by both training (Blickensderfer, Cannon-Bowers, and Salas, 1997) and leader behavior (Marks, Zaccaro, and Mathieu, 2000).

Although having shared mental models is important in any context, it is particularly important in military contexts: team members may have different perspectives but think they share the same ones as their teammates. For example, when there are joint operations with military units from different nations, there may be differences in small unit tactics, and the troops may not realize all the consequences of those differences. When a person trained in one army finds himself or herself in a unit of another army, the person may assume that others in the unit share his or her perspective, which leads to increased chances of errors and misunderstanding, particularly under the stress of combat.

Although both mental models and transitive memory are typically limited to team members' beliefs and perceptions, these domains can be expanded with information technology (e.g., through computer-supported cooperative work). Extending team memory, adding decision-making capacity with intelligent systems, and totally changing the meaning of distance and time through synchronous and asynchronous interaction in space and time in virtual teams are radically changing the nature and results of cognitive processes in teams (Olson and Olson, 2003). For example, the concepts of shared memory and shared representations are related to the concept of distributed cognition. This view represents a shift in the study of cognition from being the sole property of an individual to its being a property of groups, material artifacts, and cultures (Hutchins, 1995; Suchman, 1987). This viewpoint is increasingly gaining acceptance in cognitive science and human-computer interaction research. Its importance in the military is evident as robots, unmanned aerial vehicles, and other automated systems with the capacity to learn from their own experience are imbedded in teams whose mission requires both human and nonhuman interaction for success.

Distributed cognition has two central points of inquiry, one that emphasizes the inherently social and collaborative nature of cognition and one that characterizes the mediating effects of technology or other artifacts on cognition. Clearly, this model of cognition can be closely interwoven with the study of teams, especially those in environments characterized by high levels of technology.

A number of affective, mood, and emotional constructs that are important for individual effectiveness have also been found to affect team effectiveness, including satisfaction or identification with the team and commitment. Interestingly, the effect of these factors is greater on member outcomes or team viability outcomes than it is on performance criteria of team effectiveness (see Kozlowski and Ilgen, 2006). These factors also affect critical team processes of cooperation, coordination, and collaboration, and so are worthy of study in the team context as well as in the areas described elsewhere in this report (see Chapter 5, Chapter 6, and Chapter 7). From the perspectives of both internal team and the setting in which teams operate, multicultural factors are also becoming increasingly important influences on team process. Understanding how culture influences cognitive and emotional processing in ways that affect team functioning is at an early stage; research on this topic will yield results in the long term 10-20 years (see, e.g., Gelfand, in this volume). For example, as attitudes change within a culture toward minority racial, ethnic, or religious groups, they might affect the ability of the military to train and maintain effective team functioning. Such changes in attitudes and in society and within the military itself have been documented by sociologists (see, e.g., Segal, 1989; Segal and Segal, 2004) and historians.

When teams share what are commonly called values, it is frequently labeled team climate. There is significant empirical support for the consequences of team climate on team effectiveness (Ostroff, Kinicki, and Tamkins, 2003). These value and motivational factors that develop in teams play a role not only in the teams themselves, but also with respect to establishing commitment of the team members to the larger military context. With a voluntary military, staffing is always critical. Interpersonal bonds that are established in teams have the potential of influencing soldiers' long-term commitment to a career in the military. Although it is likely that the construct of "climate" influences team effectiveness in technologically rich environments, understanding of how it works there is limited.

Another set of team processes addresses linkages among team members or between team members and their tasks. Cohesion, conflict, cooperation, and coordination are processes that, by definition, involve interactions among two or more team members. There has been a great deal of research on each of these, addressing both their effects on team effectiveness and on the factors that cause these processes (for some meta-analytic reviews, see Beal, Cohen, Burke, and McLendon, 2003; DeDrue and Weingart, 2003; and Gully, Devine, and Whitney, 1995).

Technology that takes into account the psychology, sociology, and anthropology of teams will be much more effective than technology that requires teams to adapt in ways that conflict with the ways people usually work together. The impact that technology has on a team's effectiveness can be either devastating or enabling. Behavioral and social science research can help ensure that it is the latter.

INFLUENCING TEAM EFFECTIVENESS

Understanding team processes is absolutely essential for building a foundation for understanding team effectiveness. It is also necessary to understand the conditions that allow team processes to operate in positive ways in one or more of the three domains of effectiveness: performance, meeting members' needs, and improving team viability. These domains can also be characterized by the issues of staffing; training and development; leadership; and the design of the organization.

Staffing

Key functions of staffing are recruitment, selection, and placement. Well-developed and validated policies and practices for these functions have been developed for individuals, and much of what is known at the individual level holds for teams when the pool of knowledge, skills, and abilities of individuals is expanded to include teamwork-relevant knowledge, skills, and abilities.

The staffing paradigm as it relates to placement at the team level is different than at the individual level because team members may be added and dropped over time, creating the need for dynamic models. There are some models, such as Schneider's (1987) attraction, assimilation, and attrition model, that describe staffing over time, but most other models are mainly analogs of individual models. Team-level staffing also must take into account the fact that critical constructs, such as adaptability, cannot be understood by looking simply at the adaptability of individual members: the adaptability of a team involves individual and job design inputs and emerges over the life of the team in ways that are not captured well at the individual level (Burke, Stagl, Salas, Pierce, and Kendall, 2006).

One important staffing issue is that of composition with respect to diversity. There have been two hypotheses on the effects of diversity, one proposing positive effects and the other proposing negative effects. The first is that diversity among team members expands the resource pool of the team with respect to task behaviors and is helpful for performance. The second is that diversity of culture, values, gender, and other easily identifiable differences is likely to generate teamwork processes that reduce team effectiveness. An extensive review of the research on diversity (Mannix and Neale, 2006) does not support either hypothesis: diversity does not show a main effect on task performance in either direction. Rather, whether or not the diversity effect of the expanded resource pool is positive depends on the nature of the tasks to be performed. Future work is needed to better map the task and diversity space, keeping in mind the normative demands for creating and maintaining diverse teams.

Team Training and Development

The team training literature is a rich one, and there is considerable evidence that training can have a significant positive impact on team effectiveness. Klein et al. (2006) and Salas, Nichols, and Driskell (2007) looked at team training objectives, evaluating them against specific training objectives as well as what they called team building. The training was an intervention for already existing teams and monitored by the teams themselves. The authors found that more than 23 percent of the variance in team effectiveness was predicted by the team training and building programs.

Simulated exercises have been frequently used to train teams, and these methods have been found to be very useful, particularly in complex, high-reliability environments in which avoiding errors is extremely important. Another form of training, cross training, requires team members to learn the tasks of all of their team members, to the extent technologically possible, in order to increase their ability to back up others who are overloaded, to monitor others' behavior, and to detect potential problems for others. Back-up behavior is particularly critical in military settings where sudden spikes in demand for high levels of effort and performance by one or two team members may require others in the team to come to their aid. Also, when team members are incapacitated or reassigned, those who remain in the team must cover for the missing person(s) until the team is able to return to a fully staffed level.

Training that improves teamwork has been applied in a number of settings, many of them using simulations and other technologies. Meta-analyses have revealed that simulation-based training can indeed improve team performance. In particular, training for adaptability and coordination using principles first developed for the National Aeronautics and Space Administration as part of cockpit resource management has been adapted to other team settings, such as emergency rooms and surgery teams in hospitals, with good results.

Leadership

Discussions of leadership often partition factors that influence effective leadership into traits (stable characteristics of the leaders themselves), states (skills that could be trained), and situational conditions in which some states and traits are better than others. Today it is recognized that all three of these factors interact and change over time: there are relatively stable leadership propensities that do matter, but skills can be developed over time, and they are a function of both traits and experience. Furthermore, some leadership characteristics are more suited to some situations than others. According to Kozlowski and Ilgen (2006, p. 107): "[E]merging meta-analytic findings provide a useful indication of the potential value of leadership in the promotion of team effectiveness."

Team leaders can directly influence the mental models, transactive memories, and perceptions of team climate and, through them, they can affect team members' behavior and effectiveness. Leaders influence performance regulation in teams through goal setting, strategy development, and feedback and by influencing individual and team rewards as well the contingencies between behavior and outcomes. Leaders often have influence on team members' roles, the technological resources available to the teams, and the structure of tasks and interpersonal relationships. Finally, a recent meta-analytic review of research on leader behavior patterns and styles by Judge and Piccolo (2004) found that both transactional leadership (leader behaviors that influence follower rewards) and transformational leadership (similar to charisma, inspiring people to higher goals) positively influenced team effectiveness.

Anecdotal, popular reports are full of stories of military leaders who are believed to have had major impacts on their team's performance in battle. The consistency between these reports and the literature based on behavioral science research adds credence to the general nature of the effect of leadership on team performance. Moreover, leaders' influences through transformational leadership behaviors are likely to go beyond the context of the team to that of the commitment of team members to careers of military service.

Organizational Structure and Design

Structure is important for team effectiveness both within the team and as part of the larger organizational system. Research on structural effects is often focused at the interpersonal level of coordination, collaboration, influence, lines of authority, communication patterns, and other mechanistic linking mechanisms for tying individuals to tasks and to each other. These factors also have an effect at the level of units throughout an organization. Structure at a higher level is addressed in terms of organizational charts, the language in use (functional and divisional), or models (Petri-nets). All of these structural frameworks have been used at various times with teams and have been shown to alter team behavior. Yet, without denying the importance of them or the overall importance of structure and design, it is clear that most of these constructs are not independent of each other. This lack of independence has been recognized, and it is likely that a more concise conceptual space for structural frameworks will be developed in the near future.

Structure can sometimes impede performance. For example, the U.S. Army routinely conducts after action reviews (AARs), in which a training or actual exercise is critiqued, not by an outside investigating body, but by the individuals in the unit. Such reviews are conducted as collegial discussions, insofar as possible, and are not structured by rank. Sergeants can criticize lieutenants, and lieutenants can comment on captains' decisions. These exercises provide extremely useful feedback. The AAR is effective in part because it permits input from people with different perspectives. In combined operations such as are currently being conducted with the Iraqi "friendly" forces, it is essential that everyone participating in the exercise also participate in the AAR. However, the AAR violates both the hierarchical structure of the Army and the even more rigid hierarchical structure of many Middle Eastern and Asian cultures. Since feedback is very important for the improvement of performance, appropriate ways to conduct AARs that will include feedback from non-American personnel need to be developed.

Although the word "structure" implies rigidity, it does change over time. Social changes, such as a sudden—or even slow—breakdown of respect for authority or credentials, can cause dramatic changes in an organization in any society. Since such respect is crucial to the function of military teams, research by social historians and sociologists is essential to understanding the consequences of social changes.

The demand for teamwork among geographically dispersed team members has led to the development of collaborative tools—"teamware" and other software systems—designed to facilitate work in virtual space. A number of commercial programs exist for working with these systems. Those programs have been informed by very promising research on virtual teams, but at this time more work is needed to understand better how the characteristics of these systems alter team effectiveness (Kiesler and Cummings, 2002).

Teams are ubiquitous in today's organizations, including the military, and their effectiveness is absolutely critical to the performance and viability of the organizations in which they are embedded, as well as to the well-being of the people who are part of them. A large research literature focuses on understanding team behavior and functioning; it informs the design of organizations, leaders' behaviors in them, and policies and practices related to staffing teams. The complexities of teams as dynamic systems nested in organizations and changing over time present major challenges for future research that are just beginning to be addressed both theoretically and methodologically. These complexities are the focus of long-term research (10-20 years).

It is important that the momentum of research on teams continue because it is likely that work will increasingly be organized around teams rather than individuals. The challenges of diverse memberships, rapidly changing demands, and dispersion over space and time will also increase. A two-pronged, interdependent approach is needed: work on better understanding the processes that influence team effectiveness and work on the factors that influence the organizational policies, practices, structures, and leader behaviors that influence key team processes to improve their effectiveness. The two approaches must inform each other and advance in an iterative fashion, integrating their insights and results, and studying them in organizations of all types. They pose questions that must be addressed in both short- and long-term research.

As military team members work ever more closely together and yet are dispersed in space and time, their knowledge and skills must be as thorough and comprehensive as possible, and they must be finely tuned to the requirements of the mission. These objectives in turn require the best training available and lots of practice: both training and practice are expensive commodities and are currently strongly oriented to technology. These factors will influence the kinds of behavioral and social science research that promise the best payoff, in both the short and longer term.

4

Technology and Training

Training personnel is a major task for the U.S. military: when people are not engaged in military operations, their most important activity is training. Military personnel are predominantly high school graduates in the enlisted force and college graduates in the officer corps. Although a few military jobs have civilian counterparts and can be selected rather than trained (e.g., doctors, lawyers, and aircraft mechanics), most service jobs have few civilian counterparts, most obviously combat skills. In addition, the military promotes from within and develops its own leaders rather than selecting them. The training of service men and women throughout their military careers is expensive, both in terms of dollars and personnel. Since the military (like industry) pays its members to be trained, a reduction in training time results in savings of time and money.

CURRENT TRAINING APPROACHES

Training is deeply embedded in military culture as a core mission (Bratton-Jeffrey, Hoffman, and Jeffrey, 2007). Today, the training needs of the military are expanding from the need to teach skills in isolation, such as how to trouble-shoot an electronic device, to the need to teach problem-solving strategies and concepts in the context of complex and ever-changing task environments, such as how to negotiate in different cultural contexts or how to rapidly integrate information from multiple sources to make an on-the-ground decision (van Merrienboer, 2007). Fortunately, recent advances in educational technology offer highly promising ways to meet this new kind of instructional need, but basic research and research-based theory are needed in order to determine how to use educational technology productively (Mayer, 2005). This will require both short- and long-term research approaches.

The military has successfully implemented an instructional systems design approach to guide the development of training of isolated skills, but there are indications that this classic approach is not well suited to the emerging new demands for training of strategies and concepts in complex contexts (Reiser, 2007). Research is needed to support the development of both a research base and a research-based theory of instructional design for these new kinds of learning, which include decision making, information integration, communication in cultural context, and problem solving in unexpected situations.

FUTURE APPROACHES

In future military training, one can envision learners sitting in front of computer screens at school, home, or a job site and having the opportunity to learn with the help of an on-screen agent who offers useful job-related practice tasks within realistic simulations. One can also envision military personnel being able to play serious games that promote learning. Graesser and King (in this volume) describe 10 advanced learning environments that hold potential for technology-based training: computer-based training, multimedia training, interactive simulation, hypertext and hypermedia, intelligent tutoring systems, inquiry-based information retrieval, animated pedagogical agents, virtual environments with agents, serious games, and computer-supported collaborative learning. Such technology-based environments can support the learning of both individuals and teams.

Advances in computer and information communication technology have potential for greatly increasing the efficiency and effectiveness of training, and there is encouraging preliminary evidence of the efficiency and effectiveness of technological approaches under appropriate conditions (Andrews, Nullmeyer, Good, and Fitzgerald, in press; Breuer, Molkenthin, and Tennyson, 2006; Chipman, 2006; Clark and Mayer, 2003; Cuevas, Fiore, Bowers, and Salas, 2004; Fletcher, 2003; Jonassen, 2004; Mayer, 2001, 2005; Moreno, 2006; O'Neil, 2005; O'Neil and Perez, 2003, 2006; Pearson, Ferdig, Blomeyer, and Moran, 2005; Wulfeck and Wetzel-Smith, in press). In general, reviews of the literature with respect to efficiency conservatively indicate a 30 percent reduction in training time when the same objectives are taught on computers in comparison with conventional instruction (Fletcher, 2003; Kulik, 1994; Sitzmann, Kraiger, Stewart, and Wisher, 2006).

With respect to effectiveness, the critical issues are the instructional strategies and assessments embedded in the computer-based systems, not the medium per se (Clark, 2001; Kirschner, Sweller, and Clark, 2006; Sitzmann et al., 2006). When appropriate instructional strategies have been embedded in technology-based training systems, the systems have been shown to be 19 percent more effective than conventional instruction for teaching declarative knowledge (Sitzmann et al., 2006) and to have average effect sizes of 1.05 for modern intelligent tutoring systems (Fletcher, 2003). The latter finding represents an improvement of performance of 50th percentile students to the 85th percentile. Findings also show that some forms of technological support, particularly the use of computer simulations for training, offer the opportunity to train skills safely, efficiently, and effectively that are either impossible or very expensive to train without such support (e.g., pilot training, combat skills, medical skills; O'Neil and Andrews, 2000).

THE SCIENCE OF LEARNING AND THE SCIENCE OF INSTRUCTION

Although the hardware and software technologies for implementing advanced learning environments are being developed, the work often takes place without an understanding of how people learn. To complement hardware and software development efforts in creating new training technologies, basic research on how to use such training technologies to improve human learning is necessary. Currently, there is a small research base on the topic, but a serious investment of research support could significantly increase its pace and usefulness for the military in the near term.

Advances in educational technology are outpacing advances in an underlying science of learning with technology in part because the field is vendor driven, not science driven. Thus, decisions about how to design technology-based training are often based on intuitions and opinions of persons with technological development skills rather than on research evidence and a research-based theory of how people learn. As a result, training programs may not reach the optimal levels of effectiveness and efficiency. For example, there is only limited scientific research evidence that computer games facilitate the learning of adults (O'Neil and Fisher, 2004; O'Neil, Wainess, and Baker, 2005), yet they continue to be promoted and used in the military context. Given the centrality of training for the military, it is critical that technology-based training is based on research evidence and research-based theory.

Training programs should be based on an understanding of how people learn and how instructional methods affect learning. It is tempting to focus on the tremendous technological advances in education, including web-based training, without sufficient attention to the people who need to be trained. For example, in taking a technology-centered approach, instructional designers begin with a cutting-edge technology and try to build learning environments for users rather than starting with the user and trying to determine what technology can meet their needs. In his review of the history of educational technology during the 20th century, Cuban (1986) has shown that cutting-edge technologies of each era have failed to have much impact on improving education—including motion pictures in the 1920s, educational radio in the 1930s and 1940s, educational television in the 1950s, and computer-based programmed instruction in the 1960s. In contrast, in taking a learner-centered approach, instructional designers begin with an understanding of how people learn and seek to use technology as a cognitive tool to aid learning (Mayer, 2001; Sweller, in press). For example, technology-supported instruction that was based on learner-centered design principles (in this case, the cognitive theory of multimedia learning), test performance improved by 0.6 to 1.3 standard deviations as compared to conventional practice (Mayer, 2001, 2005).

Research is needed to develop a theory of learning—or science of learning—that is relevant to learning with technology, particularly in the military. How do people learn from words (such as spoken or printed text) and graphics (such as illustrations, photos, animation, or video)? How do people learn from on-screen agents? How does interactivity influence learning? How do people use and learn self-regulatory skills in technology-based environments? These are the kinds of basic questions that need to be addressed in building a science of learning with technology that can benefit the training needs of the military.

Training programs should also be based on an understanding of how instructional methods affect learning. In spite of stunning advances in computer and information technology, the way to incorporate these technologies in the service of human learning requires behavioral, not technological, research. As noted above, there is broad consensus that learning results from instructional methods rather than instructional media (Clark, 2001). Using a particular medium—such as a computer-based multimedia lesson or a serious game—does not ensure an improvement in learning. Rather, the medium needs to follow from knowledge about instruction and learning. Research can identify the effects of technology-supported instructional methods and clarify the conditions under which the methods are effective (e.g., Mayer, 2001, 2005; Sweller, in press). One topic that crosses disciplinary boundaries and is of considerable significance to the military is the role of feedback in computer-based simulations used for training and assessment of teams. This type of feedback is called after-event review (Ellis, Mendel, and Nir, 2006) or after-action review in the military (Meliza and Goldberg, in press). The goal of research on such issues should be the establishment of a set of research-based principles for how to design technology-based training to meet military needs.

Training programs should incorporate specification of the knowledge to be learned and assessment of what learners know. Many technology-based training applications focus on increasing learners' cognitive knowledge (National Research Council, 2001), but motivational or affective learning is also of importance. For example, much of the assumed effectiveness of serious games is attributed to motivational effects. There is, to date, very limited research on assessing the cognition and motivation for individuals, teams, and organizations. Much of the assessment in training technology relies on single formats such as multiple-choice testing, which is most useful for recalling facts (Anderson et al., 2001), not motivation or other affective components of learning. Some of the most interesting technological training applications—such as simulation, games, team training, and after-action reviews—do not include assessments of knowledge that permit real-time diagnosis of learning and prescriptions for improvement.

Currently, the most frequently used assessments are think-aloud protocols, behavioral observation systems for teamwork training, and face validity for simulation applications. Yet, none of these techniques permits real-time feedback. And, these approaches seldom address issues of reliability or validity. What is needed is a model-based approach to assessment and a psychometrics of simulation. A model-based assessment approach (Baker and O'Neil, 2006; Baker and Mayer, 1999) would focus on a model of learning, not a model of content. It would (a) draw on elements from learning and assessment scientific knowledge, (b) be empirically developed, (c) have both domain-independent and domain-dependent aspects, (d) have reusable components that would result in time and cost savings, and (e) give evidence of technical quality obtained. Multiple purposes of assessment would also be supported (e.g., program evaluation, system monitoring, individual/team certification, selection and classification, individual and team diagnosis and prescription). A psychometrics of simulation approach would deal with traditional psychometric issues in the simulation domain (e.g., difficulty, norming and equating, reliability, and validity). Finally, affective and motivational models of learning, as well as social capital ideas for organizational improvement, would drive new assessment methodology.

TECHNOLOGY TO MEET MILITARY NEEDS

Basic research on technology and training can contribute to solving problems for each of the five major needs for the military identified in this report: leadership, training, personnel, social interactions, and organizational structure. It can improve instruction in leadership skills, including computer-based simulations to enable decision-making practice in simulated settings. Promising approaches in leadership training include the AXL, ELECT, and Vector projects (see Zbylut, Metcalf, Kim, Hill, Rocher, and Vowels, 2007; Hill, Gordon, and Kim, 2004; Hill, Belanich, Core, Lane, Dixon, Forbell, Kim, and Hart, 2006; Zachary, Le Mentec, Miller, Read, and Thomas-Meyers, 2005).

Clearly, basic research on technology and training can improve the effectiveness and efficiency of training in the military, even in the near term. In particular, the committee believes that the application of scientifically tested instructional principles can improve performance by at least 0.8 standard deviations, which is considered a large effect. We also expect that technology-supported testing itself can enhance learning, as reflected in the test enhanced learning effect, in which taking repeated tests improves student learning (Roediger and Karpicke, 2006).

With respect to personnel, basic research on technology and training is needed to determine the role of individual differences in learning, including how to design adaptive learning environments based on assessments of learners' characteristics and progress during instructional lesson. Basic research on technology and training is also needed to determine how to use social cues and group-based methods to foster better learning and also to determine how best to teach social interaction skills, such as negotiation. Finally, basic research on technology and training is needed to determine how to embed training programs in existing organizational structures and practices. This type of research will yield results in both the short and long terms.

Overall, the goal of basic behavioral research on technology and training is to create a science of learning (National Research Council, 1999) that is relevant to issues in military training, builds a research base that can guide instructional design of technology-based training in the military, and identifies and assesses instructional methods that have large effects on learning. Basic behavioral research on technology and training will enable military trainers to take an evidence-based approach to designing training for individuals and for teams.

TECHNOLOGY AND OTHER RECOMMENDED RESEARCH

Knowledge about technology and training interacts with each of the other research topics identified in this report: intercultural competence, teams and complex environments, nonverbal communication, emotion, and neurophysiology. For example, the appropriate design of collaborative learning environments depends on research on intercultural competence training programs aimed at teaching intercultural skills, and it is similarly dependent on research on teams operating in complex environments (Salas and Priest, 2005). Research on nonverbal processes is directly relevant to the design of on-screen agents, including the role of gesture, expressions, and voice. Understanding affective processing in learning, including ways in which learners react to frustration or contentment during learning, is useful in designing training programs. Neurobiological markers can be used to measure physiological states of learners during the learning process (see Chapter 7) and can be particularly useful in understanding the role of stress in learning and performance.

5

Nonverbal Communication

Life-or-death decisions sometimes depend on subtle nonverbal signals: facial expressions, tone of voice, even the distance people maintain among themselves. According to Triandis (1994, in Carnevale and Choi, 2000), the first Gulf War could have been avoided if not for a misinterpretation of nonverbal cues:

> In January, 1991, James Baker, then the United States Secretary of State, met with Tariq Aziz, the foreign minister of Iraq. They met in an effort to reach an agreement that would prevent a war. Also present in the room was the half-brother of Saddam Hussein, whose role included frequent calls to Hussein with updates on the talks. Baker stated, in his standard calm manner, that the U.S. would attack if Iraq did not move out of Kuwait. Hussein's half brother heard these words and reported that "the Americans will not attack. They are weak. They are calm. They are not angry. They are only talking." Six days later Iraq saw Desert Storm and the loss of about 175,000 of their citizens. Triandis argued that Iraqis attend to how something is said more than what is said. He further suggests that if Baker had pounded the table, yelled, and shown outward signs of anger, the outcome may have been entirely different.

Other examples abound. In a recent California murder case, for example, jurors pointed to the defendant's physical demeanor when justifying their death penalty recommendation: "No emotion, no anything. That spoke a thousand words" (Dornin, 2004). Americans' impression of the famous Kennedy-Nixon debate apparently depended on whether you heard the debate on the radio or watched it on television (Druckman, 2003).

Nonverbal cues also play a key role in more mundane interactions. For example, Prickett, Gada-Jain, and Bernieri (2000) found that judgments formed in the first 10 seconds of a job interview predicted its outcome. When misunderstood, nonverbal signals escalate conflicts, deepen intercultural misunderstandings, and undermine leadership and team cohesion. By laying the theoretical foundation for more effective communication, classroom instruction, and organizational processes, nonverbal research ultimately will enhance soldiers' ability to communicate, persuade, and avoid misunderstandings before they escalate.

SIGNIFICANCE OF CONTEXT

Nonverbal behaviors are different from language because they (e.g., gestures or facial expressions) rarely carry specific intrinsic meanings. Although nonverbal behavior can act as words—for example, the "thumbs up" gesture has a specific, though culturally varying meaning—most nonverbal communication is contextual, less conscious, and it performs a variety of nonlinguistic functions. Nonverbal signals change depending on the social context; indeed, it is often through observing someone's behavior that people become aware of the contexts: Is this person a leader? A follower? Surrounded by friends or enemies? Through nonverbal signals, people convey emotion (see Chapter 6), project power, manage interpersonal distance, modulate the flow of conversation, and construct ideas about how another person's mind works. These processes largely proceed outside of conscious awareness, thus explaining the perniciousness of social biases that arise from subtle cues, such as a person's appearance or accent.

The automatic and contextual nature of nonverbal communication has been a thorny problem for study and analysis. Researchers have often failed to properly distinguish between the production ("encoding") and interpretation ("decoding") of nonverbal signals. For example, early research by Paul Ekman (see, e.g., Ekman and Friesen, 1975) argued for the existence of discrete emotional states on the basis of the finding that widely disparate cultures could correctly identify an expression portrayed by an actor. However, subsequent findings showed that such experiments only assess people's ability to recognize (i.e., decode) facial expressions, but provide little information about people's behavior during actual emotional episodes. Indeed, there are well-known differences between the behaviors of actors and people in naturalistic settings (Coats, Feldman, and Philippot, 1999). Actors use stylized or exaggerated displays in an attempt to make their behavior easier to decode. Naturalistic behavior is far more complex and dynamic, and it often involves strategic attempts to mask or modulate nonverbal displays. Furthermore, even when there are reliable cues that encode a cognitive act, such as deception, observers often attend to irrelevant cues.

In the discussion below, it is important to keep in mind the distinction between three aspects of nonverbal communication: (1) how nonverbal messages are truly encoded, which is important for detecting deception or a person's true emotional state; (2) how such messages are decoded, which is important for promoting efficient and persuasive communication; and (3) the relationship between these processes, which is important for understanding the source of biases and cultural misunderstandings. Nonverbal behavior plays an important role in almost any face-to-face encounter; its absence in telecommunications can contribute to errors and misunderstandings. Not surprisingly, nonverbal communication research directly affects several areas that are important to the military, as discussed below.

LEADERSHIP AND PERSUASION

Nonverbal behavior plays an important role in the exercise of social power. Whether it is in formal leadership settings, as when a lieutenant commands a platoon, or less formal settings, as when a physician attempts to change the behavior of a patient, nonverbal signals vary dramatically with social role. Nonverbal cues may be valuable in predicting the effectiveness of attempts to exercise social power and influence (Tiedens and Fragale, 2003). In formal leadership settings, much of the research has focused on charismatic leadership and the role of nonverbal signals in conveying a leader's sense of enthusiasm or confidence (Riggio, 1987). More generally, dominant partners in two-person interactions show distinctive patterns of facial expression, posture, and eye gaze. For example, dominant partners tend to use more relaxed facial expressions and more directed gazes.

Outside of formal leadership settings, research has extensively documented the effects of nonverbal behavior on persuasive relationships, particularly the role of rapport and its nonverbal correlates. Cappella (1990, p. 303) states that rapport is "one of the central, if not *the* central, constructs necessary to understanding successful helping relationships and to explaining the development of personal relationships." Rapport is correlated with characteristic nonverbal behaviors. Tickle-Degnen and Rosenthal (1990) equate rapport with behaviors indicating mutual attentiveness (e.g., mutual gaze), positivity (e.g., head nods or smiles), and coordination (e.g., postural mimicry or synchronized movements). Rapport can be experimentally induced or disrupted by altering these nonverbal signals (e.g., Bavelas, Coates, and Johnson, 2000; Drolet and Morris, 2000), suggesting a causal relationship between such behavior and social effects. The benefits of rapport are widespread, influencing esprit de corps, success in negotiations (Drolet and Morris, 2000; Goldberg, 2005), worker compliance (Cogger, 1982), psychotherapeutic effectiveness (Tsui and Schultz, 1985), test performances in classrooms (Fuchs, 1987), quality of child care (Burns, 1984), and even susceptibility to hypnosis (Gfeller, Lynn, and Pribble, 1987).

There are significant research opportunities for the U.S. military at the intersection of leadership and nonverbal behavior. The rise of network-centric operations has placed increased emphasis on the exercise of leadership "at a distance," and research on nonverbal behavior has implications for the use of communication technology and could inform the design of more efficient command and control systems. Different communication settings (e.g., telephone, email, video link, or face to face) create different styles of interaction and influence the content of communications (Parkinson, in press). For example, a reduction of nonverbal cues in email can reduce participants' feelings of connection with their conversation partners ("social presence;" see Joinson, 2003), with the consequence that they show less concern for the emotional consequences of their communication. People tend to be more honest in emails, which can be an advantage in certain settings, but they often use intemperate language (e.g., "flaming") with negative interpersonal consequences. By understanding the relationship between nonverbal cues and communication style, one could potentially design communication technology that is best suited to particular operational environments.

Research on rapport can inform military training and operations, although current findings have to be further translated to the military context of formalized leadership structures, joint teams, and cross-cultural meetings. Understanding how leadership and rapport are nonverbally expressed (i.e., encoded) in such contexts could allow trained observers or even the use of automated techniques to better decode and identify tactically relevant information (e.g., the dominant partner in an interaction). Training individuals to produce nonverbal indicators of effective leadership and rapport may have value as well, though basic questions remain about such learning (see below).

NEGOTIATION

Nonverbal behavior plays a significant role in negotiation and conflict resolution (see Brosig, Weimann, and Yang, 2004; Drolet and Morris, 2000; Frank, Gilovich, and Regan, 1993). For example, a situation in which people see the nonverbal behavior of a negotiation partner can lead to better negotiated outcomes for the former than when that behavior is hidden (Drolet and Morris, 2000). Positive nonverbal information seems to facilitate the establishment of rapport and social bonds and presumably facilitates partners' understanding of each other's goals and intentions. Nonverbal behavior can also be exploited for strategic advantage. For example, feigning anger can sometimes elicit greater concessions, even when the display is recognized as insincere (see van Kleef et al., 2004). Nonverbal cues are often misinterpreted, and these decoding errors increase when negotiation partners are from different groups or cultures, usually with negative consequences for the negotiation process: This outcome may result from systematic differences in nonverbal behavior, but it may also be the result of their preconceived notions of "the other" (see Chapter 2). Nonverbal behavior research can help military negotiators acquire better negotiation tactics and avoid the miscommunications that escalate conflict and undermine successful negotiated outcomes.

CULTURAL FLUENCY

Although some nonverbal signals seem universal, others differ dramatically across cultures, and these differences can contribute to cross-cultural misunderstandings (see Chapter 2). Nonverbal behaviors associated with language (e.g., gestures) can differ considerably, and in some cases the same gesture can have very different meanings. Even something as basic as a smile can be misinterpreted: in Japan a smile is a common indicator of discomfort or embarrassment. Other subtle cues, such as the use of personal space or gaze, can be misconstrued. For example, the more direct body language of Arabs may be interpreted as aggressive by Western observers (Watson and Graves, 1966).

People can learn to recognize and compensate for these differences, and there is some evidence that explicit nonverbal training can facilitate the effectiveness of cross-cultural interactions when participants come from different cultures (see Collet, 1971; Garratt, Baxter, and Rozelle, 1981). Yet basic questions about the best ways to train remain unanswered. Moreover, the research has not been focused on issues that are necessarily relevant for the military. For example, the extensive research on cultural differences in nonverbal behavior has emphasized business negotiations, typically between Western and East Asian participants. However, it is important to note that there is no research on using nonverbal behavioral cues to identify someone intending to carry out a suicide bombing or other attack, especially someone of another culture. Research on situations other than business and among many more cultural groups would be an important military investment for the long term.

TRAINING AND LEARNING

There has been relatively little research on the role of nonverbal communication in education settings, and even less is known about how to teach nonverbal skills. Perhaps the clearest effects of nonverbal behavior on learning have been demonstrated by research on interpersonal expectations, known as "self-fulfilling prophecies." This research shows that teacher biases can be clearly communicated to students through nonverbal behavior and eventually affect learning outcomes. For example, in Rosenthal and Jacobson's (1992) classic experiment, teachers were misled to believe that certain students had higher aptitudes than others. Teachers used different nonverbal cues, as well as different overt behavior towards those students, creating a warmer socioemotional climate and providing them more feedback and more time to respond. Perhaps not surprisingly, these students learned better, though subsequent research has questioned the generality of this effect. More recently and conclusively, Singer and Goldin-Meadow (2005) have shown that judicious use of gestures by teachers improved their students' math scores.

Despite the power of such communicated expectations, it seems difficult for teachers to mask their biases. For example, Babad, Bernieri, and Rosenthal (1991) found that teachers actually compensated for their biases through their speech and facial expressions, but still "leaked" their biases through their expressive body behavior. These observations have provided some encouragement to those who would like to teach others how to decode important nonverbal signals, like those associated with deception. Indeed, some progress has been shown in training people to do just that (Cao, Crews, Nunamaker, Burgoon, and Lin, 2004), and there have been some demonstrations that such decoding skill can smooth cross-cultural encounters (see Collet, 1971; Garratt et al., 1981). How nonverbal communication skills can be most effectively taught, particularly in a military context, remains a fundamental question for research. For example, it is possible to teach soldiers to replicate accurately the gestures of another culture, but it is not known if this ability leads to operational benefits. There is the possibility that such attempts may be perceived by others as disingenuous or as mocking the other culture. Furthermore, it is unclear if one should focus on specific knowledge (what a particular gesture means in a given culture), or teach a general awareness that people may have different beliefs and goals (i.e., teach people to be open minded, ask questions, etc.). Recently, there has been considerable interest in the potential of new media and computer technology to overcome many of the challenges in teaching such skills but the effectiveness of such techniques is yet to be determined. This can be addressed by research carried out in the next 5-10 years. Addressing these fundamental questions would go a long way towards the translation of research findings into tangible results for soldiers in the field.

TECHNOLOGICAL OPPORTUNITIES AND CHALLENGES

Recent technological developments hold promise for transforming research on nonverbal behavior and providing new vehicles to translate this research into practice. For example, research advances in artificial intelligence, computer animation, and computational linguistics have enabled the creation of realistic "virtual humans" that can approximate human verbal and nonverbal interaction (Gratch et al., 2002; Swartout et al., 2006). Virtual human technology creates the opportunity to transform both the study of nonverbal behavior and the teaching of nonverbal skills.

Virtual humans can address one of the many methodological challenges in nonverbal research: demonstrating a causal as opposed to correlational relationship between nonverbal behavior and its presumed social effects. Due to the rapid and automatic nature of nonverbal communication, it is difficult to experimentally manipulate people's nonverbal behaviors, something that is necessary to show a causal relationship. Although some clever manipulations have been developed to get people to alter their nonverbal behavior—for example, Bavelas et al. (2000) had people listen to a narrator while subtracting by sevens—these kinds of manipulation, while effective in disrupting normal behavior, are inadequate for replacing normal behaviors with believable alternatives. Rather than using human confederates who attempt to change their nonverbal behavior and are then quickly perceived as unnatural, virtual humans can precisely and consistently modulate the nonverbal behavior they present to interaction partners. In one study, Gratch et al. (2006) showed that a "listening agent" that gives rapid nonverbal feedback to speakers dramatically increases speaker fluency and engagement in comparison with a less responsive virtual character. Such techniques have already proven successful in testing theories of communicative efficiency, learning, trust, mood, impression formation, and social influence (Bailenson, Beall, Loomis, Blascovich, and Turk, 2004; Blascovich, 2002).

But more than testing theory, virtual humans have the potential to teach nonverbal competencies. A number of systems, some with branching video but increasingly using advanced character animation and game technology, have been developed primarily to teach decoding skills and cultural fluency. For teaching decoding skills, several systems have been developed to teach "shoot/no-shoot" decision making to law enforcement officers, and a number of systems attempt to train interrogators on how to recognize deception (e.g., Cao et al., 2004). For cultural awareness, the Tactical Language System attempts to teach culturally specific gestures in the context of an Arabic language training system (Johnson, Vilhjálmsson, and Marsella, 2004), and Ward (Bayyari and Ward, 2007) attempts to teach nonverbal "active listening" behaviors in Arabic.

The promise and rapid advancement of this technology can be a two-edged sword. Lush virtual environments and the present hype surrounding "edutainment" have created enormous interest in rapidly moving the technology to training applications. The danger is that the advances in the underlying technology may outstrip the science of how to use the technology effectively. Furthermore, the primary driver of this technology, the game industry, is working at cross-purposes to the goal of effective training. By focusing on the goal of entertainment, game characters, much like good actors, emphasize engaging and easily decoded behaviors that are quite different from the way people act in real situations. Using such technology without care might easily result in "negative training," in which one performs worse after training than before. It remains unclear how to mimic the rapid, subtle, and interactive nature of human nonverbal behavior and exactly what level of detail is needed to provide effective skills training.

MOTION ANALYSIS AND MULTIMODAL DATABASES

A major impediment to research on nonverbal behavior is its reliance on coded data. Participants in a study are video recorded, and the resulting data are laboriously hand-coded for their nonverbal content. Methods for coding nonverbal behavior, such as the Facial Action Coding System or Laban motion analysis require extensive training and multiple coders to achieve reliability. Yet when data are collected, they are rarely shared among research groups—because there are insufficient incentives to do so–and so the research is time-consuming and expensive.

Research is needed in order to create tools that rapidly construct multimodal databases and to create mechanisms for collecting and distributing multimodal databases, particularly ones that emphasize military-relevant data, to the research community. Research on sensing technology that can automatically detect and characterize nonverbal communication would also mitigate the data collection bottleneck and promote rapid advancement in the fields. Such methods must be sensitive to the rapid and dynamic nature of nonverbal communication, since it is often changes in behavior rather than static poses that convey information. Distributing such databases, whether manually or automatically created, would facilitate rapid advances in nonverbal research.

Other fields, such as verbal communication and machine translation, have seen dramatic progress as a result of the wide availability of machine-readable data, which can be analyzed by computational methods. For example, The Linguistic Data Consortium, which grew out of a project funded by DARPA (the Defense Advanced Research Projects Agency), supports language-related education and research and technology development by creating and sharing linguistic data, tools, and standards. Funding the development of such tools and shared databases, particularly ones that emphasize military-relevant data, presents an opportunity to expand the utility of nonverbal research and to direct it to military applications within the next 5-15 years.

6

Emotion

Emotions play a powerful, central role in everyday life and, not surprisingly, they play an equally central role in military planning and training. Emotions shape how people perceive the world, they bias beliefs, and they influence our decisions and in large measure guide how people adapt their behavior to the physical and social environment.

Recent advances in psychology and neurophysiology have highlighted the rational and adaptive nature of our emotions (Lazarus, 1991; Damasio, 1994). It is clear that emotions can impair decisions, a fact exploited in a range of military tactics. Military planners throughout history have incorporated an emotional element into training and operations. Training exercises are often designed to elicit the strong emotions soldiers will feel on the battlefield and to create the shared emotions that lead to esprit de corps. And the more recent emphasis on "winning the peace" has placed a premium on soldiers who can understand and defuse the emotions of others. In terms of tactics, Machiavelli (1515) wrote that to motivate citizens to withstand a long siege one should encourage "fear of the cruelty of the enemy." The more modern strategy of "shock and awe" relies just as explicitly on an appeal to emotion (Ullman and Wade, 1996). A 1994 U.S. Army leadership manual (U.S. Department of the Army, p. 8-1) illustrates the role of emotions in operational terms:

> Commanders, while shielding their own troops from stress, should attempt to promote terror and disintegration in the opposing force. . .Some examples of stress-creating actions are attacks on his command structure; the use of artillery, air delivered weapons, smoke; deception; psychological

> warfare; and the use of special operations forces. Such stress-creating actions can hasten the destruction of the enemy's capability for combat.

The leadership manual also states ominously that "failure to consider the human factors in an environment of increased lethality and uncertainty could cause a nation's concept of warfare to be irrelevant" (p. 1-9).

Despite this commonsense grasp of the importance of emotion, as a topic of scientific investigation the study of emotion has waxed and waned. In the past 20 years, however, behavioral scientists have firmly established the importance of emotion in understanding such diverse individual behaviors as perception, attention, memory, and judgment and decision making (Musch and Klauer, 2003), as well as such social behaviors as leadership, persuasion, self-regulation, social intelligence, contagion, productivity, and organizational effectiveness (Judge and Larsen, 2001). Indeed, there has been a revolution in psychology and other behavioral and social sciences (e.g., economics, neuroeconomics) in terms of viewing emotion as a critical variable in understanding a wide variety of human behaviors, many of which have obvious relevance to military needs, even in the short term.

NATURE OF EMOTIONS

Research on emotion is not without its controversies. As described by Barrett (in this volume), a major debate concerns whether emotions are best understood as discrete entities that have specific eliciting stimuli and distinct signatures (e.g., facial expressions, physiology, action tendencies, etc.), or whether they might be better conceptualized as broad dimensions, such as valance and arousal. A researcher's position in this debate influences how emotion is conceived, measured, and investigated, and useful knowledge has been generated from both sides of the debate.

Researchers agree that emotion represents a universal and intrinsic aspect of human consciousness, which functions as an evaluative representation of the environment to the person experiencing the emotion and moderates important cognitive, behavioral, and physiological phenomena. Just as the human retina transduces light waves into the experience of color, the human mind transduces events in the environment into evaluative experiences, i.e., emotions. Emotions are, at their core, internal representations of the affective evaluations one attaches to events in the external environment.

Emotions, in turn, produce effects at every level of cognition and influence many social behaviors, and there are important individual differences in those effects. Many of the main effects of emotion, and their individual differences, could be important for the military and as topics of potentially important and mission-relevant research. For example, the use of virtual reality methods for military training could be developed to include evocative virtual training scenarios that are capable of inducing emotion, including mixed emotions, in a manner similar to real-world military operations. This is currently being attempted with computer simulations for the treatment of posttraumatic stress disorder (PTSD), but it remains to be validated in the next few years.

Military operations often involve "in extremis" decision making and action. Such operations can involve intense emotions including those associated with notice of deployment, reactions during training, anticipation of operations, sometimes terrifying conditions during operations, and emotions following return from operational theater (e.g., intense feelings of euphoria, regret, grief, anger, or disgust). Over longer periods, the failure to regulate emotional responses can lead to poor long-term performance (e.g., decision making) and health declines (e.g., PSTD), as well as disruptions to social (e.g., family, unit) function.

It has been said that war is 5 percent anger, terror, and horror, interspersed with long periods of waiting and boredom. The periods between operations may grow longer when soldiers are used in peace support missions, in which soldiers who are trained for offensive and defensive operations must engage a high degree of prolonged self-restraint. Consequently, how soldiers, and hence the military, cope with the emotional consequences of boredom is also important. For example, how can soldiers maintain a high level of alertness, attentiveness, and "situational awareness" during these periods? How can military leaders prevent troop boredom from transforming into aggression, despair, or hatred? How can soldiers be trained to discern the ethical implications of their actions in a wide variety of situations, including the periods between operations?

COGNITION AND EMOTION

A person's affective state is primarily influenced by a mostly automatic process generically labeled evaluation (Bargh and Ferguson, 2000; Barrett, 2006a; Blascovich, in press; Brendl and Higgins, 1995; Lazarus and Folkman, 1984; Tesser and Martin, 1996). Evaluation is a fast and simple form of analysis in which something is judged (often unconsciously) as "good for me" or "bad for me" in a given situation, producing some change in a person's feelings and affect. People continually and automatically evaluate situations and objects for their relevance and value (Bargh and Ferguson, 2000; but see Storbeck and Robinson, 2004): that is, whether or not properties of the situation signify something important to one's survival, well-being, and goals (Ellsworth and Scherer, 2003), leading to changes in affect. Evaluation can occur outside of awareness, can happen very rapidly, and can be independent of conscious control (for a recent review, see Moors and De Houwer, 2006).

The brain's cognitive architecture appears to have specialized modules (at least metaphorically) for the fast and efficient processing of stimuli that have evaluative consequences. For example, in perceptual search paradigms, facial displays of fear and anger produce faster identification times than do neutral faces (e.g., Pernilla, Lundqvist, Karlsson, and Ohman, 2005). Studies using the dot-probe paradigm (a laboratory technique for tracking attention) also find an attentional bias toward angry faces (e.g., Cooper and Langton, 2006).

Other threatening stimuli, such as spiders and snakes, also produce such perceptual and attentional biases (Barrett, in this volume). Mapping out the boundary conditions for such effects, along with individual differences and emotional specificity, is relevant for many military situations. For example, can soldiers be trained to use and rely on the fast perceptual processing that occurs with threatening stimuli? How can they best minimize false alarms—the perception of threat when threat does not exist? Can surveillance systems be engineered that produce the same perceptual superiority for threat detection?

Once initiated, the effects of evaluation and subsequent affective states on other cognitive processes are immediate and relatively diffuse in the cognitive system. For example, affective states not only influence how people interpret what they see, but literally what they see (Duncan and Barrett, in press). Affect can modulate processing in the visual ventral stream (the brain's object perception system) even as far back as V1, a visual area in the cortex (Stolarova, Keil, and Moratti, 2006).

People use their affective reactions as additional sources of information to make judgments, especially in uncertain conditions, in both explicit (Schwarz and Clore, 1983) and implicit ways (Bechara, Damasio, et al., 1994; Bechara, Tranel, Damasio, and Damasio, 1996, but see Dunn, Dalgleish, and Lawrence, 2006). In some instances, people misattribute their affective reactions (Payne, Cheng, Govorun, and Stewart, 2005) or give a "false alarm," and see a threat where none is present (Quigley and Barrett, 1999), sometimes with dire consequences (e.g., shooting a suspect who actually poses no threat). More research on emotion will lead to better understanding of when affect helps, and when it hinders, the accurate perception of threat and reward. Military situations are fraught with uncertainty, and understanding the role of emotion in arriving at accurate situational awareness may prove useful in optimizing decision processes.

Emotion has effects at all levels of cognitive processing; many of them are directly relevant to military contexts. For example, mild emotion sometimes facilitates memory (e.g., better recall for items associated with affect), but stronger emotions (intense fear) sometimes produce amnesia for events right before and after the eliciting event. Emotions can influence perceptual activity: for example, fearful faces enhance contrast sensitivity for visual information (Gasper and Clore, 2002). Emotions can also affect judgment: for example, induced sadness influences judgments of the steepness of a hill (Storbeck and Clore, 2005). Thus, emotions may influence soldiers' assessments of their own ability to undertake and complete missions.

Affective context can also influence behaviors: people exhibit more anger and outrage in a disgusting environment than in a benign one (Clore, Gasper, and Garvin, 2001). Affective heuristics also influence judgment and decision making. New research in a field called affective forecasting (Kermer, Driver-Linn, Wilson, and Gilbert, 2006) reveals that people often make decisions on the basis of anticipated future affect, even though such anticipations are often incorrect. Other research (e.g., Wilson, Lisle, Schooler, and Hodges, 1993) suggests that introspection about one's reasons for making a decision can reduce satisfaction with the choice. Such findings are likely to have implications for how the military makes some types of decisions and how it conducts postmission reviews.

Emotion can also have important effects on decision making. For example, Loewenstein, Read, and Baumeister (2003) have shown that discounting rates (the tendency to see near-term consequences, both costs and benefits, as worth more than identical consequences further out in the future) are steeper when the consequences have emotional connotations. Moreover, decision strategies can change toward compensatory models (i.e., careful weighting and balancing) when people have to make difficult negative emotional tradeoffs (Luce, Bettman, and Payne, 1997). Emotion can influence judgments directly: for example, one study showed that watching a murder movie influenced subjects' later judgments for punishment of perpetrators of unrelated crimes (Lerner and Goldberg, 1999). A related military application concerns postconflict behavior and understanding, such as how soldiers react to and treat captured enemy combatants and local civilians. Understanding how emotions influence moral decision making should be of interest because of the inevitability of intense emotions in these situations. Anticipated regret can also influence decision making: one study found that people reverse their preferences when they are told they will get the feedback necessary to know whether they should or should not regret the decision (Connolly and Zoolenberg, 2002). Research has also shown that emotions can also bring about self-deception (e.g., Mele, 2000) or overwhelm reason (Shiv and Fedorikhin, 1999) in making decisions. Because of the importance of decisions in military operations, research on the nature of emotional effects on decision making is of crucial importance to the U.S. military; this is a research agenda for the long term.

EMOTION AND SELF-REGULATION

The self-regulation of mood and emotion is an important topic in the study of emotion. Currently, some researchers are focusing on a few strategies for self-regulation, such as suppression and reappraisal (Gross and John, 2003); others are focusing on a wider taxonomy of strategies and behaviors that may be effective at remediating stress and negative emotions (e.g., Larsen and Prizmic, 2005). Key topics for research in the field—which are relevant to the military—include the relative efficacy of different emotion regulation strategies, the degree to which such strategies can be taught and learned, whether some strategies work better in regulating one emotion than another, and whether some individuals are better than others in regulating their emotions. This last topic is, of course, central to the concept of emotional intelligence, which is already of interest to the U.S. military.[1] The concept of emotional intelligence is hotly debated among researchers, and the military has many reasons to be interested in the resolution of this debate. If it is a viable concept, emotional intelligence could be relevant to many military problems, including: prevention and detection of PTSD and the timely return to combat duty, the selection of military recruits for specific roles on the basis of their levels of emotional intelligence, the training of soldiers to recognize emotions in themselves and others and to cope with extreme emotions, the training of leaders to manage emotions in themselves and their subordinates, and the design of training environments to simulate realistic scenarios that require emotionally adaptive skills.

EMOTION AND SOCIAL BEHAVIOR

A wide variety of social behaviors is influenced by affect. For example, the effectiveness of persuasion can be influenced by the emotional terms in which the persuasive appeal is presented: that is, what a person has to gain (positive frame) versus what the person has to lose (negative frame). Persuasion is important to the military in a number of settings, ranging from enlistment and retention to negotiation and communication with enemy combatants and civilians in the field. In addition, this line of research should also be of considerable value for psychological operations—situations in which the military attempts to influence or persuade civilians or combatants through alternatives to force (e.g., communications or propaganda).

Another important topic is the role of emotion in prejudice and stereotyping, both within the U.S. military and between U.S. military or civilian

[1] For example there was a workshop on emotional intelligence held in November 2003 by the Educational Testing Service and the U.S. Army Research Institute; see also Bar-On, Handley, and Fund (2005).

personnel and opposing forces in the field or enemy combatants under U.S. control. What are the behavioral, cultural, and sociological processes that contribute to dehumanizing effects, such as those observed at the Abu Ghraib prison? Can people be trained to resist such effects? What role does a long period of vigilance or boredom play in making soldiers susceptible to such effects or other negative consequences?

Another area of developing research concerns emotions in work settings (e.g., Weiss and Cropanzano, 1996). Several questions are relevant for military settings: What are the display rules for emotions in various military work settings? What are the effects of emotions on work performance or on attitudes toward work and the organization? What are the effects of dispositional influences, such as temperament and personality, on the likelihood of experiencing specific affective states (see, e.g., Fritz and Sonnentag, 2006)? What opportunities in the military workplace exist for the effective remediation of negative emotions? For example, when troops interact closely with local populations, as they do during low-intensity warfare, there are inevitably cases in which troops suffer casualties due to "betrayal" by someone in that population. Such events can give rise to extremely negative attitudes and prejudices regarding the entire local population and lead to unwarranted actions against innocent indigents, which, in turn, disrupts attempts to build rapport with the population. This situation poses a very serious challenge for small unit leaders, especially when troops are exposed to low-level combat for an extended period of time.

Sophisticated methods for measuring affect (as well as cognition and performance) in naturalistic settings are now available, such as computerized palm-like devices that administer experience-sampling protocols (Beal and Weiss, 2003). Such devices could facilitate the study of emotional processes in real time in military settings, especially when coupled with on-line ambulatory assessment of physiological processes (see Chapter 7).

In work settings, an important question concerns the carryover of affective events from one setting (e.g., home) to another (e.g., work) and vice versa (Demerouti, Bakker, and Bulters, 2004; Illies et al., 2006; Sonnentag, 2003; Sonnentag and Zijlstra, 2006). The quality of a soldier's personal life (marriage, social network, community) influences important work and performance behaviors, and work outcomes influence personal life as well. Emotional carryover between the battlefield and R&R (rest and relaxation), as well as from one mission (combat) to another (peace keeping), represent important areas for investigation.

EMOTION AND LEADERSHIP

Emotion plays a role in several important aspects of leadership. One phenomenon, known as emotional contagion, refers to the spreading of an affective state from person to person in a group, such as a military unit. These effects may be negative, such as when the affect contagion concerns a disorganizing emotion such as extreme fear, or they may be positive, such as the spreading belief in a group's capability to succeed at some task. The latter contagion is known as "collective efficacy" (Bandura, 1990), which is defined as a unit's shared perception that the group is able to succeed at a given task. This phenomenon is being investigated in various athletic teams (Bandura, 1997; Feltz and Lirgg, 1998; Heuzé, Raimbault, and Fontayne, 2006), and it might be generalizable to military units with defined goals and standards for success. An important research question for the military is how a team leader might promote collective efficacy and how he or she might inhibit the effects of contagion of negative emotion.

Another leadership question concerns a component of emotional intelligence that relates to the perception of emotion in others and the ability to regulate emotion and motivation in others (Bar-On, 2004). This aspect of emotional intelligence has been understudied relative to the self-regulation of emotion, and it has important implications for leadership effectiveness in military settings (Druskat, Sala, and Mount, 2005). Measures of this aspect of emotional intelligence could be investigated with reference to important leadership criteria and, if predictive, might be very useful for selection purposes in the military. A related topic is leadership paranoia, in which leaders who are isolated may develop beliefs about their subordinates that are inaccurate.

EMOTION AND CULTURE

The topic of emotion and culture defines a large and growing research literature that holds important insights for the military. One aspect of this topic concerns how emotions are communicated from person to person and how this communication is affected when the participants are from different cultures. As one example, the Japanese culture encourages socially engaging emotions (e.g., friendly feelings, guilt), and North American culture fosters socially disengaging emotions (e.g., pride, anger) (Kitayama, Mesquita, and Karasawa, 2006). Japanese people show a tendency to experience engaging emotions more strongly than disengaging emotions, while Americans are prone to the opposite tendency. For traditional Japanese people, subjective well-being is more closely associated with the experience of positive engaging emotions (friendliness), while in North America subjective well-being is more closely associated with the experience of positive disengaging emotions (pride). Such cultural differences in the experience of and comfort with various emotional states are very important in such areas as negotiation, training, and persuasion, which are important issues for the U.S. military. In general, cultures differ in the importance attached to certain goals, which can lead in turn to different emotional reactions to the same event (Mesquita, 2001; Parkinson, Fischer, and Manstead, 2005). As the military increasingly trains and conducts missions with forces from different cultures, detailed knowledge of those cultural differences, in particular the emotional aspects of those cultures, will be important to mission success. For example, what gestures do people from a particular culture find threatening? What gestures signify respect? Are there culture-specific triggers of aggression? When negotiating with people from a given culture, do they have certain goals that differ from ours? Are there culture-specific ways of motivating people? Are there culture-specific ways of eliciting cooperation? It will take many years for scientists to determine the answers to these questions.

7

Behavioral Neurophysiology

Behavioral neurophysiology is broadly defined here as the study of the interplay between basic behavioral processes (e.g., affective, cognitive, motivational) and biological processes, including control (e.g., neural, endocrine) and operational (e.g., autonomic and somatic) ones. The field includes not only the areas and technologies of the behavioral brain sciences (e.g., affective, cognitive, perceptual, and social neuroscience) but psychoneuroendocrine and peripheral psychophysiological ones, as well. The last 25 years have seen important advances at all levels in the field, including philosophical, theoretical, and technological ones.

PHILOSOPHICAL, THEORETICAL, AND TECHNOLOGICAL ADVANCES

Philosophically, the breakdown of the ancient concept of mind/body dualism continues (see Damasio, 1994; LeDoux, 1996; Pinker, 1997). The subject matters of the behavioral and biological sciences are now regarded as interdependent rather than as necessarily independent. No longer is the scientific impetus for understanding the interplay between behavior and biology one of reductionism. Pioneering contributions such as Ader and Cohen's (1975) startling discovery that immunosuppression could be classically conditioned led others (e.g., Kiecolt-Glaser and Glaser, 1995) to begin to study how human behavior and the nervous, endocrine, and immune systems influence one another. Technologically, rapid advancements in computerized neurophysiological recording systems—such as peripheral physiological (autonomic and somatic) recording devices, endocrine assay tools, and brain imaging technologies—have allowed for the noninvasive collection, cleaning, storage, and sophisticated analysis of behavioral neurophysiological data at both central and peripheral levels. Biopsychosocial approaches and models of affect, motivation, and cognition have become firmly established in scientific theory.

These advances have initiated a paradigm shift, integrating behavioral and neurophysiological research approaches to the understanding of human behavior. The advantages of biopsychosocial approaches to classic issues in the behavioral, biological, and biomedical sciences are not only important in terms of advancement in theory and basic understanding of the human condition, but also hold great promise for applications to military, as well as civilian, work in such areas as leadership, assessment of human performance, training, and health. This research is taking advantage of new technologies that increase the value and scope of empirical assessments of basic processes. Sophisticated tools are helping behavioral scientists, such as cognitive and social psychologists, to investigate empirically the implicit (fast, automatic) processes that underlie human behavior, such as social perception, evaluation, and decision making. More broadly, these tools are leading to the development of more powerful, comprehensive, and integrated theories that account for the interaction among implicit and explicit (effortful, deliberate) processes in ways that were not possible even as recently as a decade or two ago.

Importantly, many neurophysiological technologies make possible online, continuous, and covert assessments that provide rich databases for theoretical analyses. These technologies do not necessarily constrain or interfere with the thoughts and, often, even the overt behaviors of research participants. They include technologies that permit advanced noninvasive measurement of autonomic processes (e.g., impedance cardiography, continuous blood pressure monitoring) that are associated with potentially threatening performance situations; somatic assessments (e.g., facial electromyography and facial video tracking) that are associated with the experience and expression of affect and emotion; endocrine analyses (e.g., cortisol and cytokines assays) that are associated with stress-related health problems; and measures of brain electrophysiology (e.g., electroencephalography) and imaging (e.g., functional magnetic resonance imaging [fMRI] and positron emission tomography [PET]) that are associated with the full spectrum of psychological processes (e.g., sensation, perception, memory, affect, and motor behaviors). Among the most practical of these techniques are those that do not interfere with or constrain behaviors, especially those related to individual and group performance, social interactions, and so on, topics particularly relevant to military needs. In combination with each other and with traditional techniques, such as self-report and behavioral observation, advanced neurophysiological and behavioral technologies make possible the simultaneous collection of affective, motivational, cognitive, and behavioral data. These technologies can also be used simultaneously with other advanced technologies (e.g., immersive virtual environment technology) to create human experimental scenarios that are high in both experimental control and mundane realism. Resulting data allow for more comprehensive theories and for more generalizable or externally valid findings.

MOTIVATION AND AFFECT

Almost all areas of basic behavioral neurophysiological research have potential applied significance for the military, and several have implications for the near term, 5 to 10 years. Research should be targeted toward basic understanding of motivation, cognition, and affect. Such research should be based on extant or newly developed biopsychosocial theoretical rationales that are supported by promising data. It should be focused on high-level constructs—for example, challenge versus threat motivation, peripheral versus central attitudes, positive versus negative affect—and it should incorporate the role of individual differences. Crucial to this work is the use of validated neurophysiological markers of key theoretical constructs.

In the very near term (i.e., the next 5 years) research efforts incorporating peripheral neurophysiological (i.e., autonomic and somatic ones), neuroendocrine, and central electrophysiological (e.g., high density electroencephalographical) assessments are more likely to produce *applications* for the military than research on central neurophysiological assessments using brain imaging techniques. For example, peripheral physiological measures can be used to monitor when a soldier moves from being challenged by an activity to being on the verge of being overwhelmed by task demands. Such measures could be useful for the selection of personnel, for the monitoring and calibration of training activities, and for real-time assessment of performance in the field.

The committee's attention to inclusion of research on motivation and affect is not based on a judgment that it has more value than cognitive and perceptual research, but on what the committee perceives as a historical imbalance in the military's research portfolio. Although the military's research focus understandably mirrors historical trends in psychology, the focus now needs to reflect the dominant view that any understanding of cognitive processes unaccompanied by a simultaneous understanding of motivational and affective processes lacks relevance to behavior in real-world settings, particularly ones that are threatening, stressful, or involve social interaction.

Recent research has developed strong biopsychosocial models of motivation (e.g., Blascovich and Mendes, 2000; Dickerson and Kemeny, 2004) and affect (e.g., Barrett, 2006b) supported by empirical data that take into account individual and dispositional differences. Many of these theories have incorporated validated neurophysiological and neuroendocrine markers of superordinate motivational and affective constructs.

The committee's judgment that the military's basic behavioral and social science agencies should focus on research that incorporates peripheral neurophysiological, neuroendocrine, and central electrophysiological measures in the relative near term is based on several considerations. None of them reflects negatively on the importance and long-term value of brain imaging techniques. However, if brain imaging techniques are likely to be applicable to military needs, highly specific and sensitive theory-based brain imaging markers of affective and motivational constructs, in addition to cognitive ones, must be developed and validated, as Heatherton, Krendl, and Wagner (in this volume) point out. Such markers are not likely to be developed and validated using brain imaging technology (i.e., fMRI, PET, etc.) for at least 10-20 years, nor are the markers likely to be practical and cost-effective to use in field settings. Second, the military budget for basic behavioral and social science research, even if it is increased as the committee recommends, cannot support the expensive technology necessary for brain imaging without significantly reducing support for other important aspects of its research portfolio. Third, other military research organizations, including the Army Research Laboratory and DARPA (see Begley, 2006), are beginning to undertake brain imaging-based research.

PREDICTING PERFORMANCE

As an intensively human organization whose decisions are fraught with danger and serious geopolitical consequences, the military has a paramount stake in the quality of human performance, whether it occurs on or near a battlefield, through remote control of armaments (e.g., drones) and other battle relevant technology, or in support of military operations and readiness. Hence, it is not surprising that basic and applied military research in the behavioral and social sciences has focused on personnel in general and on personnel selection, training, leadership, and organization more particularly.

Prediction of future performance is critical not only for the recruitment of military personnel, but also for the assignment of personnel to specific performance specialties and leadership positions, as well as for the design and evaluation of training programs and organizational structures. Traditionally, research to develop predictors of military-relevant human performance has used personal and observational methods in which data are gathered through self-reports or through overt behavioral recordings during training and assessment tasks. The precision and value of the predictions based on those methods can very likely be increased by using neurophysiological methods to complement the traditional methods.

In general, neurophysiological methods (e.g., peripheral autonomic, peripheral somatic, and central electrophysiological ones) often permit data collection that is covert, continuous, and on-line. In comparison with subjective self-report and observational behavioral data, neurophysiological data are generally not affected by the individuals being studied and/or the potential biases of their observers. Neurophysiological data also can be continuously recorded, thereby permitting both increased reliability and the assessments of changes over very short or very long time periods. Finally, human neurophysiological data can be recorded and analyzed on-line (even remotely) simultaneously with performance and environmental data, with minimal or no interference and without interrupting task performance.

Several areas of behavioral neurophysiological research can translate in the relative near term to military application and use. These include, for example, somatic indexes of prejudice (e.g., Vanman, Saltz, Nathan, and Warren, 2004), endocrine markers of affect and emotion (e.g., Dickerson and Kemeny, 2004), electrodermal markers of facial memory (e.g., Tranel and Damasio, 1985), cognitive processing load (e.g., Beatty and Lucero-Wagoner, 2000), and cardiovascular markers of motivation.

Expanding on the latter as a more detailed illustration, there are theoretically based, well-validated peripheral physiological markers of motivational states that are predictive of human performance on tasks pertinent to the military. For example, over the last decade or so, research has distinguished between two types of approach-avoidance motivation: challenge and threat. Research has shown that when a person evaluates situational and task demands (consciously or unconsciously), as well as the availability of individual resources (both before and during the performance of goal-relevant tasks), the evaluation is marked by distinctive patterns of multiple cardiovascular responses (markers) over time. People who have the individual resources to meet the performance demands of a potentially threatening situation are termed "challenged." They exhibit increases in heart rate and ventricular contractility coupled with decreases in total peripheral resistance and increases in cardiac output. Those who do not have the individual resources to meet performance demands are termed "threatened." They exhibit similar increases in heart rate and ventricular contractility, but these are accompanied by little change or even increases in total peripheral resistance and decreases in cardiac output (for reviews, see Blascovich and Mendes, 2000; Blascovich, in press). Such responses can be recorded using physiological recording equipment that allows for both laboratory and field-based research.

Importantly, these markers can and have been used to predict future human performance on both metabolically demanding tasks (Blascovich, Seery, Mugridge, Norris, and Weisbuch, 2004) and nonmetabolically demanding tasks (Seery, Weisbuch-Remington, Hetenyi, Moore, and Blascovich, 2005). Generally, performance is superior when individuals are challenged rather than threatened, although threat does appear to increase performance on vigilance tasks (Hunter, 2001). Moreover, the threat pattern of cardiovascular responses is indicative of pathophysiological mechanisms leading to hypertension or cardiovascular disease or both (see Manuck, Kamarck, Kasprowicz, and Waldstein, 1993).

Research directed toward neurophysiologically assessing challenge or threat before and during performance training could use the measurement of individual differences to provide an important tool for personnel selection and training, both for leadership and other tasks. Furthermore, research on the plethora of external (i.e., nontask-specific) factors that probably influence challenge or threat motivation can help in the design of training programs themselves. Finally, the monitoring of individuals' challenge or threat physiological states while in the field can provide important on-line information for commanders, including not only motivational state and performance, but also indicators of acute cardiovascular pathology.

The above is but one example of the potential utility of behavioral neurophysiological methods. However, the principles embodied in the example (i.e., established theoretical framework; validated neurophysiological markers of theoretical constructs; the covert, continuous, and on-line nature of these markers; and their applicability in terms of prediction of performance) are ones that can be applied to behavioral neurophysiological approaches to many important military tasks and problems.

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PART II

PAPERS

Culture and Negotiations

Michele J. Gelfand

Social conflict—over resources, ideas, and interests—among people who are interdependent is ubiquitous. Understanding, predicting, and managing conflict are arguably among the most important challenges facing humans. Fortunately, over the last several decades, scholars across numerous disciplines—including economics, communication, social psychology, organizational behavior, and political science—have advanced important insights on the use of *negotiation* as one way to deal with social conflict (Pruitt and Carnevale, 1993). Research has made progress in understanding basic psychological processes in negotiation (e.g., cognition, motivation, and emotion), basic social processes in negotiation (e.g., communication, power and influence), and the effects of the social context (e.g., relationships, teams, technology) on negotiation dynamics. Arguably, few areas have developed as rapidly, and with as much depth and breadth, as negotiation (Kramer and Messick, 1995).

Despite remarkable progress in negotiation research, however, there has been little attention to understanding the *cultural context* of negotiation. Historically, much of the knowledge of negotiation and conflict management has been generated in the United States and other Western cultures, which represent roughly 30 percent of humankind (Triandis, 1994). Integrating culture in negotiation research is critical for the science of negotiation, which must capture variation outside of the borders in which it thrives. Culture and negotiation research is also critical for practice. In today's global marketplace, negotiations occur across, as well as within, cultural borders. Cultural knowledge in negotiation is critical for helping to prepare managers, military personnel, diplomats, and even travelers to negotiate effectively across different cultural contexts.

This paper reviews key findings in the area of culture and negotiation, broadly defined as conditions under which individuals have to manage their interdependence (Walton and McKersie, 1965). The review is mainly delimited to social-psychological research on culture and negotiation that has been published in the last decade; see Imai and Gelfand (in press) for an interdisciplinary review of culture and negotiation research. In what follows, I first review research that has examined culture in the context of *deal-making* negotiations or situations in which parties are seeking to form or manage an economic or social relationship. Next, I review research on culture as it relates to *disputing,* or conflict situations in which there has been a rejected claim, and relationships have become highly distressed (Brett, 2001). In each area, I discuss key findings and new promising research directions. In the final section, I highlight some additional research gaps and methodological challenges that warrant attention in future research.

CULTURE AND DEAL-MAKING NEGOTIATIONS

Following similar distinctions in mainstream negotiation research, cross-cultural research on negotiation has examined negotiator cognition, communication processes, and the role of the social context in negotiations across different national cultures.

Culture and Negotiator Cognition

Drawing heavily on behavioral decision theory, research in the United States has demonstrated that negotiators are susceptible to numerous judgment biases that interfere with the development of high-quality negotiation agreements. For example, negotiators are subject to framing, overconfidence, anchoring, availability, self-serving biases, reactive devaluation, fundamental attribution errors, among other biases, many of which lead to competitive processes and suboptimum agreements (see Thompson, Neale, and Sinaceur, 2004, for a review). Although such biases and their consequences have been consistently documented, the evidence comes almost exclusively from studies in the United States and other Western cultures. This finding naturally raises the question of cultural generalizability: Are the biases documented thus far merely local habits—characteristics Western or "individualistic" negotiators—rather than invariant, fundamental aspects of human nature? Has negotiation research overlooked other biases that are more prominent in other cultural settings?

Research on culture and negotiation has begun to address these questions and has found that there is systematic variability in negotiator cognition across cultures. For example, Gelfand, Nishii, Holcombe, Dyer, Ohbuchi et al. (2001) illustrated that culture influences cognitive representations of conflicts (or conflict frames), and that *identical* conflict episodes can be perceived differently across cultures. Using multidimensional scaling, they found that Americans perceived conflicts to be concerned with individual rights and autonomy, whereas Japanese perceived the same conflicts to be concerned with violations of duties and obligations (*giri violations*). Japanese students also perceived conflicts to be largely about compromise (having mutual blame), whereas U.S. students perceived the same conflicts to be more about winning (with one party to blame). Analyses of newspaper accounts of conflicts in the United States and Japan are also consistent with these findings. These findings empirically illustrated that the same conflicts may be perceived quite differently across cultures. From a practical point of view, Gelfand et al. (2001) concluded that in intercultural situations, metalevel conflicts—those that arise from very different definitions of the conflict itself—may make it especially difficult to come to agreements.

Several cross-cultural studies have also examined whether negotiators' judgment biases, which have been consistently found in the West, are found in non-Western cultures. For example, the "fixed-pie bias" occurs when negotiators falsely assume that there is no room for integrative bargaining (i.e., that counterparts' interests are diametrically opposed to their own) (Thompson and Hastie, 1990). In particular, this bias occurs when negotiations are framed as a game with a winner and loser, like sports, as opposed to a collaborative undertaking, like joint problem solving (Pinkley, 1990). Indeed, this bias is persistent and difficult to change. Pinkley and Northcraft (1994) found that U.S. negotiators apply a win/lose frame even after they have been provided full information that shows that the interests of the parties are not diametrically opposed. In a cross-cultural study of fixed-pie biases, Gelfand and Christakopoulou (1999) argued that the readiness with which U.S. negotiators apply fixed-pie perspectives may be reflective of the emphasis on win-lose competitions (and sports metaphors) that are emphasized in U.S. culture. They found that U.S. negotiators exhibited more fixed-pie biases (i.e., were less accurate in reporting the priorities of their counterparts) than Greeks in intercultural negotiations, even after the same priority information was exchanged within dyads. Yet the Americans, interestingly, were more (over)confident that they understood their counterparts' interests than the Greeks.

Similar results were found with respect to egocentrism, or self-serving perceptions, in negotiation. Research in mainstream negotiation has illustrated that negotiators tend to view their own behaviors as more fair than others (Thompson and Loewenstein, 1992), which leads to more aggressive behavior, less concessions, and ultimately less positive outcomes (Babcock and Loewenstein, 1997). Gelfand, Higgins, Raver, Nishii, Dominguez et al.

(2002) theorized that egocentrism in negotiation would be consistent with ideals in individualistic cultures, in which the self is served by focusing on one's positive attributes in order to "stand out" and be better than others, but it would be disruptive to ideals in collectivistic cultures, in which the self is served by focusing on one's negative characteristics in order to "blend in" and maintain interdependence with others (Heine, Lehman, Markus, and Kitayama, 1999). Four studies in the United States and Japan supported this notion (see also Wade-Benzoni et al., 2002, for similar findings). Others have shown that people use different criteria in forming fairness judgments in negotiation across cultures. For example, Buchan, Croson, and Johnson (2004) found that U.S. negotiators based their fairness assessments on their BATNAs (best alternative to negotiated agreements), whereas Japanese based their fairness assessments on their obligations to others. In all, what is perceived as "fair" in negotiations varies across cultures.

Another set of negotiation errors that result from bias in social judgment are misattributions of traits to one's counterpart. Negotiators often have illusory impressions of each other's characteristics (e.g., inflexibility, greed) because they fail to weigh situational influences in understanding each other's behavior. Moreover, dispositionist attributional errors lead negotiators to interpret disagreement as being caused by personality traits, and not the situation, which leads to competitive processes (Morris, Larrick, and Su, 1999). Like other biases reviewed here, however, there is evidence that this bias is subject to cultural variability. The dispositionist bias, so robust among U.S. participants that it was designated the "fundamental attribution error," is less dramatic among East Asians for whom the concept of the individual person as agentic is less absolute. The default conceptions of agency applied by East Asians enable them to understand the situationally contingent nature of an individual's behavior (Morris and Peng, 1994). In negotiation contexts, research has indeed illustrated that Americans tend to make more internal attributions to their counterparts' behavior than negotiators in other cultures, such as Korea and Hong Kong (Morris et al., 2004; Valenzuela, Srivastava, and Lee, 2005). More generally, these results indicate that fixed-pie, self-serving, and dispositional attributions may not be universal biases in negotiation; rather, those biases may reflect different cultural ideals that negotiators have internalized.

Far less attention, however, has been given to judgment biases that might be more prevalent in negotiations in other cultures. For example, it seems reasonable to expect that group-serving biases and group fixed-pie biases, and subsequent hypercompetition between groups might be more prevalent in negotiations in collectivistic cultures. Similarly, attributions of group traits to dispositions, and subsequent misattributions and competition, might be more prevalent in collectivistic cultures. Some initial support for this notion can be found in Menon, Morris, Chiu, and Hong (1999), who found that Asians make different attribution errors than Americans when the event being explained is an act by a group or organization. In this context, Asians exhibit a stronger dispositionist bias than do Americans. Nevertheless, there is a dearth of culture and negotiation research that has examined contexts in which competitive judgment biases become acute in other cultures; such work should be a priority in future research.

Culture and Negotiation Processes

Moving beyond the individual level of analysis, a number of studies have examined the dynamics of how parties communicate and sequence their actions when negotiating and how this varies across cultures. A key finding is that in low-context, individualistic cultures such as the United States, negotiators tend to share information directly (e.g., through direct questions about their preferences and priorities). By contrast, in high-context, collectivistic cultures such as Japan, Russia, Hong Kong, and Brazil, negotiators tend to share information indirectly (e.g., through the patterns of their offers) (Adair, Brett, Lempereur, Okumura, Shikhirev, Tinsley, and Lytle, 2004; Adair, Okumura, and Brett, 2001). Moreover, the path to obtaining joint gains in negotiation is culturally contingent. For example, U.S. negotiators achieve higher joint gains when they share information directly, whereas Japanese negotiators achieve higher joint gains when they share information indirectly (Adair et al., 2001).

Communication sequences are also affected by culture. Negotiators from collectivistic cultures use more flexible complementary sequences and are better able to use direct and indirect forms of information exchange than are negotiators from individualistic cultures. In effect, collectivistic negotiators can master both direct and indirect information sharing (i.e., understanding both the meaning of words and the meaning of contexts), whereas individualistic negotiators are primarily skilled in direct information sharing (Adair et al., 2001; Adair and Brett, 2005). Apart from these studies on culture and information exchange, surprisingly very little cross-cultural research has been done on other negotiation processes, such as persuasion. Emotional appeals are theorized to be more common in collectivistic cultures, while rational appeals are theorized to be more common in individualistic cultures (Gelfand and Dyer, 2000). Future research needs to systematically examine cultural differences in persuasion processes in negotiation given this process is so central in negotiation.

The discussion thus far has focused on intracultural comparisons of negotiation processes. Much less attention has been given to the dynamics of *intercultural* negotiations. What evidence does exist, however, suggests that there are a variety of challenges that negotiators face in intercultural negotiations. Graham (1985) found that intercultural dyads (American-Japanese) used fewer problem-solving and cooperative tactics than intracultural dyads (American-American; Japanese-Japanese). Similarly, Natlandsmyr and Rognes (1995) found that intercultural groups of Mexicans and Norwegians achieved lower profits than intracultural groups of Norwegians. More recently, Brett and Okumura (1998) found that joint gains were lower in intercultural negotiations between U.S. and Japanese negotiators than in intracultural negotiations in both cultural groups. The outcomes resulted in part from less accuracy in understanding of others' priorities, and conflicting styles of information exchange in intercultural negotiations (Adair et al., 2001).

From a cognitive perspective, intercultural negotiations may also be more challenging because it takes much longer for negotiators to develop a shared understanding of the task. Gelfand and McCusker (2002) argued that different metaphoric mappings of negotiation (e.g., sports in the United States and the *ie* ["household"] metaphor in Japan) create different goals, scripts, and feelings in negotiation in intercultural contexts, making it difficult to organize social action (Weick, 1969) and arrive at a common understanding of the task. In a laboratory simulation, Gelfand, Nishii, Godfrey, and Raver (2003) found that metaphoric similarity in negotiation (i.e., agreement on the domain to which negotiation was mapped) was indeed an important predictor of joint gain. They suggested that in intercultural negotiations, negotiators need to "negotiate the negotiation"—or come to a common metaphor about the task—prior to negotiating. Others have theorized that cultural incongruence in negotiator scripts leads to high levels of negative affect (George, Jones, and Gonzalez, 1998; Kumar, 1999). Similarly, research suggests that conflicting goals might be a problem in intercultural negotiations. For example, Cai (1998) found that U.S. negotiators focused more on achieving short-term, instrumental goals, whereas Taiwanese focused on long-term, global goals.

Clearly, there are hurdles that need to be managed in intercultural negotiations. Yet there is a dearth of research on the personal factors (personality, intelligence) and situational factors (e.g., training) that help negotiators to overcome culture biases and misunderstandings in intercultural negotiations. One promising approach is to select or train negotiators with "cultural intelligence (CQ)." Cultural intelligence refers to a "person's capability for successful adaptation to new cultural settings" (Earley and Ang, 2003, p. 9). It is conceptualized as a four-faceted construct: (1) metacognitive CQ—an individual's cultural mindfulness in adapting to a new culture, involving such skills as planning how to learn the new culture, monitoring one's own culture-specific assumptions, and evaluating one's progress of comprehending the new culture; (2) cognitive CQ—an individual's specific knowledge about the new culture; (3) motivational CQ—an individual's self-efficacy and persistence in adapting to the new culture; and (4) behavioral CQ—an individual's repertoire of verbal and nonverbal behaviors necessary to adapt to a new culture.

Imai and Gelfand (2006) recently examined the role of CQ, among other personality and intelligence constructs, in intercultural negotiations. They found that dyad-level CQ measured a week prior to negotiations predicted the extent to which negotiators reciprocated behavioral sequences, which in turn, predicted joint profit. For example, high CQ dyads engaged in sequencing of integrative information and cooperative behaviors more frequently than low CQ dyads. In effect, when dyad CQ was high, negotiators were able to gain a shared understanding of the negotiation as a cooperative, problem-solving activity, allowing the negotiators to create mutually beneficial outcomes. CQ also predicted processes and outcomes over and above other personality constructs (i.e., openness, extraversion), other forms of intelligence (e.g., IQ, emotional intelligence), and above international travel and living experience. Interestingly, the minimum CQ score in the dyad was enough to predict behavioral sequences, showing that it takes only one, not two high-CQ negotiators in order to increase beneficial outcomes. Furthermore, at the individual level, Americans with high CQ were found to engage in more culturally non-normative, indirect negotiation behaviors. I return to the importance of understanding additional factors that facilitate intercultural negotiation effectiveness in the last part of this paper.

Role of Social Context

Mainstream research in negotiation has long recognized that social contextual factors such as relationships, roles, teams, and constituencies have important effects on negotiation processes and outcomes (Kramer and Messick, 1995). By contrast, research on cross-cultural negotiation has tended to focus almost exclusively on dyadic negotiations and has only recently started to take this contextual complexity into account. What research has been done demonstrates that negotiation dynamics can change considerably in different cultures depending on nature of the social context. For example, research has shown that the nature of the relationship between individuals is a critical determinant of negotiations in collectivistic cultures. Chan (1992) found that negotiators in collectivistic cultures (e.g., Hong Kong) were much more attentive to the nature of the relationship between themselves and their negotiation counterparts than negotiators in individualistic cultures (e.g., the United States). Collectivists were much more competitive with strangers and much more cooperative with friends; individualists did not differentiate between strangers and friends as much. Consistent with this research, Probst, Carnevale, and Triandis (1999) found that collectivists were much more competitive in outgroup and intergroup negotiations (see also Chen and Li, 2005). Across eight nations, Triandis, Carnevale et al. (2001) also found that, compared to people in individualist cultures, people in collectivistic cultures were much more likely to endorse using deception in negotiations with outgroup negotiators.

Research has also shown that the effects of constituents on negotiations vary across cultures. Gelfand and Realo (1999) found that individualists react much differently to accountability pressures from their constituents. Individualists assume that their constituencies want them to be competitive (Benton and Druckman, 1973; Gruder, 1971), and not surprisingly, accountability activated competitive construals and behaviors and resulted in lower negotiation outcomes for individualistic samples than for other samples. By contrast, among collectivists, accountability activated cooperative construals and behaviors and resulted in higher negotiation outcomes. These effects were reversed in unaccountable negotiations, when, in effect, negotiators were released from normative pressures to do what was expected. In unaccountable conditions, collectivists were more competitive and achieved lower negotiation outcomes than individualists, who were more cooperative and achieved higher negotiation outcomes. These results indicate that the same "objective" condition (e.g., accountability) can produce very different dynamics in negotiations in different cultures.

Surprisingly, there has been very little research on team negotiations in different cultures. A recent study by Gelfand, Brett, Imai, Tsai, and Huang (2006) compared teams and dyadic negotiations in the United States and Taiwan. Consistent with previous research (Thompson, Peterson, and Brodt, 1996), they found that teams in individualistic cultures outperform solos when making deals. By contrast, teams far underperformed solos in Taiwan. These results suggest a number of questions that are ripe for future research. For example, research is needed on how culture affects team processes and how these processes carry over to between-group negotiations (see, e.g., Keenan and Carnevale, 1989). Research is also needed on how culture influences decision rules in team negotiations. Collectivists are anecdotally thought to spend much more time trying to build a consensus within teams than individualists (Gelfand and Cai, 2004), suggesting that within-team negotiations might take much more time among the former than the latter. In intercultural team negotiation contexts, this added layer of cultural complexity could add to frustration among teams from individualistic cultures who have different expectations regarding decision rules in teams. Overall, the research to date suggests that the nature of the social context is a key priority in cross-cultural negotiation research, a point to which I return in the conclusion.

CULTURE AND DISPUTING

Disputes are a universal phenomenon, yet the antecedents of disputes and the ways in which they are resolved can vary dramatically across cultures. Shteynberg, Gelfand, and Kim (2006) argued that disputes likely emerge when cultural focal concerns are violated. They found that violations to rights were perceived to be much more harmful and caused more anger and intentions to seek revenge in the United States than in Korea, whereas violations to face were much more harmful and caused more shame and intentions to seek revenge in Korea than in the United States. Gelfand, Bell, and Shteynberg (2005) also argued that shame is more contagious in collectivistic cultures, causing disputes between individuals to carry over to unrelated parties. They found that vicarious shame (i.e., witnessing another person' experiencing shame) was a much more powerful motivator of revenge intentions among people who endorsed collectivistic values as compared with people who endorsed individualistic values. Related research in the United States on the culture of honor (Cohen, 1996; Cohen and Nisbett, 1997) has shown that honor-related affront induces anger, and even increases cortisol and testosterone, particularly among men in the U.S. South, an important finding for the U.S. military, which draws many recruits and officers from that region.

Despite this handful of studies, there has been a dearth of attention to the types of events that cause perceptions of harm in different national cultures. To the extent that culture affects the very definition of what is harmful, it is possible that in intercultural contexts, one party may view that a serious violation has occurred, whereas another party may not even appreciate the possibility of psychological harm. Understanding cultural triggers to conflict could be helpful for developing training programs on preventing cross-cultural conflict.

Other research has focused on preferred strategies to resolve disputes across cultures. Kozan (1997) differentiated three models of conflict resolution: a direct confrontational model, a regulative model, and a harmony model. Consistent with a direct, confrontational model, people in individualistic nations prefer to resolve conflicts using their own expertise and training (Smith, Dugan, Peterson, and Leung, 1998), prefer forcing conflict resolution styles (Holt and DeVore, 2005), and tend to focus on integrating interests (Tinsley, 1998, 2001). Germans endorse a regulative model (e.g., relying on existing rules), in part due to values for explicit contracting (Tinsley 1998, 2001). By contrast, people in collectivistic cultures prefer styles of avoidance and withdrawal (Holt and DeVore, 2005), which has been explained in part by differential endorsement of the interdependent self and concerns for others' face (Oetzel et al., 2001), conservation values (i.e., Morris et al., 1998), or expectations that avoidance leads to better outcomes (Friedman, Chi, and Liu, 2006).

The situational context also affects preferences for conflict resolution styles. For example, avoidance is particularly preferred in collectivistic cultures in disputes of high intensity (Leung, 1997), with in-group members (Chan and Goto, 2003; Pearson and Stephan, 1998), and with superiors (Brew and Cairns, 2004; Friedman et al., 2006). However, it is also important to note that avoidance in Asian cultures does not necessarily have the same meaning as it does in individualistic cultures (Brett and Gelfand, 2006). Whereas avoidance reflects a lack of concern for others (as proposed in the dual concern model) and is viewed negatively in the West, it can reflect a concern for others and is viewed positively in collectivistic cultures (Gabrielidis, Stephan, Ybarra, Pearson, and Villareal, 1997). For example, Tsjovold and Sun (2002) showed that in collectivistic cultures, avoidance can include passive, nonconfrontational strategies, as well as highly proactive strategies that often involve working through third parties.

Surprisingly, there is little research on the types of strategies that help mitigate conflict in intercultural disputes. For example, research is needed on the types of accounts (e.g., apologies, excuses, justifications) that might mitigate intercultural conflicts. The effectiveness of apologies in mitigating conflict is well documented: apologies have been shown to decrease feelings of aggression (Ohbuchi, Kameda, and Agarie, 1989), repair trust (Kim, Ferrin, Cooper, and Dirks, 2004), and foster forgiveness (McCullough, Worthington, and Rachal, 1997). Yet there has been a lack of systematic attention to how apologies are given, processed, and received in different cultures. In one of the most prominent texts on apology, Tavuchis (1991) notes this omission: "A more comprehensive account of this phenomenon [apology] . . . would entail its investigation in different cultural contexts and historical settings. This remains to be done" (p. viii). This area of research also has important practical implications. For example, how should President Bush explain the Abu Ghraib situation to Iraqi civilians, and how do such explanations affect the likelihood of conflict escalation or of forgiveness? Do situations that "demand" apologies in Western cultures call for the same or dramatically different explanations in other cultures? Do apologies need to contain different elements (e.g., compensation, expressions of sympathy and remorse, accepting moral responsibility) in different cultures in order to foster forgiveness?

OTHER GAPS AND PROMISING RESEARCH DIRECTIONS

Cross-cultural research in negotiation is arguably still in its infancy, and there is much territory that has yet to be explored. In this section I elaborate on some additional promising research areas and also discuss important methodological issues that warrant consideration in future cross-cultural negotiation research.

Predicting Success in Intercultural Negotiations

As noted above, much more research is needed on the ways in which culture clashes become manifest in intercultural negotiations, and how they can be overcome. Future research should continue to examine cultural intelligence, among other personality factors, as well as compare the effectiveness of different types of cultural training and their impact on intercultural negotiation effectiveness. It is unclear, for example, as to which dimensions of CQ are most critical for intercultural negotiation effectiveness and how to best train people to increase their ability to negotiate effectively in intercultural contexts. It would also be useful to integrate research on CQ with negotiation research more generally. For example, does CQ buffer individuals from the cognitive biases found in the literature? Are high-CQ Americans less prone to fixed-pie biases, dispositional attributions, and self-serving assessments of fairness? How does CQ affect strictly distributive tasks? Do high-CQ individuals take advantage of their extensive cultural knowledge and behavioral flexibility to deceive low-CQ individuals? Or does having a high CQ necessarily imply a certain cooperative, global-minded value system that serves as a disadvantage in distributive tasks? Similarly, how does CQ affect disputing and intergroup conflict contexts? Are high-CQ individuals less prone to in-group biases and escalation? In addressing these questions, it is critical that new measures of cultural intelligence be developed that do not rely exclusively on self-reports.

Culture and Emotions

There is a dearth of attention to how emotions are experienced and expressed in negotiations in different cultures, and the implications these differences have for intercultural negotiations. Although Ekman's (1989) early pioneering work illustrated that the expressions used to convey emotions tend to be universal, there is ample evidence for cultural differences in *display* rules, or ways in which emotions are suppressed, attenuated, or enhanced. For example, dating back to Benedict's ethnographic observations (1946), Asians have been characterized as being "expressionless." More recent research has shown that it is normative in Japanese contexts to mask both positive emotions (Matsumoto, Takeuchi, Kouznetsova, and Krupp, 1998) and negative emotions (Friesen, 1972; Lebra, 1976). Others have shown that people in different cultures focus on different parts of the face to decode others' emotions. For example, Yuki, Maddux, and Masuda (2006) showed that because Asians normally subdue their emotional expressions, they tend to focus on people's eyes, the most uncontrollable part of the face in terms of displaying emotion, in interpreting others' emotions. In contrast, they found that Americans, who normally express their emotions, tend to focus on people's mouths, the most expressive part of the facial expression in interpreting others' emotions.

With such cultural variation in emotional display rules, it stands to reason that in intercultural settings, negotiators' mismatched ways of expressing and interpreting emotion likely create faulty attributions and communication breakdowns. Indeed, Triandis (1994) anecdotally argued that one of the major problems in the intercultural negotiation between Tariq Aziz and James Baker in the early 1990s was that Baker's emotional style (e.g., being very low key and not raising his voice) was misattributed by Aziz to mean that the United States was not serious about the consequences if Iraq did not withdraw its troops from Kuwait. This hypothesis is consistent with recent work that suggests that people are better able to decode emotional expressions by members of their own cultural group than those of other groups (e.g., Elfenbein and Ambady, 2002a, 2002b). Yet little research has been done on this phenomenon in intercultural negotiation contexts. Critical questions regarding culture and emotional decoding in negotiation need to be addressed. For example, how accurate are individuals at decoding others' emotions in intercultural negotiations? Which emotional displays cause the most difficulty in intercultural negotiations? Does emotional ambiguity hinder intercultural negotiation effectiveness? If so, what is the best way to train people to be more accurate in decoding in intercultural negotiations?

Culture and Social Context in Negotiation

As noted above, much research on culture and negotiation has focused on dyadic negotiations without regard to the broader context in which negotiations are embedded. Future research needs to examine negotiation processes and outcomes in both deal-making and disputing contexts as they are influenced by roles, teams, constituents, the communication form (e.g., email or face-to-face), third parties, and the like. As well, the temporal context of negotiations deserves much more attention in cross-cultural negotiation research. For example, how does trust develop in negotiations, and how might this differ across cultures? Are there cross-cultural differences in the initial stages of negotiation that influence early levels of trust, which provide a foundation for building trust in later stages? One would suspect, for example, that early relationship development is particularly important for trust-building in collectivistic cultures to signal good will. This strategy, however, might be dismissed as not task related and therefore inefficient in individualistic cultures (Sanchez-Burks, Nisbett, and Ybarra, 2000).

Other critical questions regarding culture, time, and negotiation remain largely unexplored. For example, are there cultural differences in the preferred timing of concessions in negotiation (cf. Hendon, Roy, and Ahmed, 2003)? Are there cultural differences in time-based cognitive biases that interfere with intercultural negotiations? For example, do negotiators from cultures that emphasize a short-term time horizon fail to take into account the future consequences of their actions? How does culture influence the perception of deadlines in negotiation? Integrating theories of culture, time, and negotiation will be a fruitful area for future research.

Enlarging the Methodological Toolbox

As with mainstream negotiation research, cross-cultural research on negotiation is often based on laboratory experimentation that is highly decontextualized. Laboratory research has a number of notable strengths, including its high degree of control and ability to draw causal inferences. Yet when doing research cross-culturally, the use of decontextualized roles plays presents a number of problems (Gelfand, Raver, and Ehrhart, 2002). At a minimum, future research needs to develop cross-cultural simulations that have a have a high degree of relevance in other cultural contexts.

Investment is also needed in the development of cross-culturally relevant coding manuals that are used to assess behaviors in negotiation. For example, are there different behaviors that illustrate cooperation in non-U.S. cultural contexts? Do the same codes that are indicative of competition in one culture apply in other cultures? New measures are needed to capture dimensions of performance that may be important in negotiations in non-U.S. cultures. For example, current negotiation tasks focus almost exclusively on economic capital. Measures of relational capital (Gelfand, Major, Raver, Nishii, and O'Brien, 2006) need to be developed, validated, and used in cross-cultural negotiation research. In addition to improving the use of laboratory methods, cross-cultural negotiation research needs to draw on a much broader array of methods that allow for greater contextual complexity, such as ethnographies, field studies, archival analyses, social network analyses, etc. Full-cycle research (Chatman and Flynn, 2005), which travels back and forth between natural observation and experimentation, is sorely needed in the field of culture and negotiation.

Interdisciplinary Research Teams

Cross-cultural research on negotiation would benefit from multidisciplinary research teams that span different theoretical perspectives and methodological approaches. For example, the emerging area of social neuroscience (Heatherton, Macrae, and Kelley, 2004) and neuroeconomics

(Sanfey, Rilling, Aronson, Nystrom, and Cohen, 2003; Zak, 2004), which focuses on the use of neuroscience methods to understand human behavior, is ripe for integration with cross-cultural theory and research. Such a field, which might be referred to as *cross-cultural neuroeconomics*, would by necessity involve collaborations among cross-cultural psychologists, economists, neuroscientists, and anthropologists, among others, to work together across levels of analysis to understand cultural variation in basic processes, such as trust, reciprocity, cooperation and competition, fairness, revenge, and forgiveness.

There is currently very little research in this area, but there is some new research that shows some promise to this approach. For example, Zak and colleagues (Zak and Fakhar, in press; Zak, Kurzban, and Matzner, 2005) found that cultural differences in interpersonal trust and cooperation can be explained in part by differences in consumption of estrogen-like molecules that are linked to oxytocin. Using fMRI techniques, Zhu, Zhang, Fan, and Han (in press) measured brain activity of Western and Chinese participants and provided neuroimaging evidence that culture shapes the way the self is represented in the human brain. When judging self-relevant items, both Western and Chinese participants showed activation in the medial prefrontal cortex (MPFC). Furthermore, supporting the notion that the self is merged with close others in collectivistic cultures, they found that the MPFC was activated when judging close others among Chinese but not among Western participants. These examples aside, there is very little cross-cultural research using such techniques. The development of this field would be useful for testing the neural basis of cultural differences and for exploring fundamental processes of cognition and emotion. Logistically, however, there are a number of hurdles to the development of such a field. Neuroscience techniques, as discussed by Heatherton and his colleagues (see Heatherton et al., 2004), are not without controversy and are also very expensive. Comparing fMRIs across groups also presents problems with reliability, necessitating studies that are done at the same location. Nevertheless, integrating cultural theory with neuroscience is an exciting and important frontier.

Another promising interdisciplinary approach would involve collaborations among dynamical systems theorists and cross-cultural psychologists. The work of Coleman and his colleagues (Coleman, Vallacher, Nowak, and Ngoc, 2005; Coleman, Schneider, Adams, Everett, Gameros, Hammons et al., 2005) on a dynamical systems model of conflict conceptualizes intractable conflict as strong *attractors*—a stable form of self-organization of multiple elements of conflict systems (psychological, social, community-level factors). Yet little work has examined cultural factors that contribute to these multiple elements and that promote the stability (and intractability) of conflicts. For example, despite evidence that collectivists tend to act cooperatively in order to maintain relationships, dynamical systems theory might suggest that in intergroup or intercultural contexts, collectivists are more prone to the escalation of conflict. Many elements of dynamical systems that maintain conflict—such as contagion of collective beliefs and attitudes; norms amongst group members that serve to support the in-group and distance the outgroup; intragroup socialization; sanctioning of feelings, thoughts, behaviors, collective memory and rumination of insults and injustices inflicted by outgroups (Coleman et al., 2005)—are particularly likely to be cultivated in collectivistic cultures. Dense social ties and networks should also make it relatively easy for positive feedback loops to emerge. Research on culture and dynamical systems that examines such processes and ways to change such attractors should be a key priority in future research and would invariably involve research teams of cross-cultural psychologists and dynamical systems theorists.

Moving Beyond Hofstede

Cross-cultural research needs to broaden its focus beyond East-West comparisons and the use of Hofstede's (1980) dimensions of culture to explain all cultural differences. To date, the field has been highly restricted in its cultural scope—focusing almost exclusively on individualism versus collectivism to the neglect of other dimensions of culture. In the preface to the *Handbook of Cross-Cultural Psychology*, Segall and Kagitçibasi (1997) stated: "In case anyone failed to notice, this volume makes very clear that individualism/collectivism is currently the favorite heuristic of many cross-cultural psychologists" (p. xxvii). Likewise, Earley and Gibson (1990) remarked: "After all of the studies conducted on individualism-collectivism are reviewed, one wonders what other aspects of culture are important for understanding organizational phenomena in a cultural context" (p. 298).

The use of individualism-collectivism as a catchall dimension is a serious limitation in the field, for a single dimension of culture is clearly insufficient to capture cross-cultural variation in its entirety. Accordingly, efforts are needed to develop comprehensive theories on other dimensions of cultural variation to broaden the scope of the field. There is emerging research that has begun to map countries on other cultural dimensions—cultural fatalism (Aycan, Kanungo, Mendonca, Yu et al., 2000), cultural tightness-looseness (Gelfand, 2006; Gelfand, Nishii, and Raver, in press), cultural cynicism (Bond, Leung et al., 2004), among others— that may prove useful in understanding cultural variation in negotiation and disputing. Yet even these large-scale studies often do not include many samples from the Middle East, which is a key priority for future research. Access to samples is a key logistical hurdle, yet there are a number of international organizations (e.g., the International Association for Cross-Cultural Psychology) that can help to foster multinational research teams that include samples from the Middle East as well as other areas.

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Adult Second Language Acquisition: A Cognitive Science Perspective

Judith F. Kroll

For cognitive scientists, the idea that speaking two languages might be the natural state of cognition has only recently come to be appreciated. Although more of the world's population is bilingual than monolingual, research on language and thought has focused almost exclusively on monolingual speakers. In the past decade, perhaps due in part to the recognition of the increasing cultural and linguistic diversity within the United States, this situation has changed dramatically, and there has been a virtual explosion of research on how bilingual people and second language learners negotiate their lives in two languages. The new language science of bilingualism[1] is characterized by the convergence across the disciplines that contribute to it, including psychology, linguistics, applied linguistics and second language acquisition, and neuroscience. In the past 10 years there has been a series of new scholarly journals, books, conferences, and funding initiatives dedicated to aspects of second language use and the contexts in which it holds broader implications for society (for comprehensive reviews, see Bhatia and Ritchie, 2004; Doughty and Long, 2003; Kroll and de Groot, 2005).

In this paper I review those aspects of the recent cognitive and cognitive

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[1]Cognitive research interprets bilingualism broadly to include anyone who actively uses two languages, not only those who are early bilinguals (i.e., bilingual since early childhood) or balanced in their language use. Typically, groups are differentiated on the basis of their proficiency, relative dominance in the two languages, and context of language acquisition and use.

neuroscience research on second language acquisition and bilingualism that appear to hold promise for designing training programs for adult learners to acquire a second language. On the surface, one might approach the problem of second language learning in adults with some pessimism. A theme in research on second language learning is that it is much easier for individuals to acquire a second language in early childhood than as adults. Even successful adult learners often fail to grasp subtle grammatical distinctions in the second language and speak it with a noticeable accent (e.g., Johnson and Newport, 1989; Piske, MacKay, and Flege, 2001). A full discussion of the reasons that the age of acquisition appears to constrain second language learning is beyond the scope of this paper: for two different theoretical perspectives on the effects of the age of acquisition, see Birdsong (2005) and DeKeyser and Larson-Hall (2005).

Rather than dismiss second language learning as an unattainable task for most adults, I focus on those aspects of the learner and the learning context that appear to enable at least some adult learners to acquire functional skills in a second language. I also examine the consequences of becoming proficient in a second language, not only for the second language, but also for processing in the first language and for cognition more generally. I suggest that the recent research on bilingualism and second language learning provides evidence for a degree of plasticity in the organization of the language system that makes it feasible for adult learners to achieve some measure of success.

LANGUAGE AND COGNITION IN ADULT BILINGUALS AND SECOND LANGUAGE LEARNERS

Parallel Activity of the First and Second Languages

The observation that has perhaps most critically changed understanding of bilingual language processing is that bilinguals do not appear to be able to switch off one of their languages when using the other language. The activity of the language not in use has been documented in even highly skilled language tasks, such as reading (Dijkstra, 2005), listening (Marian and Spivey, 2003), and speaking (Kroll, Bobb, and Wodniecka, 2006). The findings from a range of studies, including those that examine performance in the native language, suggest that a bilingual person is a mental juggler. A major goal of the research on this topic has been to determine the factors that eventually control the selection of the language that the bilingual intends to use. Bilinguals do not generally use the unintended language randomly, but they are also able to code switch with others who are similarly bilingual (see, e.g., Muysken, 2000; Myers-Scotton, 2002), suggesting that both of the languages are highly accessible.

Finding evidence for parallel activity among a bilingual's two languages has a number of critical implications for second language learning. First, it shows that successful learning does not imply the development of an autonomous representation for the new language that is independent of the first language. Traditional accounts of late second language acquisition have characterized learners as initially dependent on transfer (e.g., Kroll and Stewart, 1994; MacWhinney, 1997), such that only with increasing proficiency does the second language develop sufficient automaticity to permit skilled performance. The new research suggests that there is no decline in the presence of first language activity once individuals become highly skilled in a second language. Although patterns of cross-language interaction change with increasing second language proficiency, particularly with respect to whether the translation equivalent of a word is available (e.g., Sunderman and Kroll, 2006; Talamas, Kroll, and Dufour, 1999), even highly proficient bilinguals continue to reveal the influence of their first language on the second language. That is, the second language never becomes entirely independent of the first language.

A second implication of the evidence for parallel activity of the two languages is that once individuals achieve proficiency, there are also effects of the second language on the first language. Cross-language influences on the native language have been observed for learners and proficient bilinguals at the level of lexicon (e.g., Jared and Kroll, 2001; Van Hell and Dijkstra, 2002), phonology (e.g., Sundara, Polka, and Baum, 2006), and grammar (e.g., Dussias, 2003). That the native (first) language changes in response to contact with the second language and with other second language users suggests a language system that is fundamentally permeable and open to at least some reorganization. As Grosjean (1989) once warned, a bilingual person is not two monolingual people in one. Although the degree to which each language is distinguishable from that of a monolingual person will depend on the proficiency in the second language and context of language acquisition and use, there is an interesting implication for adult learners: it is possible that only those who can tolerate the change to their native language may be able to acquire any considerable skill in a second language.

Perhaps the most critical consequence of the observation that both of a bilingual's languages are engaged in parallel is that the resulting activity appears to produce competition across the two languages that must be resolved. Although there is some debate about whether proficient bilinguals can learn to resolve cross-language competition without the need for actively inhibiting one alternative to produce the other (e.g., Costa, La Heij, and Navarrete, 2006; Finkbeiner, Gollan, and Caramazza, 2006; Green, 1998), there is agreement that proficient bilingualism requires not only linguistic knowledge, but also cognitive control. (For an illustration in the domain of bilingual word recognition for how the architecture of the lexicon might reflect a distinction between an identification system and a task schema system, see Dijkstra and Van Heuven, 2002.)

Crucially, the cognitive control that is developed in response to bilingualism appears to confer benefits in the realm of executive function. Young bilingual children are superior to their monolingual counterparts on nonlinguistic tasks that specifically reflect the ability to ignore irrelevant information (see, e.g., Bialystok, 2001; Bialystok and Codd, 1997; Bialystok and Martin, 2004). Notably, bilingual children are not superior to monolingual children on all tasks, only those that appear to require the resolution of conflict across competing alternatives. On tasks in which no conflict is present, bilinguals are similar to monolinguals. And bilingual performance is inferior to monolingual performance in the domain of vocabulary acquisition (for related evidence of processing deficits for adult bilinguals, see Gollan, Montoya, Fennema-Notestine, and Morris, 2005). Thus, the bilingual advantage appears to be quite specific to the resolution of conflicting information.

Bialystok and colleagues (e.g., Bialystok, Craik, Klein, and Viswanathan, 2004; Bialystok, Craik, and Ryan, 2006) have further shown that bilingualism appears to confer a benefit to bilinguals as they age. During normal aging, there are significant cognitive declines in executive control processes. While bilingualism does not prevent cognitive aging, it appears to offer some protection against the rate of cognitive decline. On attentional tasks that require the inhibition of irrelevant information, bilinguals appear to outperform age-matched monolinguals. The hypothesis is that a life of negotiating competition across two languages creates expertise for just those cognitive skills that are tapped by tasks that measure executive control.

Bialystok et al. (2004) demonstrated the bilingualism advantage using a very simple nonlinguistic task that has been used widely in the cognitive literature to examine attention and issues of stimulus-response compatibility. In the Simon task (Simon and Rudell, 1967), colored squares are presented on a screen and participants are told to press one of two keys for each color. In the congruent conditions, the position of the square and the position of the key are aligned (e.g., both on the right or both on the left). In the incongruent conditions, the position of the square and the position of the key conflict with each other. The usual result is that a person takes longer to press the key in the incongruent conditions, and people have increasingly more difficulty with the incongruent conditions as they age. Bialystok et al. replicated this finding and then showed that the performance of elderly bilinguals did not decline as precipitously as that of their age-matched monolingual counterparts. Although there is no direct evidence in this type of study to argue that the cross-language competition is causally responsible for the observed bilingual benefits, it is tempting to propose that such a relationship might exist from a life spent sharpening cognitive skills that function to reduce interference from one language to the other.

This summary suggests that bilinguals are experts in resolving competition across competing cognitive systems. What are the implications for adult learning of a second language? One possibility is that individuals who come to the task of language learning with strong cognitive skills on those dimensions that are most affected by bilingualism will be most likely to succeed. I next consider the empirical evidence that is available to evaluate this hypothesis.

Individual Differences in Adult Second Language Learning

Although folk wisdom suggests that some people are more talented language learners than others, there is a relatively limited research literature on individual differences that have been documented to affect second language learning (Michael and Gollan, 2005; Miyake and Friedman, 1998; Segalowitz, 1997). One of the problems facing research on this topic is that not all aspects of language processing may be sensitive to the same cognitive factors. For example, it seems clear from studies of age of acquisition that the development of the lexicon, grammar, and phonology in a second language may follow a different course. Studies of childhood overhearers who are exposed to a second language during early childhood but never become proficient speakers suggest that there are savings to the phonology but not to the grammar (e.g., Au, Knightly, Jun, and Oh, 2002; but see Pallier et al., 2003). Likewise, a recent study (Slevc and Miyake, 2006) reports a relationship between musical ability and the acquisition of a second language phonology but little relationship between musical ability and lexical or grammatical acquisition. Thus, the factors that make people sensitive to the sound structure of a new language may be distinct from those that enable them to comprehend or speak words and sentences in that language. A number of studies investigating the neurocognitive basis of second language learning have also shown that age of acquisition appears to affect sensitivity to syntax but not to semantics (see, e.g., Hahne and Friederici, 2001; Weber-Fox and Neville, 1996). Again, the implication is that the same individual differences will not affect all aspects of language processing similarly.

The brief review of research on the parallel activity of the two languages in proficient bilinguals suggests that those individuals who are able to effectively negotiate competition may be better able to tolerate the demands induced by the presence of a second language. Because the second language may also make greater demands on working memory resources (e.g., Hasegawa, Carpenter, and Just, 2002), individuals with greater memory capacity may also have an advantage in learning a second language.

The evidence on the role of working memory resources in second language learning is mixed. Some older studies have shown that working memory span is correlated with aspects of the acquisition of grammar (e.g., Harrington and Sawyer, 1992; Miyake and Friedman, 1998), but more recent studies claim that the relation between working memory and second language performance is weak (e.g., Juffs, 2004). At the level of the lexicon, there is evidence that the time to translate from one language to the other is affected by working memory resources (e.g., Kroll, Michael, Tokowicz, and Dufour, 2002) and that memory resources affect the strategies that learners adopt.

Kroll et al. (2002) found that learners with low working memory span were faster to translate words that had cognate translations (i.e., translations that are lexically identical or similar across languages) than learners with high working memory span. The results suggest that low-span learners may be more likely to exploit surface cues that are potentially unreliable and do not generalize across the full vocabulary when translations are not similar or when the surface similar is deceptive, as in the case of interlingual homographs or "false friends" (e.g., the word "room" in Dutch means cream in English). In contrast, high-span learners appear better able to derive the meaning of new words in the second language (see further below). An interesting observation in the Kroll et al. study was that all learners, regardless of their memory resources, revealed a cost to the first language in a simple word naming task relative to a group of highly proficient bilinguals. The learners were slower and more error prone to name words in the second language than the proficient speakers, but they were also slower to name words in the first language, the native language of both groups. This result obtained even when word naming was blocked by language. The observed cost suggests that second language learning may impose processing costs even on native language tasks that have been taken to be highly automatic for adults, such as naming words aloud.

In addition to research on the relation between working memory and second language processing, a number of studies suggest that measures of phonological working memory specifically correlate significantly with second language vocabulary acquisition in both laboratory (Papagno, Valentine, and Baddeley, 1991; Papagno and Vallar, 1995) and classroom settings (Cheung, 1996; Service, 1992; Service and Kohonen, 1995), with high-span learners acquiring new words in the second language more easily than learners with more limited capacity. Whether these different measures are tapping into distinct or common processes is unclear.

Few studies have investigated how the components of inhibitory control might differentially affect second language acquisition. The findings of Bialystok et al. (2004) showing that elderly bilinguals are better than age-matched monolinguals on measures of inhibitory control (such as the

Simon task) might be taken to suggest that individuals who are able to effect control on similar tasks might also be advantaged language learners. A recent study by Weiss, Gerfen, Mitchel, and Rizzo (2007) examined differences in the ability of adults to segment conflicting speech streams in artificial languages as a function of the salience of available cues and individual differences in performance on the Simon task. When the available linguistic cues were in conflict, segmentation performance was highly correlated with Simon performance, again suggesting that the ability to negotiate conflict across competing conditions is modulated by an individual's cognitive resources. Few other studies have investigated the specific effects of inhibitory control on the success of second language learning.

A theme in the recent cognitive work on inhibitory control (e.g., Friedman and Miyake, 2004) is to begin to identify the specific components associated with different inhibitory functions (e.g., suppressing prepotent responses, switching between tasks, and selective attention). This is clearly a promising direction for research on second learning: also see Abutalebi and Green (2007) for a related discussion of the neural mechanisms that might support inhibitory control in bilingual production.

CONTEXTS OF SECOND LANGUAGE LEARNING

For adults exposed only to classroom instruction, second language acquisition is typically slow and only partly successful. In contrast, learners in immersion contexts are often more successful, particularly in acquiring oral proficiency in the second language (e.g., Segalowitz and Freed, 2004; see also the introduction to a special issue of *Studies in Second Language Acquisition* on learning contexts by Collentine and Freed, 2004). An obvious feature of the immersion environment is the frequency of second language input. However, from a cognitive perspective, immersion learning may also enable learners to more effectively inhibit their first language, both because there are potentially fewer opportunities to use it and because the cues to it in the larger environment are reduced.

Kroll, Michael, and Sankaranarayanan (1998) attempted to simulate this aspect of second language learning in the lab by teaching new second language vocabulary paired with English translation equivalents or with pictures of the objects to which the concepts referred. The pictures were sometimes presented in their canonical (or usual) orientation; other times they were presented in an odd, noncanonical orientation (e.g., upside down or sideways). The idea was to provide a unique cue to the second language and simultaneously slow down access to the first language name of the object. The results showed that learners were later faster to translate second language words that were associated with noncanonical representations of objects even in the absence of the object itself, suggesting that the locus of the effect was abstract and conceptual. If this sort of learning can take place in the laboratory in a few brief sessions, then it certainly should be possible to see these benefits in the presence of the richer context available during immersion in the language and culture of another country.

Two recent studies in my laboratory explored the interaction between an immersion learning context and individual learner characteristics. In these studies, English was the native (first) language, and Spanish was the second language. In one experiment, Tokowicz, Michael, and Kroll (2004) examined the errors made by learners on a word translation task as a function of whether or not they had studied abroad and how they scored on an operation span task (Turner and Engle, 1989). Learners often make errors of omission in translation when they simply don't know the word, particularly when translating from their first to their second language. However, they occasionally make other sorts of errors as well. In this study, learners who had both high working memory span as well as immersion experience were more likely to make meaning errors than high-span learners without immersion experience or low-span learners. The result suggests that the combination of high span and immersion may encourage the development of oral proficiency. Although these high-span learners still made errors by producing translations that were only approximate, it may very well be a critical step towards increased second language skill.

In a second study (Linck, Kroll, and Sunderman, 2007), we investigated language processing performance by learners of Spanish while they were immersed in a study abroad program in Spain. Their performance was compared with a group of classroom learners matched on second language experience (if anything, the classroom participants had more second language experience than the participants abroad) and on their scores on a reading span task. Each group performed two tasks: a translation recognition task in which they had to decide whether the second of two words was the correct translation of the first and a verbal fluency task in which they were asked to generate as many exemplars of a given semantic category they could think of in 30 seconds.

In the translation task, the first word always appeared in Spanish and the second word in English. On half of the trials, the second words were indeed the correct translation of the first. However, among the incorrect translation trials, there were three types of critical foils: (1) the Spanish word resembled the lexical form of the English word (e.g., *mano-man*, when *mano* means hand in Spanish); (2) the Spanish word resembled the lexical form of the translation of the English word (e.g., *hambre-man*, when *hambre* means hunger in Spanish and the correct translation of man is *hombre*); and (3) the Spanish word was semantically related to the English word (e.g., *mujer-man*, when *mujer* means woman in Spanish). The classroom learners were sensitive to each of these conditions in that they were slower to reject the foils than unrelated controls. In contrast, the immersed learners produced no interference for lexical foils but a large effect of interference for the semantic foils.

The absence of lexical interference for words resembling the translation equivalent has been taken in past studies as an index of increased second language proficiency (e.g., Sunderman and Kroll, 2006; Talamas, Kroll, and Dufour, 1999). However, the absence of a lexical interference for direct lexical neighbors stands in direct contrast to the findings for highly proficient bilinguals in word recognition tasks (for a recent review, see Dijkstra, 2005). The result suggests that in the immersion context there may be active suppression of the first language. Performance on the verbal fluency measure further supports the hypothesis that the first language is more effectively inhibited when learners are immersed in a second language. Although all learners, regardless of context, produced a larger number of exemplars in English than in Spanish, the immersed learners produced significantly fewer exemplars in English than their counterparts in the classroom, again suggesting that the first language was less accessible for immersed learners.

In the Linck et al. (2007) study, the classroom and immersed groups were matched on reading span scores and it was also possible to ask how span affected performance for each group. For the classroom learners, there was more lexical than semantic interference for the low-span learners. However, the pattern reversed for the high-span learners, suggesting that memory resources alone were sufficient to enable high-span learners to process the second language conceptually. For the immersed learners, there was greater semantic than lexical interference for both low- and high-span participants; the effect of span was simply to enhance the semantic effect for the high span learners. A striking result was that the performance of the low-span learners who were immersed resembled the high-span learners in the classroom, suggesting that the immersion context was able to provide information that low-span learners could not otherwise derive themselves.

There are a number of critical questions about language immersion that remain to be investigated, including the respective contributions of language and cultural influences. One approach to evaluating the consequences of language immersion on its own is to examine performance in domestic immersion programs (such as the summer programs at Middlebury College). Unlike immersion in a foreign country, U.S. domestic programs typically require students to agree not to speak English. In a sense, this requirement can be viewed as an effective means to enforce suppression of the first language. Again, there has been little research on language processing that has exploited the unique properties of this environment. In one study in our lab (Jacobs, Gerfen, and Kroll, 2007), we tested students immersed in a domestic summer program in Spanish. The fact that learners in domestic programs are typically not allowed to use their first language imposed restrictions on our experimental design because only processing in the second language could be evaluated without direct comparisons to the first language.

We asked how simple word production in Spanish, at the level of processing and also in the form of realizing the produced speech, would be affected by the immersion context relative to a group of control learners matched on overall second language proficiency. The critical materials in this study were Spanish cognates that were orthographically similar to their English translations. Because the phonology of cognates is never identical across two languages, it was possible to examine the voice onset times (VOTs) and articulatory duration for cognates and phonetically matched controls to determine whether cognates are less likely to reveal the influence of English in the immersion environment than in the classroom. The results showed that this was indeed the case. The learners in the immersion program, although no more proficient than their classroom counterparts in other respects, were more likely to produce the phonology of Spanish without the influence of the first language. Their VOTs were more similar to a group of advanced Spanish learners than to the proficient-matched controls, suggesting that reducing the activity of the first language may enhance the acquisition of the second language phonology. Note that if the learners' performance were simply a matter of completely acquiring particular aspects of the second language phonology, then cognates and noncognates with similar phonology should have been produced similarly.

Although cognitive and psycholinguistic research on contexts of language learning is at an early stage of development, there are reasons to think that a better understanding of language immersion and its correlated features are likely to provide useful directions for enhancing adult learner outcomes. For individuals identified as having high levels of cognitive resources, either with respect to memory capacity, attentional skills, or sensitivity to phonology, it may be possible to exploit the immersion environment as a means to jump-start rapid second language learning.

STRUCTURAL PROPERTIES OF THE SECOND LANGUAGE

In addition to the cognitive characteristics of learners and the learning context, there is also a question about how the structural relation between a native language and a new second language affects the trajectory of second language learning. Some models of learning assume that learners transfer all possible aspects of the first language to the second language. For example, the competition model (e.g., Bates and MacWhinney, 1982; MacWhinney, 1997) proposes that learners begin with a set of biases that are associated with the preferences of their native language. Thus, in English, word order is a salient syntactic cue; in other languages animacy may be more critical.

For example, in a sentence such as "The dog chased the car," only the dog is an animate noun that can be doing the chasing, and in some languages, that may be a syntactic cue. The development of second language skill is then proposed to be a competitive process in which different syntactic cues compete until the cues associated with the new language are sufficiently strong. In this model, the more structurally similar two languages are, the more easily a learner can effectively utilize existing second language knowledge. At the level of the phonology (e.g., the perceptual assimilation model [Best, 1995] and the speech learning model [Flege, 1988]) and at the level of the lexicon (e.g., Kroll and Stewart, 1994), there is also evidence that acquisition of the second language is initially processed with respect to the first language. Although there is other empirical evidence for the presence of constraints in this process, the system is impressively pliable, with changes that appear to reflect the nature of the second language exposure (e.g., Escudero and Boersma, 2004).

What is not apparent from the existing research is how the relative contribution of similarity or distinctiveness at each level of language representation and processing shapes the overall skills of the second language learners. For example, when two languages share the same alphabet, there is an opportunity for ambiguity in reading, with similar words that may or may not share the same meaning in both languages. In a language with a distinctive script, there is no opportunity for ambiguity at this level. Thus, facilitation in acquiring rudimentary literacy skills may be offset to some degree by the presence of cross-language ambiguity and resulting competition. At each level of language processing, there may be analogous tradeoffs, with similarity imposing both costs and benefits depending on the goals of a particular task. The available studies that have examined structurally distinct languages in second language speakers provide some support for the claim that differences in the surface form of a language do not appear to eliminate the types of cross-language interactions described above (e.g., Gollan, Forster, and Frost, 1997; Jiang, 1999).

To the extent that skill in a second language is based on the acquisition of an abstract level of representation, the results of these studies suggest that both the lexicon and the grammar share properties that prevent bilinguals from functionally separating the two languages even when the languages are quite distinct. Some recent studies of bimodal bilinguals who use spoken English and American Sign Language (Emmorey, Borinstein, and Thompson, 2005) suggest that even in the extreme case of two languages that use different modalities, there is evidence for cross-language interactions, demonstrating that the structural differences associated with the languages do not prevent access to lexical and grammatical representations that are fundamentally open to the influence of the other language. An interesting hypothesis—which to my knowledge has not been explored systematically—is whether structurally distinct languages impose a greater processing load than similar languages and therefore require enhanced cognitive resources to achieve levels of second language proficiency that are comparable to structurally similar languages.

OTHER PROMISING DIRECTIONS

The Declarative/Procedural Model

Ullman (2001, 2004) has made a provocative claim about why second language learning is typically more difficult for adults than for young children. According to the declarative/procedural model, different memory systems support access to the lexicon and to grammar. Grammatical, rule-based processing is hypothesized to be computed on-line (that is, processed in real time, as it actually occurs) and to be controlled by the neural mechanisms common to other tasks that also require procedural memory and skill learning. In contrast, lexical knowledge is hypothesized to be stored in declarative memory, drawing on neural resources that are common to the storage of facts and explicit meanings. The claim is that second language learning is typically difficult for adults because they no longer have access to the same procedural system that underlies the acquisition and use of rule-based grammar in their first language. Because procedural memory systems are hypothesized to be relatively unavailable to late second language learners, all forms must initially be stored and retrieved from declarative memory. To the extent that distinct brain structures support procedural and declarative systems, a different profile of neural functioning is predicted for learning a second language than for learning a first. In addition, learners who have superior declarative memory (e.g., women relative to men, see Ullman et al., 2002) are predicted to be more successful language learners.

Technology for Language Learning

Contemporary classroom instruction has changed radically with the introduction of computer-assisted technology for language delivery. However, very little research has been conducted from a cognitive perspective to determine how the method of delivery and context of learning affect the acquisition of second language skills. A study by Payne and Whitney (2002) explored the interesting hypothesis that the use of computer chat rooms might enable second language learners to acquire oral proficiency skills. The theoretical logic was that speech planning engages a series of components up to the point at which the speaker can articulate the intended utterance (e.g., Levelt, 1989). These components, from the conceptualization of the utterance to lexical retrieval and phonological encoding, are hypothesized to engage abstract representations that are then specified for articulation. The medium of articulation can take any number of different forms, from speaking to typing or writing, or signing for a person who uses sign language, but the abstract stages of planning speech prior to articulation are shared.

Payne and Whitney (2002) argued that what was critical for second language learners was gaining skill in the cognitive components of speech planning. They hypothesized that the computer chat environment would enhance that process because learners would be able to read the text that had been generated and therefore benefit from a reduction in the load on working memory that would normally be required in ordinary spoken discourse. This was indeed what they found, with the added result that the chat context appeared to be particularly beneficial for learners who had been identified as being relatively lower in their phonological memory capacity.

Assessing Learner Outcomes

A contribution of cognitive psychology and cognitive neuroscience to the field of second language acquisition is an emphasis on tasks that measure processes as they happen and thus more sensitively than metalinguistic judgments or after the fact assessments. A key issue for designing training programs for adult learners will be to determine whether the goals of a particular learning situation require that the second language be fully accessible for immediate performance (that is, on-line), or whether accuracy when there is no time pressure (an off-line task) will be sufficient for specific purposes. For example, it is notoriously difficult for adult learners to use subject-verb agreement correctly in a second language. However, Jiang (2004) demonstrated that the same Chinese-English learners who were apparently unable to process subject-verb agreement correctly in English in an on-line comprehension task were in fact capable of performing the same constructions accurately in an off-line measure. More generally, the point is that second language learners may possess knowledge of a structure but be unable to use that knowledge under the time pressures associated with speeded comprehension and production tasks.

A recent study by McLaughlin, Osterhout, and Kim (2004) provided evidence for a surprising dissociation between behavioral performance and brain activity in second language learners. The researchers examined lexical decision performance in a group of learners who had literally just begun to study French in an introductory university-level course. Lexical decision is difficult for learners because they have to discriminate letter strings that form real words from those that are nonwords in the new language. Indeed, lexical decision is often used in the literature as a measure of language proficiency to differentiate the relative skill level of learners who have many years of second language study (e.g., Huibregtse, Admiraal, and Meara, 2002). What McLaughlin et al. found was that learners in a first course in French predictably had chance probability in performing lexical decision. However, when they measured event-related potentials (ERPs) for the same conditions, they found evidence that suggested that after only 14 hours of second language study, learners were beginning to differentiate words and nonwords in French despite the fact that there were unable to do so consciously.

A related set of findings was reported by Tokowicz and MacWhinney (2005), who examined sensitivity to syntactic violations in a grammaticality judgment task. They found that second language learners were at chance in making explicit judgments of grammaticality but revealed sensitivity to violations of the second language grammar in the ERP measure. Tokowicz and MacWhinney argued that this method of identifying sensitivity to second language structures that learners are not able to process explicitly might provide an important method for identifying milestones in language development that could then be exploited by explicit instruction.

Third Language Learning by Bilinguals

Are individuals who are already proficient bilinguals better able to acquire a third language than monolinguals acquiring a second language? There are only a few studies that have explicitly addressed this issue: the available evidence suggests a positive answer to the question. For example, in the realm of vocabulary acquisition, Van Hell and Candia Mahn (1997) compared the performance of two groups learning new vocabulary. One group consisted of highly proficient Dutch-English bilinguals learning new words in Spanish and the other groups consisted of native English speakers who were functionally monolingual learning new words in Dutch. The bilingual group outperformed the monolingual group. An interesting feature of this particular bilingual group is that they were highly proficient but late second language learners, as Dutch children first learn English in school at ages 10-12. The result thus suggests that a bilingual advantage in third language acquisition may not depend on early bilingualism.

A recent set of studies on language-switching performance also suggests that there may be some advantage for proficient bilinguals when confronted with a third language. When bilinguals are required to switch from one language to the other, there are costs to the processing speed that are thought to reflect the requirement for inhibition of the unintended language. Ironically, it is often more difficult for bilinguals to switch into the more dominant (first) language than into the weaker (second) language (see, e.g., Meuter and Allport, 1999). The interpretation of an asymmetry in language switch costs is that unbalanced bilinguals will have to inhibit their first language more strongly to speak the second language than the reverse (Green, 1998). Costa and Santesteban (2004) demonstrated that highly proficient and relatively balanced bilinguals did not reveal this asymmetry; they showed switch costs that were similar for their two languages. Most critically, when these bilinguals were asked to switch between their first language and a third language in which they were less proficient, they continued to produce a pattern of switch costs that was symmetric, in contrast to learners and less proficient bilinguals who show the typical switch cost asymmetry.

Costa and Santesteban (2004) argued that the absence of a switch cost asymmetry suggested that skill as a bilingual provides a means to control the two languages without active inhibition. Although the specific interpretation of these results may be debated, what is clear is that the way in which an equally weak new language is processed differs for those for whom it is a third language and for those for whom it is a second language. The more general implication is that the cognitive consequences of bilingualism, particularly those that affect attentional control, may have equal or possibly greater significance for acquiring a third language than such factors as the structural similarity of the new language to the old languages (e.g., MacWhinney, 1997).

UNRESOLVED ISSUES AND OBSTACLES: CROSS-DISCIPLINARY CONNECTIONS

A clear priority for research is to better exploit appropriate connections between cognitive and cognitive neuroscience approaches to second language acquisition and the research on this topic from more traditional educational and sociolinguistic perspectives (e.g., Watson-Gegeo and Nielsen, 2003; Dörnyei and Skehan, 2003). A problem in bridging these approaches is that the historical tradition of research in each of the disciplines has been shaped by differences in the questions that bring researchers to the problem of second language learning.

The cognitive approach is relatively more theoretical, with a focus on how learning itself takes place and how second language learning is a model for that process. The "grain size" of the research tends to be narrow and concerned with outcomes that can be studied in the laboratory. Few cognitive scientists have direct experience in instructing second language learners. For educators, and particularly for those who come to research from foreign-language classroom experience, there is a more immediate concern for pedagogical implications. There is also reliance on research methods that are as likely to be qualitative as quantitative, and when they are quantitative, to be large-scale and correlational rather than fine-grained experimental analyses of individual behavior. As in other areas of research that have a rich cross-disciplinary mix, there are probably some aspects of second learning that could benefit from closer collaboration across the disciplines and other aspects that are better suited to specific disciplinary approaches.

A quick glance at any of the recent edited handbooks on bilingualism, second language acquisition, or applied linguistics reveals a move towards greater inclusiveness across the disciplines. However, inclusiveness itself is only a sign of recognition that different approaches make legitimate contributions to the field, not an indication of research that is genuinely interdisciplinary. But it is first step.

A number of obvious barriers make the next stages of research difficult. The academic cultures and resource associated with the disciplines that comprise second language acquisition are distinct. Language departments are typically located in colleges of humanities; cognitive science and neuroscience are located in colleges of science and social science. Until recently, it was unheard of for a faculty member in a language department to have access to a laboratory, although that situation is changing as programs in the language sciences begin to emerge.

A second focus of cross-disciplinary work is related to translational research that bridges clinical and cognitive approaches to language development. An emerging body of research, performed primarily in the context of programs in communication disorders and speech and hearing sciences, addresses the problems that young children face when they enter U.S. schools without English language skills (e.g., Bedore, Peña, García, and Cortez, 2005). These children are at risk for academic failure and also for the misdiagnosis of language disorders because the traditional methods of assessing language are almost entirely in English. As they acquire English, their performance may differ from monolingual native speaker norms because they genuinely have a language disorder or because their bilingualism affects their performance in both their first and second languages. Although some of this research may appear to have an agenda that is quite distinct from the goals for adult learners, there is a shared concern with developing methods that might facilitate the rapid acquisition of literacy and oral proficiency in a second language.

Finally, recent developments in social neuroscience will certainly benefit studies of second language learning. The affective side of second language learning has only recently begun to receive attention from both sociocultural and experimental perspectives (e.g., Harris, Ayçiçegi, and Gleason, 2003; Pavlenko, 2005). Few studies have addressed the issue of how acculturation might be assessed rigorously and how it might affect second language learning (e.g., Stephenson, 2000) and how personality, emotional, and affective states might modulate the experience of immersion in a new language and culture. This will be an important component of the research agenda for adult language training and, indeed, for understanding second language acquisition more generally.

CONCLUSIONS

Although knowledge of the cognitive and neural basis of second language learning in adults is far from complete, the research to date demonstrates the fundamental plasticity of the language learning mechanism. While there are clearly constraints that reflect the way in which the first language is learned during early childhood (e.g., Pallier, Colomé, and Sebastián-Gallés, 2001; Weber-Fox and Neville, 1996), those constraints do not appear to characterize the degree to which an adult language system is open to new learning and to the effects of language context when the environment of language use changes. A research program that identifies the ways in which language and cognition interact to allow these changes to occur and the ways in which those interactions are shaped by the larger context in which learning takes place will provide a foundation for increasing the second language skills of adult learners.

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Technology-Based Training

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There undeniably has been an extraordinary change in technology-based training in recent decades. Fifty years ago none of the genres of learning environments that will be addressed in this paper even existed: (1) computer-based training, (2) multimedia, (3) interactive simulation, (4) hypertext and hypermedia, (5) intelligent tutoring systems, (6) inquiry-based information retrieval, (7) animated pedagogical agents, (8) virtual environments with agents, (9) serious games, and (10) computer-supported collaborative learning. All but the first two were not available 20 years ago, and most are not mainstream technologies in schools today. Yet the web has either exemplars or mature technologies for all 10 of them, so they are potentially available to all web users. The gap between the potential of and actual technology-based training translates into a critical, if not desperate, need for research in the social and behavioral sciences. Before addressing each of the 10 technologies, we discuss learning environments more broadly and their critical role in how technologies are developed, understood, and used.

LEARNING ENVIRONMENTS

Most learners do not know how to use the advanced learning environments effectively; indeed, learners often do not even know how to get started. The learning environments they confront are often limited or disappointing because the developers of the systems have not had sufficient training in cognitive science, pedagogy, behavioral sciences, and learning technologies. There is a shortage of trained professionals in these areas of the social and behavioral sciences, particularly those who have a background in conducting projects in interdisciplinary research teams—what is needed to design and develop an advanced learning environment. Far too many learning environments are launched without the required empirical testing on usability, engagement, and learning gains. The pace of new technologies hitting the market is so fast that there typically is not enough time to adequately test the systems. Therefore, there is a need for basic research, theoretical models, and tools to forecast the quality of learning environment designs before or during their potential development.

The role of technology in training has had its critics. Cuban (1986, 2001) documented that technology has historically had a negligible impact on improvements in education. Clark (1983) argued that it is the pedagogy underlying a learning environment, not the technology per se, that typically explains learning gains. That conclusion of course suggests that we investigate how particular technologies are aligned with particular pedagogical principles, theories, models, hypotheses, or intuitions. For example, a film clip on how to dismantle an improvised explosive device is not a technology or subject matter naturally aligned with a pedagogical theory that emphasizes active discovery learning. Reading texts on the web about negotiation strategies is not well aligned with a social learning theory that embraces modeling-scaffolding-fading.

It is important to start with a broad perspective on the landscape of learning technologies and learning theories (National Research Council, 2000; O'Neil and Perez, 2003). Any given technology, *T,* affords a number of cognitive, social, and pedagogical mechanisms, *M* (Gee, 2003; Kozma, 1994; Norman, 1988). In addition to these *TM* mappings, it is essential to consider the goals, *G,* of the learning environment: Is the learning environment designed for quick training on shallow knowledge about an easy topic or for deep learning about explanations of a complex system? It is essential to consider the characteristics of the learner, *L,* such as high or low knowledge of the subject matter and high or low verbal ability. The resulting *TMGL* landscape of cells needs to be explored. Some cells are promising conditions for learning, others are impossible, and groups of cells give rise to interesting interactions.

We advocate a long-term research roadmap that identifies an appropriate *TMGL* landscape for military training and that selects research projects that strategically cover cells that need attention. For example, there has not been enough research on learning gains from serious games that afford active discovery learning in adults with low reading ability. In contrast, there is a wealth of research on learning gains from intelligent tutoring systems on algebra and physics that spans the gamut of learner characteristics, pedagogical mechanisms, and learning goals (Anderson, Corbett, Koedinger, and Pelletier, 1995; Corbett, 2001; VanLehn et al., 2002). There are debates about the conditions under which animated pedagogical agents are effective in improving learning and motivation, so the corresponding cells would need attention. A *TMGL* landscape (or a comparable, perhaps continuous space) would provide a useful guide for inviting and selecting research projects.

The set of cognitive, social, and pedagogical mechanisms to explore is of course too extensive to identify in this paper. The prominent ones associated with each genre of learning environment are discussed below. Examples of pedagogical mechanisms are mastery learning with presentation-test-feedback-branching; building on prerequisites; practice with problems and examples; multimedia learning; modeling-scaffolding fading; reciprocal training; problem-based learning and curricula; inquiry learning; and collaborative knowledge construction. Nearly all of these mechanisms emphasize that learners actively construct knowledge and build skills, as opposed to merely being exposed to information delivered by a learning environment.

Learning environments significantly vary in development costs. The approximate cost for a 1-hour training session with conventional computer-based training would be $10,000; for a 10-hour course with conventional computer-based training and rudimentary multimedia would be $100,000; for an information-rich hypertext-hypermedia system would be $1,000,000; for a sophisticated intelligent tutoring system would be $10,000,000; and for a serious game on the web with thousands of users would be $100,000,000. These very approximate costs would depend further on detailed parameters of the relevant cells in the *TMGL* landscape. Moreover, the estimated costs for the newer advanced learning environments are perhaps misleading because they represent the development of initial systems or early designs. Costs are dramatically less when existing technologies are reused for the development of new material.

Given that training systems have costs and that some have nontrivial costs, there have been major efforts to find ways to cut the price, development time, and other resources needed for building systems. At the same time, however, it would be important to preserve the quality of the learning experience. One successful effort is that of the Advanced Distributed Learning initiative (see http://www.adlnet.org [accessed June 2007]; Dodds and Fletcher, 2004; Duval, Hodgins, Rehak, and Robson, 2004; Fletcher, 2003), which was launched by the Department of Defense. Learning content for computer-based training, multimedia, and some of the more advanced learning technologies is standardized by being decomposed, packaged, and organized into learning objects that conform to the standards of SCORM (sharable content object reference model). Each learning object is a package of learning material with a set of meta-tags that identify the relevant contexts of its application. A SCORM-conformant learning object can be used in most learning management systems, so the content is sharable, interoperable, reusable, and extendable. This feature creates substantial savings in costs: once content is created in a SCORM-conformant fashion, it can be used throughout the electronic learning world. One of the chief challenges now is to get designers of courseware to use the SCORM-conformant learning objects (Brusilovsky and Nijhawan, 2002; Sampson and Karampiperis, 2006). Such use will depend on building and indexing large repositories of SCORM-conformant content, as in Content Object Repository Discovery and Registration/Resolution Architecture or CORDRA (see http://cordra.net [accessed June 2007]; Rehak, 2005), and to somehow market and encourage such repositories to be used. A second major challenge is to develop SCORM standards for the more advanced learning environments (numbers 3-10) now that SCORM is mainstream for computer-based training and most multimedia. We assume that advanced distributed learning (see http://www.adlnet.gov/ [accessed June 2007]) and SCORM will continue to be a priority for military funding.

There are other methods of reducing costs in building the learning environments. Authoring tools are available for easy preparation of course content for computer-based training and multimedia, but better authoring tools are needed to build new course content with the more advanced learning environments (Murray, Blessing, and Ainsworth, 2003). The existing authoring tools for advanced systems are very difficult to learn and use. Some of them are so complex that only the most advanced cognitive scientists and computer scientist can use them—often only the original designers of the systems. In order to make authoring tools more widely used by individuals with varying backgrounds, there needs to be systematic research in human factors and human computer interaction on the *process* of developing course content with them. Otherwise, it is difficult to see how these advanced systems will scale up to handle the large volume of training needs in the military. One side benefit is that these authoring tools can also be viewed as learning environments themselves. One way of learning a complex system at a deep level is to build an advanced learning environment on the system with an authoring tool.

Learning environments must be evaluated from the standpoint of learning gains, usage, engagement, and return on investment. Such performance criteria need to have measures that are operationally defined—a task well suited to social and behavioral scientists. For learning gains, the outcome variables include tests of retention for shallow or deep knowledge, problem solving, and transfer of knowledge and skill to different but related contexts. Meta-analyses have revealed that computerized learning environments fare well in comparison with classroom instruction (Dodds and Fetcher, 2004; Wisher and Fletcher, 2004): the effect sizes (i.e., sigma, differences between treatment and control conditions, measured in standard deviation units) are 0.39 for computer-based training, 0.50 for multimedia, and 1.08 for intelligent tutoring systems. There are few data on learning gains from various classes of learning environments, such as inquiry-based information retrieval, virtual environments with agents, serious games, and computer-supported collaborative learning: research is needed on them. Although learning gains are routinely reported in published studies, there are often incomplete data on use (attrition), engagement (including how much the learners like the system), system development time, study time, and costs. The latter measures are needed to systematically assess return on investment.

TEN GENRES OF LEARNING ENVIRONMENTS

For each of the 10 learning environments discussed in this section, we identify salient theoretical frameworks, empirical findings, and opportunities for future research.

Computer-Based Training

A prototypical computer-based training system involves mastery learning. The learner (a) studies material presented in a lesson, (b) gets tested with a multiple choice or other objective test, (c) gets feedback on the test performance, (d) restudies the material if the test performance is below a specified threshold, and (e) progresses to a new topic if the test performance exceeds the threshold. The order of topics presented and tested can follow different pedagogical models, such as ordering on prerequisites (Gagne, 1985), a structured top-down hierarchical organization (Ausubel, Novak, and Hanesian, 1978), a knowledge space model that attempts to fill learning deficits and correct misconceptions (Doignon and Falmagne, 1999), or other models that allow dynamic sequencing and navigation (O'Neil and Perez, 2003).

The materials presented in a lesson can vary considerably in computer-based training on the web. There can be organized text with figures, tables, and diagrams (essentially, books on the web), multimedia, problems to solve, example problems with solutions worked out, and other classes of learning objects. Computer-based training has been extensively studied over the last few decades and has evolved into a mature technology that is ripe for scaling up at an economical cost. As noted above, meta-analyses show effect sizes of 0.39 sigma in comparison with classroom learning (Dodds and Fletcher, 2004). The amount of time that learners spend studying the material in computer-based training has a 0.35 correlation with learning performance (Taraban, Rynearson, and Stalcup, 2001) and can be optimized by contingencies that distribute practice. Interactions between learner characteristics and the sequencing of learning objects have been documented. For example, available evidence suggests that for high-knowledge learners, it is best to have problems followed by worked-out solutions; for low-knowledge learners, it is best to have worked-out example solutions followed by problems. Learning researchers will always be discovering and testing theoretically inspired aptitude-treatment interactions.

The nature of the feedback in computer-based training merits careful attention (Kulhavy and Stock, 1989; Moreno and Mayer, 2005; Shute, 2007). A test influences the course of learning in a formative evaluation, but in a summative evaluation it simply scales a learner's mastery (Hunt and Pellegrino, 2002). A test score alone is adequate feedback for informing learners how well they are doing, but it is not useful for clarifying specific deficits in knowledge or skill. There needs to be a better understanding of the conditions under which a learner benefits from feedback in the form of correct answers, explanations of why correct answers are correct, identification of misconceptions, explanations of the misconceptions, and other forms of elaboration. It is important to identify conditions in which it is best to withhold feedback so that learners acquire self-regulated learning strategies.

The nature of the test format calls for additional research. Most multiple choice questions in actual courses, electronic learning facilities, and commercial test banks tap shallow rather than deep levels of comprehension (Ozuru, Graesser, Rowe, and Floyd, 2005; Wisher and Graesser, 2005). Shallow questions quiz a learner on explicit information in the lessons, definitions of terms, properties of concepts, steps in procedures, and other forms of perception-based and memory-based processes that require little or no reasoning. Deep-level questions require a learner to understand causal mechanisms, logical justification of claims, explanations of complex systems, mental models, inferences, and applications (Bloom, 1956; Chi, de Leeuw, Chiu, and LaVancher, 1994; Graesser and Person, 1994).

An emphasis in training on shallow knowledge has the unfortunate consequence of letting learners settle for shallow standards of comprehension (Baker, 1985; Dwyer, 2005; Otero and Graesser, 2001). As a consequence, learners often perform well on tests with shallow questions but not tests with deep questions. Experimental investigations need to manipulate the quality of questions affiliated with a course and measure the effects on retention, problem solving, and transfer performance. High-quality assessments need to be developed that not only satisfy psychometric criteria but also pedagogical theory in the cognitive and learning sciences (Dwyer, 2005). This direction is being pursued at Educational Testing Service and the College Board.

There are two potential disadvantages of conventional computer-based training, both of which need confirmation with additional research. First, some populations of learners are not engaged in the learning process provided by computer-based training, particularly learning environments that lack multimedia. Conventional electronic page turning is fine for motivated learners who want to be trained on easy-to-moderate material in the minimum amount of time, but not for those who lack motivation and need more entertainment. Second, computer-based training seems more appropriate for acquiring inert knowledge than active application of knowledge (Bereiter and Scardamalia, 1985; National Research Council, 2000) and for shallow knowledge rather than deep knowledge. Other learning environment genres appear to be more appropriate for enhancing engagement, active application of knowledge and skills, and depth of mastery.

Multimedia

In a multimedia learning environment, material can be delivered in different presentation modes (verbal, pictorial), sensory modalities (auditory, visual), and delivery media (text, video, simulations). The impact of different forms of multimedia has been extensively investigated by Mayer and his colleagues (see Mayer, 2005). Meta-analyses reported by Dodds and Fletcher (2004) indicate an effect size of 0.50 sigma for multimedia learning in comparison with traditional instruction; the effect size for the meta-analyses reported by Mayer (2005) is considerably higher, about 1.00. In many of these studies, retention, problem solving, and transfer of training is facilitated by multimedia because the separate modalities offer multiple codes (Paivio, 1986), conceptually richer and deeper representations (Craik and Lockhart, 1972), and multiple retrieval routes. Additional research is of course needed to identify the content and characteristics of the learners who benefit most from multimedia.

It is important that a multimedia presentation does not present so large a cognitive load that it splits a learner's attention (Kalyuga, Chandler, and Sweller, 1999; Sweller and Chandler, 1994). For example, a picture on the screen with a voice that explains highlighted aspects of the picture provides multiple codes without overloading working memory. However, if there is text on the screen that redundantly echoes the spoken explanations, then there may be cognitive overload, interference, and a split attention effect (between print and the picture). Inputs in the same sensory modality interfere with each other more than inputs from different modalities.

Mayer (2005) has documented and empirically confirmed a number of principles that predict when different forms of multimedia facilitate learning. Among these are the principles of multimedia, modality, spatial and temporal continuity, coherence, redundancy, and individual differences. The principles are based on a cognitive model that specifies the processes of selecting, organizing, and integrating information. Mayer's multimedia learning model attempts to predict when and how to highlight a text or diagram with arrows, lines, color, sound, spoken messages, and so on.

One counterintuitive result of research with multimedia is that noninteractive animations of a complex process often have no effects on learning (Lowe, 2004; Rieber, 1996; Tversky, Morrison, and Betrancourt, 2002). Such animations run a number of risks: not being easy to understand, being transient, moving too quickly, presenting distracting material, placing demands on working memory, and depicting processes in a fashion other than one that the learner would otherwise actively construct (Hegarty, 2004). In contrast, a static picture remains on the screen for inspection, is available for active construction of interpretations at the learner's leisure, and potentially stimulates a mental construction of the dynamic process (Hegarty, Kriz, and Cate, 2003). Although some researchers have documented learning gains from animations, there is a persistent question of whether there is information equivalence between the simulation and control conditions in that research.

There is a need for a formal cognitive model that predicts the effects of particular forms of multimedia on learning at varying levels of depth. What is desired, for example, is a GOMS (goals, operators, methods, and selection rules) model (Card, Moran, and Newell, 1983; Gray, John, and Atwood, 1993) of multimedia learning that has the theoretical scope, analytical precision, and predictive power that GOMS provided for the field of human-computer action in the 1980s and 1990s. A satisfactory model would need to consider the cognitive representations of the content, the processes needed to perceive and interpret the multimedia presentations, knowledge of the learner, and the tasks the learner needs to perform. A fine-grained cognitive model would resolve at least some of the inconsistent findings in the literature and could be used to make a priori predictions.

Social science research is needed to resolve a number of other questions about multimedia. How can learners be trained to interpret complex multimedia displays? What sort of semiotic theory is needed to explain how pictures and icons are interpreted and integrated with verbal input? How can cognitive theories inform graphic artists? How can multimedia presentations be tailored to the profile of learners, including those with disabilities? How can different forms of content be represented with different types of multimedia? Given that most research on multimedia is based on experiments in which material is presented for less than 1 hour, how well does that research reflect the learning environments that are used for several weeks? Will the razzle dazzle of exotic multimedia end up being too exhausting to a learner over a longer period of time?

Interactive Simulation

Interactive simulation allegedly produces more learning than simply viewing simulations because a learner can actively control input parameters and observe the results on the system. A learner can slow down animations to inspect the process in detail, zoom in on important subcomponents of a system during the course of a simulation, observe the system from multiple viewpoints, and systematically relate inputs to outputs (Kozma, 2000). Some studies have indeed shown advantages of interactive simulation on learning, but others have shown no gains of interactive simulation in comparison with various control conditions (Deimann and Keller, 2006; Dillon and Gabbard, 1998; Jackson, Olney, Graesser, and Kim, 2006; Stern et al., 2006; van der Meij and de Jong, 2006). The empirical results are therefore mixed and in need of a meta-analysis, assuming that a sufficient number of empirical studies have been conducted.

Unfortunately, simulations and many other advanced learning environments tend to have complex content and interfaces that are unfamiliar to learners. Learners with low domain knowledge or computer expertise have trouble getting started and managing the human-computer interface. Even learners with medium or high knowledge and expertise often do not understand how to strategically interact with the simulation to advance learning. Consequently, designers of these systems are sometimes disappointed on how little or ineffectively the simulations are used.

There needs to be training, modeling, and scaffolding of the use of complex simulations before they can be used effectively. A game environment with points and feedback (as in the case of Flight Simulator, see http://www.microsoft.com/games/flightsimulator/ [accessed August 2007]) is believed to motivate learners and be effective in promoting learning gains. Research is needed on the cognitive and motivational mechanisms that encourage intelligent interactions with interactive simulations.

Hypertext and Hypermedia

Hypertext and hypermedia systems provide a large space of web pages with texts, pictures, animations, and other media. Each page has hot spots for the learner to click and explore. The learner has free reign to maneuver through the space, which can be an ideal environment for active learning and inquiry. Unfortunately, most learners do not have the skills of self-regulation and metacognition to intelligently search through a hypertext/hypermedia space (Azevedo and Cromley, 2004; Conklin, 1987; Winne, 2001): they get lost, get sidetracked by seductive details, and lose sight of the primary learning goals.

These known liabilities of this technology have resulted in mixed reports of learning gains from hypertext/hypermedia when compared with a designed sequence of materials by an expert author (Azevedo and Cromley, 2004; Rouet, 2006). Learners benefit from a navigational guide that trains, models, and scaffolds good inquiry strategies (Azevedo and Cromley, 2004). Another aid is an interface that shows the learner an overview of the space and where the learner has visited; a graphical interface or labeled hierarchy may be suitable for providing this global context (Lee and Baylor, 2006). More research is needed on training learners how to effectively use hypertext and hypermedia to achieve specific learning goals. Research is also needed to assess and increase the likelihood that designers of these environments use principles of cognition, human factors, semiotics, and human-computer interaction. Many designers congest the web pages with excessive options, clutter, and seductive details (i.e., feature bloat), which overloads the cognitive system and distracts learners, especially those with low ability.

Intelligent Tutoring Systems

Intelligent tutoring systems track the knowledge states of learners in fine detail and adaptively respond with activities that are sensitive to those knowledge states. The processes of tracking knowledge (called user modeling) and adaptively responding to a learner ideally incorporate computational models in artificial intelligence and cognitive science, such as production systems, case-based reasoning, Bayes networks, theorem proving, and constraint satisfaction algorithms. Successful systems have been developed for mathematically well-formed topics, including algebra, geometry, programming languages (the Cognitive Tutors, Anderson et al., 1995; Koedinger et al., 1997), physics (Andes, Atlas, and Why/Atlas, VanLehn et al., 2002; VanLehn et al., 2007), electronics (Lesgold and Nahemow, 2001), and information technology (Mitrovic, Suraweera, Martin, and Weerasinghe, 2004). These systems show impressive learning gains compared to control instruction (an effect size of approximately 1.00 sigma), particularly for deeper levels of comprehension.

School systems are adopting intelligent tutoring systems at an increasing pace, particularly those developed at LearnLab and Carnegie Learning in the Pittsburgh area. Carnegie Mellon and Pittsburgh have a Science of Learning Center (funded by the National Science Foundation) to scale up their systems in mathematics, physics, and foreign languages.

Intelligent tutoring systems are expensive to build but are now in the phase of scaling up. One challenge in getting widespread use of these systems is that instructors do not know what systems are available, how to access and use them, and how to integrate the systems in course curricula.

Advanced distributed learning networks and projects hold some promise in facilitating more widespread use of intelligent tutoring systems.

A second challenge lies in the authoring of new subject matter content in a system at a pace with the growth of knowledge. Some of the newer systems have attempted to handle knowledge domains that are not mathematically precise and well formed. The Intelligent Essay Assessor (Foltz, Gilliam, and Kendall, 2000; Landauer, Laham, and Foltz, 2000) and e-Rater (Burstein, 2003) grade essays on science, history, and other topics as reliably as experts of English composition. Summary Street (Kintsch, Steinhart, Stahl, and LSA Research Group, 2000) helps learners summarize texts by identifying idea gaps and irrelevant information. AutoTutor (Graesser, Lu et al., 2004; Graesser, Chipman, Haynes, and Olney, 2005) helps college students learn about computer literacy, physics, and critical thinking skills by holding conversations in natural language. AutoTutor shows learning gains of approximately 0.80 sigma in comparison with reading a textbook for an equivalent amount of time (Graesser, Lu et al., 2004; VanLehn, Graesser et al., 2007). These systems automatically analyze language and discourse by incorporating recent advances in computational linguistics (Jurafsky and Martin, 2000) and information retrieval, notably latent semantic analysis (Dumais, 2003; Landauer, McNamara, Dennis, and Kintsch, 2007; Millis et al., 2004).

There are three major reasons for encouraging more research on developing and testing intelligent tutoring systems with tutorial dialogue in natural language. First, the military has needs for intelligent training on subject matters that involve conceptualizations and verbal reasoning that is not mathematically well formed. Second, natural language dialogue is a frequent form of communication, as in the case of chat rooms, MUD (multiuser domain) games, MOO (MUD object oriented), other computer games, and instant messaging (Kinzie, Whitaker, and Hofer, 2005; Looi, 2005). The majority of teenagers in the United States use instant messaging every day. Third, the revolutionary advances in computational linguistics, corpus analyses, speech recognition, and discourse processing (Graesser, Gernsbacher, and Goldman, 2003) make it possible to make significant progress in developing natural language dialogue systems.

However, two points of caution are needed. It is important to focus on making the conversational systems more responsive to learners' ideas, threads of reasoning, and questions, rather than merely coaching learners in following the system's agenda. The second caution is that there needs to be a fine-grained assessment of what aspects of natural language dialogue facilitate learning, engagement, and motivation. Learners get irritated with conversation partners who do not seem to be listening at a sufficiently deep level (Mishra, 2006; Walker et al., 2003).

Inquiry-Based Information Retrieval

One type of inquiry learning consists of asking questions and searching for answers in an information repository (Graesser, Hu, Jackson, Person, and Toth, 2004; Wisher and Graesser, 2005). High-knowledge individuals sometimes do not have the patience to wade through learning materials; they prefer to actively ask questions to achieve their goals. Query-based information retrieval occurs when Google is used to access information on the web. The queries do not need to be well formed semantically and syntactically because the system uses keyword search algorithms. The responses are not direct answers to queries, but rather are web pages and documents that hopefully contain the answers. Recently, advances in computational linguistics have made it possible for information retrieval systems to parse and interpret well-formed questions and return answers to users (Harabagiu, Maiorano, and Pasca, 2002; Voorhees, 2001). The information repositories have varied from focal topics (terrorism, finances in Wall Street Journal) to open searches on the web.

Formal evaluations of these question answering systems have been held in the TREC QA and ARDA AQUAINT initiatives (see http:/www.informedia.cs.cmu.edu/aquaint/index.html [accessed August 2007]). The performance of these query-based information retrieval systems has been quite impressive for short-answer questions (who, what, when, where) but not for questions that require lengthy answers (why, how). For the latter questions, the best that can be accomplished is returning a paragraph from the text that may contain the answer. What has been rare in evaluations of these systems is performance in the context of learning environments. In one study on a learning environment on research ethics, the performance in terms of the accuracy of paragraphs returned in an inquiry, with 95 percent of the paragraphs judged relevant by the learners and 50 percent were judged informative (Graesser, Hu et al., 2004). More research is needed to assess the questions that learners ask during learning and the fidelity of the answers delivered by the question-answer systems in the learning environments.

One challenge that limits the utility of query-based retrieval systems is that most learners ask very few questions, and most of the questions they ask are shallow (Graesser and Person, 1994; Graesser, McNamara, and VanLehn, 2005). Questions are typically asked when learners experience cognitive disequilibrium as a result of obstacles to goals, contradictions, anomalous information, difficult decisions, and salient knowledge gaps (Graesser and Olde, 2003). But even in those situations, most learners need to be trained to ask good questions. Such training of question-asking skills improves question quality and also comprehension (King, 1994; Rosenshine, Meister, and Chapman, 1996). Learners need to be exposed to good models of question asking, inquiry, and curiosity. A curious learner is something too rarely seen in classrooms and other natural settings.

A different sense of inquiry learning is manifested in learning environments that stimulate reasoning akin to the scientific method, such as Inquiry Island (White and Frederiksen, 2005). Learners are presented authentic challenges that motivate them to generate hypotheses and plans for testing them, reports to colleagues, revisions of hypotheses, and so on. Ideally, learners will be intrinsically motivated by the problem and the affordances of the learning environment so that they become engaged in the inquiry process. However, there is a need to investigate the process of scaffolding effective inquiry for a wide range of learner profiles. Many learning environments fail to stimulate genuine inquiry in most learners, so this is an area greatly in need of research. The time-course of learning from these learning environments involves weeks, months, or years (not 1-hour training sessions), so the research is expensive and takes months or years for adequate evaluations. A pragmatic skeptic might ask how, when, or whether these broad-scale inquiry learning environments are relevant to military training.

Animated Pedagogical Agents

Embodied animated conversational (pedagogical) agents have become very popular in information and communication technologies, but the most serious applications have been in learning technologies (Atkinson, 2002; Baylor and Kim, 2005; Cole et al., 2003; Graesser, Jackson, and McDaniel, in press; Johnson, 2001; Johnson, Rickel, and Lester, 2000; McNamara, Levinstein, and Boonthum, 2004; Moreno and Mayer, 2004; Reeves and Nass, 1996). These agents speak, point, gesture, walk, and exhibit facial expressions. Some are built in the image of humans, and some are animals or cartoon characters. The potential power of these agents, from the standpoint of learning environments, is that they can mimic face-to-face communication with human tutors, instructors, mentors, peers, and people in other roles. Ensembles of agents can model social interaction. Single agents can model individuals with different knowledge, personalities, physical features, and styles. Both single agents and ensembles of agents can be carefully choreographed to mimic virtually any social situation: curious learning, negotiation, interrogation, arguments, empathetic support, helping, and so on. Agent technologies have the potential for a revolutionary impact on behavioral and social science research.

Researchers have investigated the conditions in which single agents promote learning either alone or in the presence of other media (Mayer, 2005). For example, is it better to have information presented in print or spoken by agents? Are realistic agents better than cartoon agents? Does the attractiveness or conversational style of the agent matter? These and similar questions can be related to the previous research on multimedia, discourse, and social psychology that was conducted before the emergence of agent technologies. It is of course important to make sure that an agent does not create cognitive overload, a split attention effect, or a distraction from other information on the display that has higher importance (Moreno and Mayer, 2004). It is also important to make sure that an agent is not so realistic that the learner has unrealistically high expectations of its intelligence (Norman, 1994; Shneiderman and Plaisant, 2005). The research suggests that it is the content of what is expressed, rather than the aesthetic quality of the speech or face, that is most important in predicting learning from pedagogical agents (Graesser, Moreno et al., 2003). Research also suggests that it is possible to create social presence from facial icons with expressions, a minimalist form of the persona effect.

There are four research directions that merit attention of social and behavioral scientists in this area. First, ensembles of agents can model learning processes, so researchers can investigate how learning is systematically affected by different theories of social interaction. There can be dyads between peer learners, between a teacher and a student, or between an intelligent tutoring system and a student; there can be triads among teachers, intelligent tutors, and peers (McNamara et al., 2004). Learners can vicariously learn from such interactions (Craig, Gholson, Ventura, Graesser, and the TRG, 2000). The possibilities are endless.

Second, researchers can explore the processes that designers and learners go through when they create agents with the tool kits that have been developed. In addition to understanding these design processes, researchers will accumulate a broader population of agents to test in their studies (i.e., beyond Microsoft Agents), including those with diverse physical appearances, personalities, and styles that specific learner populations are responsive to (Baylor and Kim, 2005).

Third, researchers can develop agents that deeply interpret what learners express in tutorial dialogue or other forms of human-computer interaction. This direction requires integration of advances from computational linguistics, cognitive science, and artificial intelligence.

Fourth, researchers can investigate alternative ways that agents can be responsive to learners as learners make contributions that vary in quality. This is already being done in AutoTutor (Graesser et al., 2005), which holds a mixed initiative dialogue with a learner. AutoTutor has dialogue moves that are responsive to the learner's knowledge states: short feedback (positive, neutral, negative), prompts for information (*What else?*), hints, answers to learner questions, and corrections of student misconceptions. Similiarly, the iSTART system (see McNamara, Levinstein, and Boonthum, 2004) has groups of agents that adaptively respond to learners who generate self-explanations while reading science texts. These responsive agents, developed at the University of Memphis, require more built-in intelligence than the prepared choreographed agents.

Virtual Environments with Agents

Outstanding examples of virtual environments with agents are those developed at University of Southern California, particularly Mission Rehearsal (Gratch et al., 2002) and Tactical Iraqi (Johnson and Beal, 2005). These virtual worlds are very close to authentic interactions in war scenarios or interactions between soldiers and people in another culture with a different language. The learner holds a dialogue in natural language, with speech recognition, and multiple agents. These award-winning virtual environments are major milestones and have involved major investments by the military.

Continued research on these large-scale virtual environments is of course very prudent. Highly encouraged are evaluations of these systems on learning gains, usability, learner impressions, and the fidelity of specific computational modules. It would be useful to augment the interdisciplinary development team with more social and behavioral scientists. These learning environments are not currently on the web, so the feasibility of transporting simpler versions on simpler platforms remains a question. More modest virtual environments with agents are available in MOOs (Slator, Hill, and Del Val, 2004).

Serious Games

The game industry has certainly captured the imagination of this generation of young adults, with revenues larger than the movie industry. Serious teenage gamers play approximately 20 hours per week (Yee, 2006). There is a rich taxonomy of games, nearly all of which could be integrated with military training, such as first person shooter games, multiparty games, and simulations of cities. A large-scale game like *America's Army* is extremely engaging for both young and older people because it is fun and weaves in serious content about the Army. The challenge of combining entertainment and pedagogical content is the foundational question of serious games (Brody, 1993). Understanding the mechanisms that lead to fun and learning is an important topic for behavioral and social science research.

Although the components of games have been analyzed at considerable depth (Gee, 2003; Salen and Zimmerman, 2003), there has been very little research on the impact of these components on learning gains, engagement, and usability (Cameron and Dwyer, 2005; de Jong and van Joolingen, 1998; Lawrence, 2004; Malone and Lepper, 1987; Moreno and Mayer, 2005; Virvou, Katsionis, and Manos, 2005). Presumably, the success of a game can be attributed to feedback, progress markers, engaging content, fantasy, competition, challenge, uncertainty, curiosity, control, and other factors that involve cognition, emotions, motivation, and art. Investigating the relationships between game features and outcome measures should be an important priority for behavioral and social scientists because scientific data are sparse and the impact of games on society is enormous.

Computer-Supported Collaborative Learning

In computer-supported collaborative learning, groups of learners collaboratively construct knowledge on a topic in pursuit of project goals that are usually provided by instructors (Lee, Chan, and Aalst, 2006). For example, in Knowledge Forum (Bereiter, 2002; Scardamalia and Bereiter, 1994), students create messages that others can review, elaborate, critique, and build on. These systems support threads of conversations that involve formulating arguments, problem solving, planning, report writing, and countless other tasks (Gunawardena, Lowe, and Anderson, 1997). In current practice, the length of most of these conversational threads is short (2.2 to 2.7 turns per thread; Hewitt, 2005), so attempts have been made to design the systems to lengthen the threads. There is some evidence that computer-supported collaborative learning systems facilitate deep learning, critical thinking, shared understanding, and long-term retention (Garrison, Anderson, and Archer, 2001; Johnson and Johnson, 2001), but the scale of these distributed learning environments makes it very difficult to perform systematic evaluations.

Social and behavioral scientists can improve these systems in several ways (Clark and Brennan, 1991; Dillenbourg and Traum, 2006; Looi, 2005; Mazur, 2004; Soller et al., 1998; Wang, 2005). How do learners figure out how to use the complex interfaces on multiparty computer-mediated communication systems? How does a potential contributor learn how and when to speak? How is knowledge grounded in such distributed systems? How can moderators guide a group of learners in productive directions?

FUNDING PRIORITIES AND CONCLUSION

This paper identifies 10 genres of learning environments and dozens of research directions for social, cognitive, and behavioral scientists. This section identifies five directions that we believe should have the highest priority for funding in the near future. They are not listed in order of priority.

Blended instruction that assigns the optimal learning environment to a particular learner at the right time. The *TMGL* landscape (technology, pedagogical mechanism, goals, and learning characteristics) would be applied to individuals with different learning profiles over long stretches of time (i.e., months or years, not 1-hour training sessions). Cells in the landscape would not only be selected on a principled theoretical basis, but would also be empirically tested as data are accumulated from large samples of learners with different learning profiles.

Agents that model and scaffold the use of complex learning environments and human-computer interfaces. Modeling would involve single agents that take on different roles (mentors, tutors, peers, struggling learner agents for the learner to teach) and ensembles of agents that choreograph different patterns of interaction. Scaffolding would require a deep interpretation of a learner's contributions, including natural language, multimodal sensing, and a dynamic generation of computer actions.

Modeling and testing the conditions under which interactive simulation with multimedia promotes deep learning. There typically are a large number of displays, media, controls, input channels, forms of feedback, icons with particular semiotic functions, and other interface features in interactive simulations. There needs to be a GOMS model (or a similar quantitative model) that generates theoretical predictions on human actions, time, and errors on benchmark tasks. The hope is that the quantitative model would resolve discrepant findings in the literature in addition to generating testable predictions.

Systematic tests of the impact of serious games on learning. There needs to be rigorous evaluations on usability, engagement, and learning at different levels of depth and for different types of learners' knowledge and skills.

Examining the process of authoring advanced learning environments. The process of authoring advanced learning environments needs to be explored for instructors, learners, and the designers of learning environments.

Many experts are convinced that learning gains from technologies are best attributed to the underlying pedagogies rather than the technologies per se. At the same time, we all recognize that various technologies have affordances (i.e., properties, constraints) that support the opportunity for learners to benefit from specific pedagogies. One strong but arguable claim is that the social, cognitive, and behavioral sciences will provide the most incisive mapping between technology and pedagogy. However, it will be necessary for these social, cognitive, and behavioral scientists to be part of interdisciplinary teams of learning environment designers, developers, and deliverers.

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Nonverbal Communication

Nicole C. Krämer

FRAMEWORKS FOR NONVERBAL BEHAVIOR

Human communication can be described as a "multichannel reality" (Poyatos, 1983, p. 175) consisting of language, paralanguage (i.e., vocal aspects, such as intonation), and kinesics (i.e., visual aspects). The latter two are referred to as nonverbal behavior. Kinesics, especially, constitutes a complex system of channels. People know each of these channels from everyday experience: facial expressions, gaze, gestures, postures, and head and body movements (Wallbott, 1994). Other aspects of communication are often classified as nonverbal communication, particularly haptics (the use of touch) and proxemics (the use of space) (see Burgoon, Buller, and Woodall, 1989). Moreover, chronemics (the use of time), physical appearance, and the use of artifacts or olfactory cues are also sometimes mentioned as nonverbal cue systems (Burgoon, Buller, and Woodall, 1989; Wallbott, 1994).

Empirical data show that all of the nonverbal aspects have a strong impact on the process and the results of people's communicative efforts and play a vital role in person perception processes, such as the process of forming opinions on other people (Argyle, Salter, Nicholson, Williams, and Burgess, 1970; Mehrabian and Wiener, 1967; Schneider, Hastorf, and Ellsworth, 1979). Summarizing findings from different studies, Burgoon (1994) suggests that overall approximately 60-65 percent of social meaning is derived from nonverbal behaviors.

This paper deals with the two most prominent aspects of nonverbal language, paralanguage and kinesics. The rest of this section provides an account of the intellectual history and development of the research area and an account of functions, attributes, and cognitive aspects of nonverbal behavior as they are discussed in the relevant literature. The next major section looks at that literature with a special focus on culture, leadership and effective communication, and the subsequent section considers the methods and technologies used in the research. The last major section considers applications, and the paper ends with a brief conclusion.

Intellectual History and Development

Nonverbal behavior has received considerable attention by a wide range of disciplines, including biology, anthropology, sociology, and communications, as well as social and experimental psychology (see DePaulo and Friedman, 1998; Burgoon et al., 1989). This interdisciplinary nature has helped protect research from the intellectual biases and sterility inherent in isolation (see DePaulo and Friedman, 1998). However, the interdisciplinary character of the field may also be responsible for the noticeable change of research foci over the years. For example, during the 1970s turn-taking behaviors were studied extensively. This topic has now seemingly vanished from the agenda of most research groups, while socioemotional effects, for example, are being analyzed in detail.

Regardless of specific research foci, however, one development is pervasive: when the research domain of nonverbal communication in the 1960s and 1970s became increasingly important, the explicit goal was to relate specific signals to specific meanings, such as emotional states or personality traits. Early manuscripts tended to suggest that once the meaning of specific cues was known, one might become able to read another person's emotions like a book. It should be noted that this belief is still reflected in some nonscientific literature. However, today's scholars stress the enormous complexity of nonverbal behavior, and no one would seek to unravel the meaning of specific signals.

In contrast to language, nonverbal behavior is not believed to refer to an explicit semantic code. Burgoon and Bacue (2003) conclude: "It is important to underscore the polysemous nature of nonverbal behaviors as well as their substitutability. A single nonverbal cue may have multiple meanings, and the same meaning may be conveyed by a number of different nonverbal cues" (p. 187). Today, in fact, no manner of communication, not even verbal interaction, is still modeled as a one-to-one transmission of meaning from sender to receiver as originally depicted by Shannon and Weaver (1948). In particular, representatives of constructivist assumptions or general systems theory (Watzlawick, Beavin, and Jackson, 1967; Maturana, 1978) argue that meaning is not fixed, encoded into a signal, transmitted, and decoded, but, rather, that it is constructed by the receiver and depends heavily on the receiver's perception of situation and context. And nonverbal aspects of communication are even less ascribable to a common semantic code than verbal aspects because of several specific characteristics of nonverbal behavior that make the phenomena more complex (and thus also more difficult to study) than language and verbal communication. In this paper these characteristics are distinguished as processual character/subtle dynamics, context dependency, and production and perception outside awareness. These current and promising frameworks for understanding nonverbal behavior are described in the rest of this section.

Attributes of Nonverbal Behavior

It is nowadays commonly assumed that it is not feasible to establish a list that links specific behaviors to their effects or meaning. In contrast to speech, nonverbal behavior does not refer to an explicit semantic code, mainly because nonverbal signals are highly context dependent and involve subtle dynamics instead of static, isolated elements (e.g., postures) (Grammer, 1990; Grammer et al., 1999). Nonverbal behavior is thus characterized by dimensional as well as processual complexity (see Barker, 1964; Bente and Krämer, 2003).

With regard to context dependency, several approaches to classify different contexts have been suggested. Bavelas and Chovil (1997; Chovil, 1997) differentiate two forms of contextual information that influence the interpretation of nonverbal cues: cumulative context (topic of conversation, earlier events and behaviors) and simultaneous context (accompanying words, gestures, etc.). Similarly, Krämer (2001) mentions (1) attributes of the sender (e.g., gender, age, ethnicity, physical appearance), (2) situation, (3) verbal context, and (4) nonverbal context as important modulators. Empirical evidence has especially been presented for the latter three of these aspects.

Situational context: The so-called Kulechov effect demonstrates that situational context is sometimes more important for the attribution of a movie character's emotions than his or her facial expressions (Pudowkin, 1961; Wallbott, 1988). In a short movie sequence, the Soviet director Lev Kulechov combined an actor's neutral face with a dead woman's body, or a little girl playing, or a pot of soup. Depending on the context, the actor's neutral face was interpreted as displaying either terror, joy, or contentment (see also the replication of Goldberg, 1951, in a controlled study).

Verbal context: Chovil (1991b) showed that information conveyed by facial displays (more specifically, eyebrow movements) is dependent on the verbal context in which they occur:

> Meaning conveyed by the displays cannot be understood by examining the

> physical properties of the display by themselves but rather by seeing the actions in their verbal and conversational context. It is through examination of the facial displays in their linguistic context that the discourse functions of facial displays are revealed (p. 190).

The information provided by eyebrow movements depending on context varied from emphasis, marked questions and offers, surprise, or disbelief to listener attention.

Nonverbal context: As outlined above, nonverbal behavior is complex, with multiple behaviors happening simultaneously in various channels. Thus, one of the most important contexts for nonverbal behavior is nonverbal behavior (see Bente and Krämer, 2003). In fact, there are many empirical examples for situations in which an activity in one channel affects those simultaneously occurring in another. For example, Grammer (1990) shows that the function of laughter is modulated by additional signals: "the function of laughter could reach from signaling aversion to signaling sexual enticement depending from the postures and movements which are sent parallel to laughter" (p. 232). More surprisingly, Frey et al. (1983) demonstrated that the evaluation of Mona Lisa's smile is dependent on the lateral tilt of her head.

Besides the modulating effect of different contexts, there seem to be additional aspects affecting the effects of a specific behavior. Interestingly, these aspects seem to lie within the behavior itself: the movement quality and subtle dynamics inherent in every behavior. As early as 1970, Birdwhistell described the importance of the quality of the movements:

> The salute, a conventionalized movement of the right hand to the vicinity of the anterior portion of the cap or hat, could, without occasioning a court material, be performed in a manner which could satisfy, please or enrage the demanding officer. By shifts in stance, facial expression, the velocity or duration of the movement of salutation, and even in the selection of inappropriate contexts for the act, the soldier could dignify, ridicule, demean, seduce, insult, or promote the recipient of the salute. By often imperceptible variations in the performance of the act, he could comment upon the bravery or cowardice of his enemy or ally [or] could signal his attitude toward army life (Birdwhistell, 1970, pp. 79-80).

Recent studies indicate that the quality of a movement may even have a stronger impact on the observers' impressions than so-called semantic aspects, although they might not be identified as a possible cause (Grammer et al., 1999). Physical properties of body and face movements, such as speed, acceleration, dimensional complexity, and symmetry, have been shown to be especially highly significant. For instance, Grammer, Filova, and Fieder (1997) showed that very subtle changes in women's movements (a full body turn lasting 3 seconds) could be attributed to whether or not they were interested in a man who was observing those movements. Especially when a specific level of estrogen is reached, a woman in the presence of a man shows movements that are more complex but slower that in other situations. Male observers do not consciously notice these subtle changes, but they nevertheless involuntarily adapt their behavior. These results were generated by means of an innovative video analysis tool that merely assessed physical aspects of movement (see below). Krumhuber and Kappas (2005) show that movement quality is equally important when observing facial behavior: the evaluation of a smile as authentic is dependent on the temporal dynamics of the smile.

Against this background, Grammer et al. (1997) suggest a new conceptualization of nonverbal communication that radically differs from current category-oriented "body language" approaches: they postulate discrete and meaningful movement patterns. In parallel to this conceptualization, Gallese and Goldman (1998) posit that perception of nonverbal behavior is mediated by the recently described "mirror neurons" (Gallese, Fadiga, and Rizolatti, 1996; Iacaboni et al., 1999; Rizolatti et al., 1996) that are assumed to be activated not only when one conducts a movement, but also when observing an action—thus allowing to directly sense the sender's intentions, emotional states, etc. (For first assumptions in this direction, see also the earlier literature on emotion contagion and interactional synchrony: Bavelas, Black, Chovil, Lemery, and Mullett, 1988; Bavelas, Black, Lemery, and Mullett, 1986; Hatfield, Cacioppo, and Rapson, 1994).

In sum, it can be stated that temporal, i.e., processual, aspects as reflected in the quality of movements play a vital role in nonverbal communication. Burgoon et al. (1989) aptly state that "we need to understand nonverbal communication as an ongoing, dynamic process rather than just a static snapshot of cues or final outcomes at one moment of time" (p. 23). Methodological approaches that take these assumptions into account have been proposed by Cappella and Palmer (1990), Frey et al. (1983), and Grammer et al. (1997, 1999).

Cognitive Aspects

With regard to cognitive aspects of nonverbal behavior, Patterson (1994, 1995, 1996) suggests a parallel process model. He criticizes the current procedure of separately analyzing social behavior (production aspect of nonverbal communication, encoding) and social cognition (perception aspect, decoding). He argues that both processes should be considered in parallel, given that they always occur simultaneously. The two processes mutually affect each other because they both draw on a finite pool of cognitive resources. However, even when it is necessary to spend large portions of resources on strategic, controlled behavior, usually both aspects can be processed since person perception might be executed automatically. In fact, Gilbert and Krull (1988) demonstrate that attributions with regard to a job applicant were more accurate when only small resources were available for person perception—thus forcing participants to engage in automatic processing of nonverbal cues: "The present study suggests that under some circumstances (viz., when non-linguistic behavior is more diagnostic than linguistic behavior) cognitively busy perceivers may be relatively immune to correspondence bias, an error of overprocessing" (p. 201).

Choi et al. (2005) also suggest that the degree of automatization for both encoding and decoding is fairly high. Consistent with the definition of automaticity by Bargh (1994), nonverbal communication is seen as unaware, efficient, uncontrollable (i.e., cannot be stopped), and unintentional. Against the background of numerous empirical examples, especially from the realm of encoding and decoding of emotional displays, they conclude:

> Because of the need to act quickly in social life, much of human behavior has acquired an almost reflexlike nature. This is not to say that we are automatons, completely at the mercy of processes to which we do not have access. Most social tasks are composed of components over which we can exercise a great deal of conscious control. For example, our decisions to initiate social goals can be largely conscious, though we may not be consciously aware of all the steps that are set in motion to fulfill these goals (Choi et al., 2005, p. 327).

Similarly, Burgoon et al. (2000) assume that unconscious processing—or in their terminology, *mindlessness*—is ubiquitous when communicating nonverbally. With regard to the production of nonverbal behavior, they state: "Just as language users routinely create grammatical sentences without being able to articulate the rules of grammar, interactants may be relatively unaware of the specific communication tactics they develop in service of their goals" (p. 109).

Grammer et al. (1997, 1999), as part of their analogous communication approach (see above), also stress the importance of automatic processing, but they focus on perception. In line with their assumptions on the importance of subtle aspects, such as movement quality, they conceptualize the processing of these aspects is largely automatic—without involving direct and conscious cognitive processing. Also, Frey (1999) proposes so-called *inferential communication* with regard to the perception of nonverbal behavior. He assumes that all visually perceptible stimuli possess an overwhelming suggestive force. Referring to Helmholtz's concept of unconscious conclusions, he argues that the effects of visual stimuli are not subject to cognitive control and leave people defenseless, while affecting people both immediately and deeply. In this line of argumentation, Buck et al. (1992, p. 962) aptly state that nonverbal communication is "conversation between limbic systems."

Functions of Nonverbal Behavior

Functions of nonverbal signals are manifold: They help to structure the course of verbal exchange, they complement speech activity, they determine social impressions, and they affect the emotional climate of conversations. Several classifications of functions have been proposed (see Hecht, DeVito, and Guerrero, 1999). Patterson (1990) differentiates (a) provision of information (on emotional state, personality), (b) regulation of interaction (turn-taking), (c) communication of intimacy, (d) mechanisms of social control (status, persuasion, impression management), (e) presentation of identity, (f) affect management (maximizing of positive and minimizing of negative affect, e.g., using touch), and (g) facilitation of formal situations. Burgoon and Bacue (2003) similarly distinguish (a) expressive communication, (b) conversational management (in terms of the "lubricant that keeps the machinery of conversation well oiled," p. 192), (c) relational communication (including social support, comforting, and conflict management), and (d) image management and influence processes. In an attempt to unify several approaches, Bente and Krämer (in press) suggested three functional levels of nonverbal behavior: (1) discourse functions (behaviors, like pointing or illustrative gestures, that are closely related to verbal behavior, Efron, 1941; Ekman and Friesen, 1969), (2) dialogue functions (behaviors that serve the smooth flow of interaction when exchanging speaker and listener roles, Duncan, 1972), and (3) socioemotional functions (behaviors that affect person perception, evaluation, and interaction climate).

With regard to general functions of nonverbal behavior that pertain to socioemotional aspects, in recent years a controversy emerged. The assumption that emotion and expression are directly linked and that emotional states automatically lead to expressions specific for the respective emotion (Izard, 1997; Tomkins, 1962; Ekman, 1997; see Manstead, Fischer, and Jacobs, 1999, for a review) has been challenged. Researchers following the so-called social-communicative view (Chovil, 1991a; Fridlund, 1991a; Russell, 1997) argue that emotional nonverbal behaviors are determined not by emotional states but exclusively by social intentions. Referring to empirical findings and evolutionary psychology, Fridlund (1991a) argues in his "behavioral ecology view" that it is simply dysfunctional to directly show one's emotional states. Instead, individuals use their emotional displays in a socially reasonable and manipulative way (e.g., not to cry when one is saddest but to cry when assistance is most readily available). In sum, nonverbal behavior (such as facial displays) is seen as motivated by social goals and intentions, not by emotion; the behavior is seen as strategic, but still as automatic and unconscious.

Empirical evidence confirms that facial displays are more pronounced in social situations (Fridlund et al., 1992; Fridlund, 1991b; Chovil, 1991a; Kraut and Johnston, 1979; Fernandez-Dols, Sanchez, Carrera, and Ruiz-Belda, 1997). In fact, there is ample evidence that the social situation strongly affects nonverbal behavior. It has been demonstrated that people behave differently when others are present than when they are alone: for example, Brightman, Segal, Werther, and Steiner (1977) show that people eating a salty sandwich on their own do not show any reaction, but when they are in the presence of others they strongly display their dislike. Also, the smiling of 18-month-old children depends almost exclusively on the visual attention of the mother (Jones and Raag, 1989). This finding has been taken as evidence for the notion that nonverbal behavior is solely motivated by social goals. In addition, more sophisticated studies demonstrate that the type of audience also has a significant influence. For example, friends elicit different behaviors than do strangers. In an excellent review on the impact of social situations on nonverbal behavior, Wagner and Lee (1999) identify the *role* of the other person and the *relationship* of the people as important determinants for the elicitation of nonverbal behavior in social situations. For example, co-action usually leads to facilitation of facial expressions, and being observed leads to less facilitation, or to inhibition. If the people present are friends or acquaintances, facilitation emerges; if the people present are merely experimenters or observers, inhibition occurs.

Overall, most evidence points to the enormous influence of the sociality of a situation on the nonverbal behavior—affirming the notion that nonverbal behavior serves social goals. In consequence, nonverbal behavior is seen as a vital means to manipulate interlocutors automatically (for a review see Manstead, Fischer, and Jacobs, 1999; Krämer, 2001), for example, in the course of impression management (self-presentation), a phenomenon that today is also modeled as ubiquitous, strategic, automatic, and occurring without the individual's awareness (Leary, 1995). Thus, Wagner et al. (1992) argued in favor of a functional account of nonverbal behavior in line with impression management theories: "People use facial and other nonverbal behavior to communicate. . . . We believe that such an approach puts expressive behavior more firmly into social psychological theory, and renders unnecessary the invocation of the limited concept of cultural display rules" (p.18).

In sum, nonverbal behavior and its effects are highly complex, and single cues cannot be translated directly into distinct meaning. Nonverbal behavior is characterized by a high *dimensional complexity,* which results in the effects of single cues being dependent on the occurrence of other cues, and a high *processual complexity,* which articulates itself in the importance of the quality of movements (e.g., in terms of the effects of subtle dynamics). Moreover, nonverbal behavior has been shown to be both produced and perceived automatically and outside awareness. Last but not least, nonverbal behavior constitutes an important means of impression management and serves social goals—also automatically and nonconsciously—by manipulating the social environment.

CURRENT AND PROMISING RESEARCH

This section gives an overview of current findings and promising research with regard to specific research fields. It first considers two aspects that exert influence on nonverbal communication: culture and setting with regard to status and dominance (in terms of leadership settings). It then specifies characteristics of effective versus ineffective communication, again drawing on the situations and settings mentioned above.

Influence of Culture

"I am convinced that much of our difficulty with people in other countries stems from the fact that so little is known about cross-cultural communication" (Hall, 1959, p.10). Unfortunately, this statement is still true today. Although novels or movies frequently highlight misunderstandings in cross-cultural communication, academic coverage of the topic is unsatisfactory. If anything can be found in the area of nonverbal communication, findings are mostly anecdotal. Research is scarce and superficially focuses on emblems, proxemics, or facial expressions. Even fewer studies take subtle movement qualities and other subtle cues into account. Here, a first approach by Grammer and colleagues (1999) indicates that there are differences between Japanese and German participants in terms of gaze and speech but none with regard to movement quality.

A summary of findings (see below) suggests that there are different layers of behavior, ranging from complete universality to pronounced dissimilarity. While subtle signals with a genuine temporal pattern, like the eyebrow flash (Grammer et al., 1988; Eibl-Eibesfeld, 1972), do not differ across cultures, especially those nonverbal behaviors that are closely tied to language (e.g., the gesture categories emblems and illustrators; Efron, 1941) differ heavily. Referring to LaFrance and Mayo (1978), Burgoon et al. (1989) state:

> the innermost core represents nonverbal behaviors considered to be universal and innate; facial expressions of some emotional states belong to this core. Next come the nonverbal behaviors that show both uniformity and diversity; members of all cultures display affect, express intimacy, and deal with status but the particular signs of doing so are variable. Finally, there

> are culture-bound nonverbal behaviors which manifest great dissimilarity across cultures—language-related acts such as emblems, illustrators, and regulators show this diversity most clearly (p. 73).

Even more surprisingly, there is almost no systematic research on cross-cultural communication. In most cases, differences between cultures are merely described, and any actual problems or misunderstandings have to be inferred. After describing the empirical results below, implications for cross-cultural communication and training will be discussed in the last paragraph of the section.

Gestures Since *emblems* are gestures that have a direct verbal meaning and are closely related to speech (e.g., the peace sign), they are not shared across cultures. In some cases, similar gestures occur but have different meanings—a fact that can easily compromise someone not familiar with cultural specifics. Thus, Richard Nixon met with disapproval when he gave the "A-OK" gesture in Latin America, where it is an obscene gesture (see Burgoon et al., 1989). Other emblems possess contradictory meaning when displayed cross-culturally, for example Bulgarians shaking their heads for "yes" and using an upward the head throw for "no" (Burgoon et al., 1989). Also, illustrative (i.e., speech accompanying) gestures have been shown to vary across cultures (Efron, 1941).

Proxemics Hall (1959, 1966) found that the interpersonal distance people use in different kinds of social encounters varies across cultures. He differentiated contact (e.g., Latin American, French, Arab) versus non-contact cultures (e.g., German and American). Burgoon et al. (1989) offer a critique of this approach and argue that context factors (such as gender, experimental setting) should be considered more carefully. Although they also affirmed intercultural differences, Sussman and Rosenfeld (1982) observed that when Japanese and Venezuelan communicators spoke English, they adopted distances similar to those of Americans.

Facial expressions The research on the cultural specificity of facial expressions—which, according to Kupperbusch et al. (1999), is the area that is most extensively studied with regard to cultural context—basically started with Darwin's (1872) book, *The Expression of the Emotions in Man and Animals*. Although he stated that there are "strong biological underpinnings for (and hence universality in) the communication of intimacy, affiliation, aggression and so on" (quoted in DePaulo and Friedman, 1998, p. 5), there is also ample evidence that there are cultural differences regarding both production and recognition of facial displays.

With regard to the *production* of facial expressions, only a few studies have been conducted. The most important conclusion that has been drawn from them is the existence of *display rules*—culturally learned rules regarding the appropriateness of showing certain expressions in certain situations (Ekman and Friesen, 1969). This assumption has been confirmed by Ekman (1972) and Friesen (1972), who presented video clips that elicited disgust to Japanese and American participants. There were no differences when participants thought they were alone, but when interviewed after the presentation, the Japanese participants masked their disgust with smiling. In a better controlled version of the same procedure, Matsumoto and Kuppersbusch (2001) showed that participants from collectivist countries (e.g., Japan) tend to conceal both positive and negative emotions when others are present. Moreover, social context factors modulate these results: participants from individualistic countries (e.g., the United States) consider it more appropriate to mask negative emotions when interacting with an out-group (e.g., business partners), while people from collectivistic cultures are more likely to mask negative emotions with an in-group (e.g., family).

With regard to *recognition* of facial expression, most data comparing literate and preliterate cultures support the notion of universality (Ekman, 1972; Ekman and Friesen, 1971; Izard, 1971). However, it should be noted that the method of using photographs of (in most cases) posed (i.e., non-natural) expressions has been heavily criticized (Russell, 1997; Wierzbicka, 1995; for a review, see also Kuppersbusch et al., 1999; Parkinson, Fischer, and Manstead, 2005). In a more sophisticated study, Matsumoto (1992) showed that American subjects were better able to recognize anger, disgust, fear, and sadness than Japanese subjects, but that there was no difference for happiness or surprise. This finding has been interpreted as avoidance of emotions that threaten group harmony: those emotions are neither shown nor recognized.

Immediacy Cues that communicate immediacy in Western culture (high expressivity, close proximity, direct facing and eye contact, touch) may be considered overly direct, aggressive, or invasive in other cultures (Burgoon and Bacue, 2003). For example, Indonesians use less direct body orientation than Australians (Noesjirwan, 1978). However, Arabs use more direct body orientation than Americans (Watson and Graves, 1966). In the United States it is expected that a stranger smiles in response to another person's smile, but this pattern is uncommon in Israel (Alexander and Babad, 1981).

Gaze In contrast to many Western cultures, people from Asian and African cultures are taught to avoid eye contact (Burgoon et al., 1989; Byers and Byers, 1972; Bond and Komai, 1976). Hence, direct or frequent gaze may be regarded as rude or a violation of privacy (Burgoon and Bacue, 2003). Arabs, on the other hand, engage in more eye contact than Americans (Watson and Graves, 1966).

Intercultural Communication and Resolving Conflict Although almost no research in cross-cultural settings has been conducted, it can be inferred from the results summarized above that the use of culturally specific behaviors might confuse, irritate, or even provoke an interlocutor with a different cultural background. Understanding of what actually happens when people from different cultures meet (e.g., whether there is automatic adaptation on subtle layers of nonverbal behavior) is incomplete. It is also not yet known whether there are also differences with regard to movement quality or other subtle aspects of behavior (as discussed above). On this topic, research is just beginning (Grammer et al., 1999).

Manusov (1999) has already demonstrated that stereotypes and expectations about how people from a different culture will behave affect what people see and how they themselves behave during conversations. If, for example, people have a positive attitude (which may or may not be determined by a stereotype), they show more direct body orientation and more gaze—especially during the first 5 minutes of an interaction. But Manusov (1999) also shows that if stereotypes are violated, people are influenced by how other people actually behave.

In order to resolve conflict and intercultural misunderstandings, Burgoon et al. (2000)—against the background that conflict is characterized by relatively mindless cycles of blaming—suggest mindfulness: "Competent conflict management tactics appear to be those that increase the mindfulness of conflict behavior by bringing unstated assumptions under scrutiny, more clearly articulating the positions of self and other" (p. 119). With regard to cross-cultural interactions, however, Burgoon et al. (2000) also express reservations about what is often seen as the ideal way to resolve conflict: to find common ground. This is seen as potentially dangerous in intercultural interactions, because it may distract partners from existing differences: "This presumption of communality in fact may be an unrecognized contributor to many intercultural communication difficulties" (p. 119).

Yet knowledge about and salience of differences alone is probably not sufficient. Also, as Burgoon et al. (1989) state, simple exposure to another culture does not guarantee more accurate nonverbal communication (see Michael and Willis, 1969, for early results). Burgoon et al. (1989) suggest instead that training in the production of culture-specific cues is necessary. The usefulness of such training has been demonstrated by Collett (1971), who trained Britons to behave nonverbally like Arabs. As a result, those Britons were rated more favorably than untrained British communicators (see also Garrat, Baxter, and Rozelle, 1981, who trained white policemen to communicate more effectively with Afro-Americans). Yet such training concepts clearly rely on both the knowledge given and the possibility to consciously choose and produce adequate signals. This approach may well be possible for emblems, as these are researched well, relatively easy to learn, and might be produced consciously. However, with regard to more subtle and often automatic signals, such as head movement activity, this approach will be less useful (for alternative approaches, see below).

Nonverbal Communication in Leadership Settings

Although it is frequently stated that the analysis of nonverbal behavior is of great importance when studying leadership (Gitter, Black, and Goldman, 1975; Gitter, Black, and Walkley, 1976; Gitter, Black, and Fishman, 1975), there has been surprisingly little research directly examining nonverbal communication processes (Anderson and Bowman, 1999; Riggio, 2005). Uhl-Bien (2004), for example, suggests that a leader's nonverbal communication skills are crucial for building effective leader-member relationships. Berger (1985) even suggests:

> . . . nonverbal behaviors are more significant in determining the experience of power than are variables related to verbal content. One conclusion to be drawn here is that failure to take into account nonverbal behavior in the study of communication and power relationships is to doom oneself to study the tip of a very large iceberg (p. 483).

The most prominent concept in leadership settings that is closely tied to nonverbal communication is that of charismatic leadership: the specific behavior of a leader is seen as a crucial variable (Friedman, Prince, Riggio, and DiMatteo, 1980). Patterns of nonverbal behavior that convey a sense of a leader's enthusiasm and confidence are emphasized as particularly important (Riggio, 1987). According to Cherulnik, Donley, Wiewel, and Miller (2001), charismatic behavior is characterized by nonverbal expressiveness and immediacy. As already posited by Weber (1921/1946), this is efficient because a charismatic leader elicits emotional arousal in followers. The phenomenon of emotional contagion is thus seen as a possible mediator for how the nonverbal expressiveness of a leader positively affects the followers. This view holds that the observation of a leader's facial displays leads to the automatic mimicry of facial movements and subsequently—due to the interlinkage of facial muscles and brain regions associated with emotions (see facial feedback theory, Zajonc, Murphy, and Inglehart, 1989)—to the corresponding feelings in followers.

It has been demonstrated empirically that people do indeed react with corresponding emotions to televised emotional expressions of political leaders (Masters and Sullivan, 1993). However, in line with the assumptions discussed above, the interrelationship of a leader's nonverbal behavior, a viewer's emotions, and lasting attitudes is extraordinarily complex: Masters and Sullivan (1993) identify at least 16 different variables that seem to moderate followers' reactions to watching a political leader. Also, Cherulnik, Donley, Wiewel, and Miller (2001) have shown that charisma is contagious: in one laboratory study using televised presidential debates, they showed that at least the nonverbal behavior is contagious—but only if the leader exhibits truly charismatic behavior.

Another approach that is used to explain leadership behavior is the model of the bases of social power by French and Raven (1959). Collins and Raven (1969) state that social influence and power might be based on (1) reward (resulting from the ability to provide positive reinforcement), (2) coercive power (reflecting the potential to exert punishment), (3) referent power (based on the relationship of influencer and influencee in terms of respect and esteem), (4) legitimate power (based on authority recognized in accordance with position in an organizational structure), (5) expert power (form of referent power resulting from recognized expertise), or (6) informational power (variation of legitimate power resulting from the ability to control the availability of information).

Leaders thus might refer to different power bases and influence followers either by rapport (referent power), power (legitimate power), or incentives (reward/coercive power). In order to work in everyday interactions, these power bases necessarily have to be accompanied by adequate nonverbal behavior. However, little is known about the nonverbal correlates of these types of social power. Bente (1984) demonstrated that coercive and expert powers are accompanied by increased general head movement activity, while referent power is characterized by a head movement activity that is less than average. In contrast, Krämer (1997) showed that coercive behavior is accompanied by decreased sagittal head (up and down) movements, while sagittal movement is increased when referent power is exerted.

With regard to influence and persuasion and their connection to nonverbal communication, there is also less research than one would expect. A meta-analysis of 50 studies indicates that gaze, touch (i.e., light touch on a person's upper arm or shoulder), moderately close distances, and professional clothing are associated with successful compliance (e.g., with regard to signing a petition, loaning money, etc.) (Segrin, 1999). More surprisingly, there is evidence that verbal compliance techniques to achieve compliance are no more effective than nonverbal.

Apart from these approaches there is a large body of research not directly connected to leadership but to the concept of dominance. Burgoon and Bacue (2003, p. 200) argue that "Nonverbal behavior is a major avenue for communicating power, dominance, and status in everyday interactions and may even form a universally recognized vocabulary by which a given social community interprets and expresses privilege and control."

According to Dunbar and Burgoon (2005b) and Burgoon and Bacue (2003), dominance can be conceptualized as the behavioral manifestation of the relational construct of power—the latter being defined as the capability to produce intended effects. Unlike Rollins and Bahr (1976), who originally argued for a linear relationship between dominance and power, Dunbar and Burgoon (2005b) assume a curvilinear relationship: partners who perceive their power as extremely high or low will use fewer control attempts and dominance behaviors than partners who perceive their partner as of similar power as themselves.

Furthermore, Burgoon and Dunbar (2000) model interpersonal dominance as a dynamic, situationally contingent social skill. They empirically verify the notion that there are strong commonalities between the communication style of socially skilled people and interpersonal dominance by demonstrating that people with greater self-reported social skills are perceived as more dominant. People who are both socially skilled and dominant are better than less skilled and dominant people at expressing themselves verbally and nonverbally, at controlling their presentations to foster a favorable impression, and at conveying confidence, friendliness, and dynamism. This relationship is seen as resulting from the fact that, in Western culture, dominance is evaluated positively: "Preference is given to the dominant rather than the submissive end of the behavioral continuum" (Burgoon and Dunbar, 2000, p. 116).

Other work also supports the assumption that dominance displays are adapted to communicative circumstances and thus supports the view of interpersonal dominance as a situationally and relationally contingent social skill. In contrast, however, work by Driskell and Salas (2005) and others (Carli, LaFleur, and Loeber, 1995; Driskell, Olmstead, and Salas, 1993) suggests that dominance behavior is a generally ineffective influence tactic in groups and leads to negative evaluations from others, such as incompetence, resentment, and dislike. The approach of Kalma, Visser, and Peeters (1993) might provide a possibility to integrate the different results: they distinguish sociable dominance (characterized by positive social relationships) and aggressive dominance (low on socioemotional leadership) and give evidence that these two groups differ with regard to nonverbal behavior. Socially dominant people look more directly at the person speaking, use more gesticulation (which according to Freedman [1972], represents a strong communicative intention), and show prolonged gaze pattern during turn taking—thus indicating more directly from whom they expect a reaction. In leadership contexts, sociably dominant people using these kinds of immediacy signals thus seem to possess the capacity to influence followers by referent power and building rapport. Thus, they can be expected to be successful relationship-oriented leaders (see Michigan studies that differentiate relationship-oriented and task-oriented styles, Likert, 1961), and successful with "consideration" instead of "initiating structure" style (see Ohio state studies, Fleishman, 1953).

In general, there has been extensive research on which nonverbal cues signal dominance, which is summarized briefly below: for comprehensive overviews, see Anderson and Bowman (1999), Burgoon, Buller, and Woodall (1989), Dunbar and Burgoon (2005b), and Krämer (2001). According to Burgoon et al. (1989), the literature is organized by channel/code—including face, kinesics, proxemics and haptics, and gaze—because most of the research has targeted one or two isolated behaviors and their correlation with status, dominance, or dominant personality traits.

Face It has been found that the absence of a smile and lowered brows, in terms of a stern, angry face, convey dominance (Bucy, 2000; Edinger and Patterson, 1983; Henley, 1977; Keating, 1985; Keating, Mazur, and Segall, 1977; Mehrabian and Williams, 1969). It is still controversial, though, whether smiling is actually related to submissiveness (pro: Burgoon and Bacue, 2003; Edinger and Patterson, 1983; Henley, 1977; Keating, 1985; Keating and Bai, 1986; Keating, Mazur and Segall, 1977; contra: Aries, 1987; Carli et al., 1995; Hall, 1984; Hall and Halberstadt, 1986; see also LaFrance and Hecht, 1999).

Kinesics The kinesic cues that have been shown to communicate dominance are the so-called relaxation cues, e.g., a backward or sideward lean, relaxed hands, asymmetry of arms (Mehrabian, 1969a, 1969b, 1972). However, most of the cues have not been verified in other studies (Aguinis, Simonsen, and Pierce, 1998; Carli et al., 1995). Other cues that have been identified to be related to dominance are physical activity, frequent and expansive gestures, and dynamic expressive displays (Henley, 1977; Mehrabian, 1969b; Mehrabian and Williams, 1969; Remland, 1982).

Proxemics and Haptics According to Burgoon and Bacue (2003), proxemics and haptics work in tandem: both convey dominance when personal space is invaded and when these signals are unreciprocated (Remland, 1982). Thus, power and control are communicated through the initiation of touch (Burgoon and Saine, 1978; Henley, 1977; Patterson, Powell, and Lenihan, 1986), and more dominant people claim larger territories as others keep a distance from them (Meharbian, 1969b).

Gaze Results with regard to gaze are ambiguous: some studies suggest that dominant people look more (Thayer, 1969; Strongman and Chapness, 1968), and other studies demonstrate that submissive people gaze more at dominant people (Exline, 1972). The different results have been integrated in a model that takes accounts of the importance of speaker role: dominant people show a higher looking-while-speaking to looking-while-listening ratio (Dovidio, Ellyson, Keating, Heltman, and Brown, 1988; Exline, Ellyson and Long, 1975). Dominant people thus "can stare more but have to look less" (DePaulo and Friedman, 1998, p. 12). In a study of a military organization, Exline et al. (1975) found that cadets who paid visual attention to low-status persons were rated low in status. They concluded that "one is not obligated to look at lower-status persons and may actually lose status by doing so" (p. 323).

Although research has thus identified various cues that indicate dominance, Dunbar and Burgoon (2005b) aptly advise to be cautious and not infer the effects on a perceiver just from one cue: "dominance is a multifaceted construct that can be demonstrated interactively in many ways and whose meaning depends on the context and the perceiver" (p. 228). One of the most important weaknesses of all the research, however, is its ethnocentricity: most studies have been conducted in the United States and Europe. To the extent that the studied behavior patterns are not universal, the results may not be found in other cultures.

In sum, it can be stated that there are some results on cues that demonstrate dominance, but the current knowledge does not allow for the proposal of rules for optimal behavior. And given that subtle dynamics might play an important role, it can even be questioned whether such "rules" would be useful at all. Nevertheless, most approaches (charismatic leadership, Burgoon's work on dominance, results on persuasion) suggest that expressive and immediate nonverbal behavior is the most effective—at least when practicing relationship-oriented leadership. Also vital in this context might certainly be leaders' abilities to adequately interpret the nonverbal cues of their followers. The general result that sensitivity to nonverbal cues can determine social success is described in the next section, on effective communication.

Effective and Ineffective Communication

If any results on effective nonverbal communication are soundly based, they are largely centered on social skills and rapport. Gesturing and expressivity have been demonstrated to be the most significant predictors of rapport and social skills (Bernieri et al., 1996; see Dunbar and Burgoon, 2005b). Bernieri et al. (1996, p. 124) conclude:

> What is expressive is good. People who gesture and talk a lot are judged to be gregarious, dominant, not lazy, motivated, and socially skilled. . . . People who smile and are talkative are warm and not quarrelsome. It is

> not any wonder that expressivity has been considered synonymous with charisma.

In the literature, the result is pervasive: expressive people are successful communicators and they are reliably more extraverted, dominant, impulsive, playful, and popular (Dunbar and Burgoon, 2005b; DePaulo and Friedman, 1998). Expressivity leads not only to increased attribution of attractiveness (DePaulo, Blank, Swain and Hairfield, 1992), but also reliably affects every interaction:

> Expressiveness instantly makes a difference in setting the tone of social interactions. Studies of commonplace interpersonal behaviors such as walking into a room and initiating a conversation (. . . or greeting someone who is approaching. . .) suggest that this social skill is immediately influential (DePaulo and Friedman, 1998, p. 13).

Moreover, Feldman, Phillipot, and Custrini (1991), in a review on social competence and nonverbal behavior, show that not only these encoding but also decoding skills can be viewed as a manifestation of social competence. According to various results, sensitivity to nonverbal cues can determine social success: teachers, therapists, and foreign service officers who score higher with regard to decoding ability are more talented at their jobs (Rosenthal et al., 1979). Doctors who are good at reading body cues have even been shown to have more satisfied patients (DiMatteo, Hays, and Prince, 1986). Thus, in sum:

> Research indicates that individuals who exhibit nonverbal skills . . . tend to have more academic and occupational success, larger and more effective social networks . . ., more satisfying marriages, and decreased levels of stress, anxiety and hypertension (Burgoon and Bacue, 2003, p. 208).

Another research realm closely related to effectiveness of communication and its behavioral correlates is that of interactional synchrony or mimicry. Various terms are in use: reciprocity and compensation (Argyle and Cook, 1976), mirroring (Bernieri and Rosenthal, 1991), conversational adaptation (Burgoon, Dillman, and Stern, 1993), simulation patterning (Cappella, 1991), synchrony (Condon and Ogston, 1966), congruence (Scheflen, 1964; Kendon, 1973), motor mimicry (Bavelas, Black, Chovil, Lemery, and Mullett, 1988; Bavelas, Black, Lemery, and Mullett, 1986; Lipps, 1907), and accommodation (Giles, 1980; Giles, Mulac, Bradac, and Johnson, 1987; for a review, see Manusov, 1995; Wallbott, 1995).

Wallbott (1995) gives a comprehensive definition of the phenomenon: "the tendency to exhibit such nonverbal (and verbal) behaviors that resemble those of our interaction partners, when we evaluate them positively or when we want to be evaluated positively by them" (p. 93). This definition already includes the notion that interactional synchrony is associated with rapport or positive evaluations of the interaction partner. Drawing on Tickle-Degnen and Rosenthal (1987), who theoretically linked interpersonal coordination, attentiveness, and positivity to rapport, Bernieri and Rosenthal (1991) show that people coordinate their behavior to a greater degree when interacting with others whom they like. Also, interactional synchrony has been found to be an important predictor of self-reports of rapport (see also Bernieri, Gilles, Davis, and Grahe, 1996; Hess, Philippot, and Blairy, 1999; LaFrance, 1982; Scheflen, 1964). Moreover, in recent approaches that conceptualize mimicry in line with social cognition assumptions of automaticity as nonconscious, passive, and unintentional (Chartrand and Bargh, 1999; Van Baaren, Holland, Kawakami, and van Knippenberg, 2004), it was demonstrated that mimicry facilitates the smoothness of interactions, increases liking between interaction partners, and fosters prosocial behavior. Kendon (1970), as well as Condon and Ogston (1966), however, did not show that synchrony is associated with positive evaluation, but is rather due to similarities in attitudes and mimicking of superior persons.

But a word of caution is in order: studies using more sophisticated or innovative methods indicate that it is worthwhile to analyze the phenomenon closely (i.e., considering subtle aspects of nonverbal behavior and their precise timing). Using time-series analysis, Cappella and Planalp (1981) demonstrated that reciprocal influence exists with regard to *matching* but also with regard to *compensation*. Grammer, Kruck, and Magnusson (1998), by means of a sophisticated search algorithm (see below), showed that synchronization in gender-heterogeneous dyads does not necessarily have to be directly observable but shows in rhythmic patterns. "Highly complex patterns of behavior with a constant time structure" (p. 3) are idiosyncratic for the dyad and indicate interest for the partner.

Conclusion: What Isn't Known?

When looking at the findings cited above, it can be said that a satisfying amount of knowledge is available—at least with regard to cultural differences concerning flamboyant cues, nonverbal correlates of dominance and the immediacy cues necessary to build rapport. Yet it is apparent that detailed knowledge is lacking, for example, with regard to the exact cues and movements that indicate dominance or expressivity. Actually, most research on cultural and social influence, as well as on leadership and effectiveness, has not yet taken into account that nonverbal communication largely relies on subtle, dynamic patterns and specific movement quality (see above). Instead, research has focused on single cues—such as posture, smiling, and proxemics—that are assessed easily while ignoring their dynamic, temporal attributes. Especially with regard to the research targeting behavioral correlates of effective communication, it has become clear that merely considering the exact pattern of mutual influence might unravel the antecedents and consequences of interactional synchrony and mimicry.

Moreover, the different research domains have rarely been connected to each other or across cultures. Neither nonverbal communication in the context of leadership nor behavioral characteristics of effectiveness have been studied in cultures outside North America and Europe. The results can thus hardly be generalized to humankind. For example, there are no data on appropriate leadership and dominance behavior for Asia or Middle East—let alone with regard to subtle dynamics. In consequence, it is unknown whether charismatic behavior would be efficient when communicating cross-culturally. Indeed, the fact that immediacy behaviors in some cultures are experienced as inappropriately direct (see above) suggests that at least some cultures would be repelled by charismatic behavior. Also, leadership and efficiency of behavior have—except for the area of charismatic behavior—rarely been connected. For example, the characteristics needed to lead efficient negotiations (possibly cross-culturally) have not been studied with regard to single cues, not to mention subtle movement qualities.

RESEARCH METHODS AND TECHNOLOGIES

Given the complex nature of nonverbal communication, one has to carefully select the research methods capable of capturing all relevant aspects. When planning to study the *structure* of nonverbal communication (e.g., of two people interacting), it is essential to take time into account (see below). When trying to unravel the *effects* of nonverbal cues, one should keep in mind that these effects depend heavily on context and that nonverbal behavior is often produced and perceived automatically and without the individual's awareness (see below).

Assessment of Nonverbal Behavior and Subtle Dynamics

Being aware of the complexity of nonverbal communication, Monge and Kalman (1996) stress the importance of methods that take into account that nonverbal behavior is a process that develops over time: "Human communication is a dynamic, unfolding process. . . . The passing of time is so integral to communication, a facet of living experience always so ready at hand, that it tends to escape scrutiny in its own right as a dimension of analysis" (p. 71). Cappella and Palmer (1990) point out that specific relations with regard to the dynamic interaction of two conversation partners (as discussed above) might be detected only when measuring on a timeline: ". . . in order to understand when covariation is truly simultaneous, rather than simply occurring in the same interaction, one needs to have temporal data" (p. 144). Nevertheless, most studies have relied on distributional instead of temporal data (see Cappella and Palmer, 1990).

One of the few instruments for measuring human movements in a highly detailed manner over time is the Bernese System for time-series notation (Frey et al., 1983; for an overview, see Donaghy, 1989). Using a video recorder, a human coder annotates the position of every part of the body at predefined intervals (most commonly every 0.5 seconds). Now, automatic tools like motion capturing devices can also be used for assessing behavior. It has been shown that the subsequent analysis yields meaningful results that are similar to those gained by the Bernese System (Altorfer, Jossen, and Würmle, 1997). In order to focus on the assessment of behavioral dynamics, Grammer, Filova, and Fieder (1997) developed an automatic videoanalysis tool called *Automatic Movie Analysis*. By image differencing (Sonka, Hlavac, and Boyle, 1993), the successive images of a video are compared in order to identify the amount of movement. Thus, motion energy (i.e., the intensity of movements) is assessed.

For the analysis of the resulting data, multivariate time-series procedures have been proposed. Cappella (1996) highlights the benefits of these methods:

> Time series procedures can unravel signal from noise and detect and quantify the relationship between the partners' behaviors. Without such procedures, it would be almost impossible to know about the presence, type, and magnitude of adaptation behaviors (p. 382; see also Cappella and Flagg, 1992; Monge and Kalman, 1996).

Grammer, Kruck, and Magnusson (1998) propose the pattern detection software THEME that identifies complex significant patterns within the behavior, given that the temporal process has been assessed adequately.

Avatars and Agents as Tools

With regard to studying not the *structural aspects* of nonverbal behavior but the interpersonal *effects* of specific cues, other problems arise. An experimental approach would be the preferred choice but employing confederates or actors who vary particular aspects of their nonverbal behavior is problematic, because most nonverbal behaviors are not consciously controllable. For example, Lewis, Derlega, Shankar, Cochard, and Finkel (1997) showed that the experimental variation of touch behavior was confounded by simultaneous variations in other nonverbal channels. They concluded that:

> in spite of specific instructions to keep nonverbal behavior consistent, confederates in the touch versus no touch condition displayed different behaviors. Confederates who touched used more nervous gestures and

fewer expressive hand gestures compared to those who did not touch (Lewis et al., 1997, p. 821).

Other investigators have tried to solve such problems by using photos, drawings, or puppets that could be controlled more easily and precisely than actors (Frey et al., 1983; Schouwstra and Hoogstraten, 1995). Despite some seemingly encouraging results, all these studies have been restricted to the investigation of static and easily manipulated features of nonverbal behavior, such as postures or positions of specific body parts.

Currently, it would appear that the only possible way to study the effects of dynamic behavior lies in the use of human-like virtual persons, such as agents and avatars, whose behavior can be controlled systematically (Bente, Krämer, Petersen, and de Ruiter, 2001; Blascovich et al., 2002). The rest of this section presents current approaches and their prerequisites.

Current Approaches

Three approaches to advance knowledge in the realm of nonverbal communication are described here: (1) the use of protocol-based, computer-animated virtual figures to conduct systematically controlled experimental research; (2) a computer simulation approach that exploits the implementation of current knowledge for basic research on gestures; and (3) the use of avatars to manipulate real social interactions in the "transformed social interaction" approach.

In the first approach, the movements of humans (that have either been coded by means of the Bernese System or recorded by motion capture devices) are transferred to computer animated virtual figures (Bente, Krämer, Petersen, and de Ruiter, 2001; Bente, Petersen, Krämer, and de Ruiter, 2001). The transcript can then be systematically varied with regard to every aspect of posture or movement quality. Subsequently, the animated figures can be presented in an experimental setting. The results are promising. In two studies, head movement activity was manipulated by a speed-up algorithm. The results showed a significant effect of the increased head movement activity on observers' impressions, but also showed that effects are context-dependent: in casual interactions, increased activity is rated as positive; in interactions that involve interpersonal conflicts, increased movements are evaluated more negatively (Krämer, 2001). In a later study it turned out that similar changes in gesture activity—even when more pronounced—did not change observers' impression to the same degree (Krämer, Tietz, and Bente, 2003). Similarly, in order to test for the factors decisive for the perception of genuineness of smiles, Krumhuber and Kappas (2005) produced virtual smiles that differed with regard to their dynamic attributes.

In classical approaches of computer simulation, a top-down approach, rules of nonverbal communication are implemented, and it is tested whether virtual agents in consequence show natural behavior (Cassell et al., 1994, 1999). In this approach, in order to be able to produce nonverbal communication, one has to know relevant rules. Cassell et al. (1994) succeeded in implementing aspects of the gesture-speech relationship and thus praise the methodological benefits of this approach: "The advantage of computer modeling in this domain is that it forces us to come up with predictive theories of the gesture-speech relationship" (p. 1). They conclude:

> Most research on gesture has been descriptive and distributional. With the evidence available, it is time to attempt predictive theories of gesture use. . . . Formal models such as ours point up gaps in knowledge, and fuzziness in theoretical explanations (Cassell et al., 1994, p. 10).

In a similar way, Pelachaud, Badler, and Steedman (1996) model the integration of speech-accompanying facial displays (e.g., eyebrow movements), paralanguage, and lip synchronization. Their summary of the benefits also indicates that a combination of first and second approaches is conceivable:

> Our model can be expected to help further research of human communicative faculties via automatically synthesized animation. In particular, it offers to linguists and cognitive scientists a tool to analyze, manipulate, and integrate several different determinants of communication. Because our program allows the user to switch each determinant on and off, the function and the information that each of them provides can be analyzed (p. 34).

In the third approach, Blascovich et al. (2002) propose immersive virtual environment technology (IVET) as an innovative paradigm within experimental social psychology. The use of virtual figures in immersive environments is seen as an opportunity to increase both experimental control and mundane realism. Summarizing the benefits, they state:

> Investigators can take apart the very fabric of social interaction using IVET, disabling or altering the operation of its components thereby reverse engineering social interaction. With this approach, social psychologists could systematically determine the critical aspects of successful and unsuccessful social interaction, at least within specified domains and interaction tasks (p. 47).

Most of the research of the group has been conducted with avatars, that is, virtual figures that transmit the nonverbal behavior of a human interaction partner. Using so-called transformed social interaction, Bailenson, Beall, Blascovich, Loomis, and Turk (2005) demonstrated that experimentally augmented gaze leads to increased social influence (see also Bailenson and Beall, 2006; Bailenson, Beall, Loomis, Blascovich, and Turk, 2004). Experiments analyzing the factors that affect proxemic behavior have also been conducted with avatars (Bailenson, Blascovich, Beall, and Loomis, 2001, 2003).

Prerequisites for Using Agents and Avatars

The most important prerequisite for using virtual persons for basic research on the effects of nonverbal behavior is that they evoke impressions and attributions that are similar to those of real humans. Especially with regard to the perception of the human observers, there should be minimal or preferably no discrepancies between live and virtual stimuli. Indeed, Bente, Krämer, Petersen, and de Ruiter (2001) have shown that virtual figures are liable to the same person perception processes as videotaped humans: when the movements of the latter are transferred to virtual figures and presented without speech, person perception ratings do not differ from those of the original humans. Moreover, virtual persons who show social facial expressions, such as smiling or eyebrow raising, lead to an activation of the same brain regions as those triggered by human-human interaction, while meaningless facial movements did not result in their activation (Schilbach et al., 2006).

While both results can merely be generalized to person perception when being in an observer role (see Patterson, 1994, pleading that social interaction consists of both person perception and behavior production simultaneously), other studies show that virtual figures also evoke human-like responses when an interaction between human and virtual entities takes place. An increasing number of studies gives evidence that (in part) autonomously acting embodied conversational agents (see Cassell et al., 2000; Gratch et al., 2002; Moreno, Mayer, Spires, and Lester, 2001) evoke social effects that are similar to those induced by human-human interaction (Krämer, 2005; Krämer, in press; Krämer and Bente, 2007; Nass and Moon, 2000). Agents have been observed to increase attentiveness (Takeuchi and Naito, 1995), invite intuitive interaction (Krämer, 2005), evoke impression management and socially desirable behavior (Sproull et al., 1996; Krämer, Bente, and Piesk, 2003), and foster social facilitation or inhibition (Rickenberg and Reeves, 2000; but see also Hoyt, Blascovich, and Swinth, 2003). In this vein, Bailenson et al. (2001) summarize the results of one of their studies: “Participants in our study clearly did not treat our agent as mere animation” (p. 595).

In general, it can therefore be concluded that virtual figures induce social effects as well as real people do and evoke similar feelings and experiences—regardless of whether they are observed or whether one interacts with them. Hence, they can be assumed to be important and useful tools for studying human social behavior within innovative research approaches.

Barriers to Advancing Scientific Progress

As depicted in the first section of this paper, nonverbal communication is extremely complex; thus its own attributes complicate research. Yet there are adequate methods to study subtle dynamics, movement qualities, interaction patterns, and effects of cues and patterns. The most important barrier to scientific progress thus seems to be that those methods are not used by all research groups analyzing nonverbal communication. In some cases, this lack of use may be due to the fact that many of them, especially tools for the assessment and analysis of detailed temporal data, are extremely laborious and complex. However, the lack of exchanges between different research groups might also be a cause. In fact, there are almost no exchanges across interdisciplinary boundaries: for example, scholars from biology and psychology (mostly focusing on emotional communication), from communications and, most recently, from computer science rarely compare methods and findings.

Another barrier to progress might be that this research realm still lacks approval from other scientific areas and disciplines. It should be apparent that nonverbal communication is very complex and requires sophisticated scientific methodology, but it may still be suffering from a reputation based on pseudoscientific literature and early simplistic assumptions of public opinion.

APPLICATIONS: GAPS BETWEEN SCIENCE AND IMPLEMENTATION

Probably the most important application area for findings with regard to nonverbal communication is the training of nonverbal decoding and encoding skills. Especially the ability to establish rapport is of great interest for many professions, as Bernieri and Rosenthal (1991) stress:

> Interpersonal coordination and synchrony may eventually explain how it is that we can "hit it off" immediately with some people and never "get it together" with others. This aspect of rapport certainly would be of concern to professions dealing with intimate personal relations. The success of psychotherapists, physicians, counselors, and teachers all depend to some extend on the degree of rapport they can achieve in their professional interactions (p. 429).

Clearly, one of the reasons for the gap between science and application is that all the complex phenomena still have not been analyzed and understood sufficiently. But other factors also play a role. With regard to decoding abilities, studies indicate that training is, in principle, feasible: Feldman, Philippot, and Crustrini (1991) trained children by providing them with feedback on how they were doing while decoding happiness, sadness, and fear from photographs. Indeed, children who had been provided with feedback proved to be more successful (but merely with regard to the recognition of fear) than a control group. However, this does not verify the authors' claim that social competence is increased. Since only photos had been presented, the results can hardly be generalized to the nonconscious decoding of subtle movement quality. Another aspect of this work is also questionable: given the assumptions of Patterson (1994), a realistic training situation should always comprise not only decoding, but also production of behavior since in real-life encounters both processes mutually affect each other.

Similar problems arise with regard to the training of encoding aspects, i.e., production on nonverbal behavior. As discussed above, at least with regard to emblems and other demonstrative cues, successful trainings (e.g., with regard to cross-cultural communication) have been conducted. Work aspects that can be learned and produced consciously ("do not back away when the Arabic interlocutor stands nearer than you would choose him to") are considered, but every behavior that might not be produced consciously is excluded from the training.

From what is known, several requirements for training that takes into account the specific qualities of nonverbal communication are clear:

- realistic setting that requires both decoding and encoding;
- immediate feedback (preferably by nonverbal rewarding and coercive signals by the training partner); and
- feedback that is given not only with regard to demonstrative cues, but also with regard to the appropriateness of subtle aspects, such as movement quality.

A promising possibility to achieve such training might be the use of virtual environments and virtual training partners (for similar suggestions, see Isbister, 2004). In such a setting, different interaction settings can be provided, a trainee's movements can be analyzed with regard to their appropriateness, and immediate feedback might be provided by subtle reactions of the virtual interaction partner. Thus, success or failure would not be explained and learned consciously but trained more subtly. As described above, this approach at least meets the prerequisite that human interlocutors evoke similar reactions as real humans do. First developments in this direction are presented in the "mission rehearsal exercise" (Swartout et al., 2001; Rickel et al., 2002) and other applications (Beal, Johnson, Rabrowski, and Wu, 2005). Especially with regard to the training of subtle aspects of nonverbal behavior, though, there is still a long way to go.

Future applications with virtual agents might be useful in overcoming the pitfalls of, for example, cross-cultural communication in a more direct sense. Once more detailed knowledge on the effects of behavior patterns in different cultures is available, agents might serve as digital mediators and translators of nonverbal cues in Internet-based interactions (see the similar approach of Isbister, Nakanishi, Ishida, and Nass, 2000)—transmitting a sender's nonverbal behavior in a version that is more appropriate for a perceiver's cultural background. While this scenario is already feasible for translation of verbal aspects (see Narayanan et al., 2003), research on the implementation of culture-specific behavior of agents is merely beginning (Traum et al., 2005).

Another field of application for findings on nonverbal communication are embodied conversational agents for human-computer interaction or pedagogical agents (Cassell et al., 2000; Moreno, Mayer, Spires, and Lester, 2001). In this approach, the implementation of adequate nonverbal behavior might contribute to facilitating human-computer interaction. In particular, pedagogical agents are expected to raise a learner's motivation due to the use of nonverbal behavior (Lester et al., 2000; Rickel and Johnson, 2000).

Although Moreno (2001; Moreno, Mayer, Spires, and Lester, 2001)—at least with regard to specific applications—shows that the voice might be more important than nonverbal cues (see also Craig, Gholson, and Driscoll, 2002), nonverbal cues can still be assumed to be largely influential (Krämer, in press). Thus, advances in the area of nonverbal communication might directly serve the advancement of efficient human-computer interfaces. Moreover, embodied agents can in themselves be a valuable research tool with regard to basic research on nonverbal communication (as discussed above).

In order to be able to eventually realize the applications discussed here, more basic research on the structure and effects of nonverbal communication in specific settings has to be conducted. Below, several examples for major research questions are given that are feasible to study by means of the methods discussed in the previous section:

- Are there cultural differences with regard to subtle dynamics and movement quality?
- What exactly happens in cross-cultural communication? Is behavior automatically varied or adapted on any level (e.g., with regard to movement quality)?

- What exactly constitutes expressiveness, given that it is an important aspect of efficient communication and supports relationship-oriented leadership? By which means can it be trained?
- Is expressive behavior evaluated positively across cultures?
- What nonverbal behavior patterns are most efficient in different leadership situations, especially with regard to task-oriented leadership, which is under-researched in comparison with relationship-oriented leadership?

CONCLUSION

Recent research has demonstrated that nonverbal communication is a complex phenomenon that is characterized by context dependency, the importance of movement quality, and subtle dynamics, as well as automaticity, that is, a production and perception largely outside awareness. However, most research on factors that influence nonverbal communication (e.g., culture, social situation, leadership setting) has not yet taken these aspects into account; rather it has focused on superficial aspects and single cues. Moreover, the different research domains have not been sufficiently connected, thus leaving unanswered the question of whether the effects of specific cues and patterns identified in Western culture will also be found in other cultures. Given that the availability of appropriate methods for analyzing both the structure of communication (with time-series notation and analysis) and the effects of cues and movement qualities (using computer-animated figures such as agents and avatars), further advances can be expected. However, the most important prerequisite for efficient research will be to pool the expertise of different disciplines—especially with regard to the potential synergies of innovative methods.

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The Science of Emotion: What People Believe, What the Evidence Shows, and Where to Go From Here

Lisa Feldman Barrett

As common sense has it, emotions are triggered automatically, happen *to* people, and cause them to act in specific and diagnostic ways. An offense triggers anger. A death triggers sadness. A gun triggers fear. As the pent-up energy of an emotion is discharged, the result is a largely inescapable set of stereotyped outputs that occur rapidly, involuntarily. People feel the heat of anger and attack, the despair of sadness and cry, or the dread of fear and freeze—or even run away. The given quality of a person's own experience, and the way that emotion seems to control behavior without awareness, is usually taken as proof that emotions are automatic responses to things that happen in the world over which people have little control. Knowledge, expectations, and beliefs seem to have little impact on emotion, although they can regulate a response once it has been triggered. As a consequence, people assume that emotions can overcome them, rapidly overriding whatever else they might have been doing, thinking, and feeling. Regulation, if it occurs at all, happens later, after the emotion has taken hold. Anger, sadness, and fear causes behavior, just as lightning causes thunder.

This folk conception of emotion—with varying degrees of elaboration and complexity—forms the basis of a consensual view that guides the scientific study of emotion. Despite the differences in their surface features, the most prominent models of emotion incorporate the intuition that emotions are automatic syndromes of behavior and bodily reactions. Those models

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also share a common set of beliefs about the nature of emotion: emotions are categories with firm boundaries that can be observed in nature (i.e., in the brain or body) and are therefore recognized, not constructed, by the human mind. People know an instance of *anger* when they see it in the face, voice, or body of another person or feel it in themselves.

In this paper I argue that despite the general importance of emotion in the science of the mind and the ever increasing pace of research on emotion, knowledge about emotion has accumulated more slowly than for other comparable concepts, such as memory or attention, because the acceptance of these commonsense assumptions are not warranted by the available empirical evidence. I then consider what moving beyond a commonsense view might look like and what it would mean for the scientific study of emotion.

A BRIEF HISTORY

The Accepted History

The received wisdom in psychology is that the science of emotion began with a golden age, with Darwin's (1859/1965) publication of *Expressions of the Emotions in Man and Animals*, where he wrote that emotions cause stereotypic bodily expressions. Darwin's book was followed by James' 1884 critique, *What Is an Emotion*?, in which James argued that bodily activity causes emotion, not the other way around. James, in turn, was criticized by Cannon in his 1927 paper, *The James-Lange Theory of Emotions: A Critical Examination and an Alternative Theory*, in which Cannon argued that the body cannot cause emotion because visceral changes are too slow and too difficult to feel and that the same visceral changes occur in both emotional and nonemotional states. Psychology, the story goes, by then in the grip of behaviorism, sank into the dark ages and did not produce anything worthwhile on the topic of emotion for about 40 years, except for some important neurobiology papers by Papez (1937) and MacLean (1949).

In the conventional story, a renaissance period then emerged in the 1960s, first with Magda Arnold's 1960 *Emotion and Personality*, followed by Tomkins 1962 and 1963 books on *Affect-Imagery-Consciousness.* Schachter and Singer's 1962 paper, *Cognitive, Social, and Physiological Determinants of an Emotional State,* was also published around this time. According to many, these works rescued the scientific study of emotion from the abyss of behaviorism and launched the modern era of scientific research on emotion.

Sylvan Tomkins became the inspiration for what has been called the "basic emotion" approach. Basic emotion models share the core assumption that there are certain biologically privileged kinds of emotion. Each kind of emotion issue is thought to come from a dedicated neural program or circuit that arose through evolution and is hardwired into the human brain at birth. These circuits are homologous with those found in nonhuman mammals, and they are responsible for the automatic syndrome of hormonal, muscular, and autonomic effects that constitutes the distinctive signature for that kind of emotional response. In essence, the basic emotion approach is a commonsense view of emotion.

Arnold, along with Schachter and Singer, it is said, launched what is called the appraisal approach to emotion. The core assumption of appraisal models is that a person's interpretation of an event or situation is necessary for an emotional response; emotions are not triggered merely by a stimulus in a reflexive or habitual way. In Arnold's terms, a meaning analysis is performed on the situation that is thought to evoke or triggers emotion. In Schachter and Singer's terms, a meaning analysis is performed on a general state of arousal in the body to render it meaningful. The initial empirical evidence for the Schachter and Singer (1962) model was weak at the outset (Reisenzein, 1983), so that Arnold's version of appraisal theory became formative for the majority of appraisal models that followed (e.g., Scherer, 1984; Frijda, 1986; Roseman, Spindel, and Jose, 1990).

Revising History

From a certain vantage point, the conventional history is accurate. Tomkins, Arnold, and to a lesser extent, Schachter and Singer, did have an enormous influence on shaping modern scientific thinking about emotion. But the accepted history of the field has itself been shaped by commonsense, while the actual historical record is more complicated, and more interesting. For example: Darwin did not emphasize the functionality of emotion; he argued that the facial behaviors associated with internal emotional states (what he called "emotional expressions") are often vestiges of the evolutionary past, like a tailbone or an appendix. The emphasis on functionality came later (Allport, 1924). William James may have inspired a century of research whose goal was to uncover the invariant autonomic nervous system (ANS) and behavioral patterns that corresponded to anger, sadness, fear, and several other emotions, but he did not, in fact, argue for *one* invariant biobehavioral pattern for each emotion category. "Surely there is no definite affection of anger in an entitative sense" (James, 1894, p. 206). When James stated that distinct physiologic and behavioral patterns produced an emotional feeling, he meant a specific instance of emotion (e.g., an instance of anger) was distinct from other instances, as long as it feels distinct.

Arnold explicitly relied on commonsense in crafting her model of emotion (Arnold, 1960, Ch. 1) and believed, following basic emotion models, that anger, sadness, fear, and so on are different biological kinds that, in essence, are grounded in distinct behaviors. Arnold's particular brand of appraisal model and those she inspired have a lot more in common with basic emotion models than is commonly assumed (see Barrett, 2006a; Barrett, Mesquita, Ochsner, and Gross, 2007). Arnold wrote:

> For each emotion, there is a distinct pattern that remains more or less constant and is recognized as characteristic for that emotion. . . . Whether we are afraid of a bear, a snake, or a thunderstorm, our bodily sensations during these experiences are very much alike . . . there will always be a core that is similar from person to person and even from man to animal (Arnold, 1960, p. 179).

Appraisals were imbued with the power to diagnose objects or situations as personally relevant and were given responsibility for triggering emotions that pre-exist within the individual.

Most important, the dark ages in emotion science never really existed. From 1900 to the 1970s, many papers and books were published on the topic of emotion. However, they were rooted in assumptions by Wundt (1897) and had a decidedly non-commonsense flavor: emotions are psychological events that can be decomposed into more basic psychological elements (Brenner, 1974; Dashiell, 1928; Duffy, 1934, 1941; Hunt, 1941; Dunlap, 1932; Mandler, 1975; Ruckmick, 1936; Schachter, 1959; Titchener, 1909; Young, 1943). The common assumption in these works is that the human experience of emotion does not necessarily reveal the causal structure of emotion. Many of these works are grounded in the observation that empirical evidence had thus far failed to produce clear and consistent evidence for the biobehavioral distinctiveness of as the events that people colloquially call anger, sadness, and fear.

> The only universal element in any emotional situation is the use by all the subjects of a common term of report, i.e., "fear." That is, while stimulus conditions and actual experiential content may vary from subject to subject, all decide upon the emotion and give it a common label, "fear" (Hunt, 1941, p. 266).

This observation has been echoed in several recent papers devoted to the topic (Barrett, 2006a; Ortony and Turner, 1990; Russell, 2003).

The Empirical Record

The Commonsense Model

A comprehensive review of the entire evidentiary body of emotion research is well beyond the scope of this paper for both practical and logical reasons. Practically speaking, several recent reviews of evidence in support of basic emotion (e.g., Ekman, 1992; Ekman, Campos, Davidson, and de Waal, 2003; Keltner and Ekman, 2000; Panksepp, 1998) and appraisal models (e.g., Scherer, Schorr, and Johnstone, 2001) already exist. My goal in this paper is to provide a complementary review that highlights and summarizes evidence that is potentially disconfirming of the commonsense view. A focus on disconfirming evidence is not only practical, it is logically preferable (Popper, 1959) because it will allow interested readers to evaluate whether the evidence is weak enough to be dismissed or strong enough to call the commonsense view into question.

Bodily Activation Despite rigorous research efforts, the idea that categories of emotion (e.g., anger, sadness, fear) are distinguished by distinct patterns of autonomic response remains debatable (for a review, see Barrett, 2006a). Although some studies have reported emotion-specific patterns of ANS and behavioral activation for at least some emotions (e.g., Ekman, Levenson, and Friesen, 1983; Levenson, Carstensen, Friesen, and Ekman, 1991; Levenson, Ekman, and Friesen, 1990; Mauss, Levenson, McCarter, Wilhelm, and Gross, 2005; Nyklicek, Thayer, and Van Doornen, 1997; Sinha, Lovallo, and Parsons, 1992; Stemmler, 1989; see Levenson, 1992), these are set against a backdrop of studies that suggest the claim of invariant emotion-specific ANS activity is unwarranted. Meta-analytic evidence indicates that there are few, if any, stable physiological patterns for categories of emotion (Cacioppo, Berntson, Larsen, Poehlmann, and Ito, 2000).

Face and Voice The lack of emotion-related patterning that is observed in autonomic measurements can also be seen in almost all measurement modalities (Barrett, 2006a). There is an on-going, lively debate about whether perception-based studies of the face and voice (where one person judges emotion in the face or voice of another) give evidence of discrete emotion categories (see, e.g., Ekman, 1994; Elfenbein and Ambady, 2002; Izard, 1994; Russell, 1994, 1995; Keltner and Ekman, 2000; Russell, Bachorowski, and Fernandez-Dols, 2003). It is important to consider, however, that studies of emotion perception (often called "emotion recognition") commonly use posed facial configurations that depict caricatures of emotion. In contrast to a prototypical expression (an expression that is closest to the average set of features for a kind of emotion), a caricature departs from the central tendency of its category in a way that will make it maximally distinctive from other categories. For example, an anger prototype would depict the average set of facial movements that have been identified as naturally occurring in actual anger episodes; in contrast, an anger caricature depicts facial movements that are exaggerated to maximally distinguish it from facial depictions of other emotion categories, such as fear. In comparison with prototypes, caricatures are more accurately categorized as belonging to a concept when the concepts in question are highly interrelated (Goldstone, Steyvers, and Rogosky, 2003).

Production-based studies of emotion in the face and voice (in which researchers measure facial muscle movements and vocal behaviors during emotionally evocative events) have thus far failed to provide clear evidence of signature patterns for particular categories of emotion. Recent summaries of the literature conclude that the bulk of evidence has failed to support the hypothesis that distinct patterns of facial muscle activity and vocal acoustics distinguish anger, sadness, fear, and so on (Cacioppo et al., 1997, 2000; Russell et al., 2003). This assessment is consistent with the evidence from infant (Camras, Lambrecht, and Michel, 1996; Camras et al., 2002; Hiatt, Compos, and Emde, 1979) and animal communication research (Seyfarth and Cheney, 2003): it has become clear that babies and animals rarely produce involuntary, reflexive displays of their emotional states. Taken together, this evidence suggests that facial movements and vocal signals do not necessarily "display" information about the sender's emotional state (see Russell et al., 2003), even though people routinely perceive those behaviors as coordinated "expressions."

Instrumental Behaviors The evidence is also lacking for distinct behavioral profiles for each category of emotion (for a review, see Barrett, 2006a). Behavioral responses, such as flight or fight, are specific, context-bound attempts to deal with a situation and so correspond to situational demands (Cacioppo et al., 2000; Lang, Bradley, and Cuthbert, 1990). If a fear-situation is defined by the presence of threat (e.g., a predator), then fear is associated with a range of different behaviors (from vigilance, to freezing, to flight, to attack), depending on the functional demands of the situation. In rats, for example, the threat (or defense) system is organized so that an animal will engage in different behaviors, depending on its psychological distance from a predator (e.g., Fanselow and Lester, 1988); this suggests that there is no one-to-one correspondence between a particular instrumental behavior and a specific emotion. Similar behavior-situation links have been observed for systems that secure desired objects, like food (Timberlake, 1994) and sexual behavior (Akins, Domjan, and Gutierrez, 1994; Akins, 2000; see Bouton, 2005). Similarly, people can attack or withdraw or even smile in anger. Given that physiological activation provides support for behavioral demands (Obrist, 1981; Obrist et al., 1970), and the same feeling can be associated with a variety of behaviors, it seems unlikely that scientists will ever find emotion-specific autonomic patterning.

Subjective Experience Contrary to popular belief, it is far from clear that everyone necessarily experiences anger, sadness, fear, and so on, as qualitatively different states. Despite early factor analytic evidence that self-reports produced discrete groupings of subjective experience (e.g., Borgatta, 1961; Nowlis, 1965; Izard, 1972), there is little consistent evidence that people, on average, routinely distinguish between feelings of anger, fear, sadness, and so on. Such reports of negative emotion experience tend to correlate so highly that they often fail capture any unique variance (e.g., Feldman, 1993; Watson and Clark, 1984; Watson and Tellegen, 1985). Even scales that are explicitly built to measure discrete emotions tend to suffer from high correlations between reports of like-valenced states (e.g., Boyle, 1986; Zuckerman and Lubin, 1985; Watson and Clark, 1994). As a result, many researchers measure broad dimensions of positive and negative activation (e.g., Watson, Clark, and Tellegen, 1988), pleasure-displeasure (valence), or feelings of activation or arousal (e.g., Barrett and Russell 1998; Mayer and Gaschke, 1988; Russell, Weiss, and Mendelsohn, 1989).

Idiographic studies of emotion experience demonstrate that there is considerable individual variation in emotional granularity—the extent to which people characterize their experiences in discrete emotional or in broadly affective terms (Barrett, 1998, 2004; Barrett, Gross et al., 2001; Feldman, 1995). Individuals high in granularity use the words "angry," "sad," and "afraid" to represent distinct experiences; those low in granularity use the words to represent a more general state of feeling "unpleasant." The same is generally true for pleasant emotional states, with those in high in granularity using the words "happy," "calm," and "excited" to refer to distinct experiences, while those lower in granularity use these words to refer to a more general "pleasant" affective state. Individuals who are granular for unpleasant emotions also tend to be granular for pleasant emotions, although the two are not perfectly correlated (Linquist and Barrett, in press). These differences are not fully accounted for by verbal intelligence or how well people understand the meaning of emotion words.

Neural Circuitry Meta-analyses of neuroimaging studies of emotion have failed to provide evidence for consistent and specific brain circuitry that distinguishes anger, sadness, fear, disgust, and happiness (for reviews, see Barrett 2006a; Barrett and Wager, 2006). In general, the findings from these meta-analyses are very similar to the pattern of findings for the psychophysiological data on emotion: unique activation patterns for each category of emotion were generally less consistent than expected. Furthermore, alternative explanations were not ruled out when consistency was observed. For example, the amygdala is widely believed to represent a core "fear system" in the brain, yet the meta-analyses found that no more than 60 percent of studies of fear reported increased activation in the amygdala. Moreover, stimulus features such as novelty (e.g., Wilson and Rolls, 1993; Wright, Martis et al., 2003) or uncertainty (Davis and Whalen, 2001; Kim, Somerville et al., 2003; Whalen, Rauch et al., 1998) also activate the amygdala and were not ruled out as alternative explanations for the observed findings. Furthermore, simple perceptual cues (e.g., eye gaze) determine whether or not facial depictions of fear result in an increase in amygdala activation (Adams, Gordon et al., 2003), and individuals with amygdala damage can correctly classify facial depictions of fear when their attention is directed towards the eyes of a stimulus face (Adolphs, Gosselin et al., 2005). Taken together, the evidence suggests that the amygdala is not the brain locus of fear, although it seems to play an important role in affective processing.

What the Evidence Shows

Even as scientific studies of emotion do not provide clear evidence for the biological or behavioral distinction between emotion categories, they do give clear and consistent evidence for a distinction between positive and negative affective states. Objective measurements used in the study of emotion, such as peripheral nervous system activation (Bradley and Lang, 2000); Cacioppo et al., 1997, 2000), facial movements (Cacioppo et al., 1997, 2000; Messinger, 2002), vocal cues (Bachorowski, 1999), expressive behavior (Cacioppo and Gardner, 1999), and neural activations (Barrett and Wager, 2006) all give evidence of the intensity or hedonic quality (pleasantness or unpleasantness) of a person's affective state. Furthermore, facial behaviors, reports of experience, and peripheral nervous system activity show strong correspondences for the affective properties of valence and intensity; effect sizes range from 0.76 to 0.90 (Lang, Greenwald et al., 1993), even when they do not show strong correspondences for anger, sadness, fear, and so on (for a review, see Barrett, 2006a). That is, affect, rather than emotion, seems to meet the criteria for a biologically verifiable state.

"Affect" is generally used to refer to any state that represents how an object or situation influences a person. The term "core affect" has been recently introduced to refer to a basic, psychologically primitive state that can be described by two psychological properties: hedonic valence (pleasure/displeasure) and arousal (activation/sleepiness). It is also possible to describe core affect in terms of related properties, such as energetic arousal (wide awake/sleepy) and tense arousal (tense/calm) (Rafaeli and Revelle, 2006; Thayer, 1989), or as negative activation (anxiety to calm) and positive activation (excitement to fatigue) (Watson and Tellegen, 1985). These terminology differences really amount to preferences in how one describes the same affective space, and the different dimensions can be mathematically derived from one another (Russell and Barrett, 1999). Core affect has been characterized as the constant stream of transient alterations in an organism's neurophysiological and somatovisceral states that represent its immediate relationship to the flow of changing events (Barrett, 2006b; Russell, 2003; Russell and Barrett, 1999). In a sense, core affect is a neurophysiologic barometer of an individual's relationship to an environment at a given time. To the extent that an object or event changes a person's "internal milieu," it can be said to have affective meaning; these changes are what is meant when one says that a person has an affective reaction to an object or stimulus. They are the means by which information about the external world is translated into an internal code or representations (Nauta, 1971; Damasio, 1999; Ongur and Price, 2000).

Core affect functions as a kind of "core knowledge" (see Spelke, 2000), the hard wiring for which is present at birth (Bridges, 1932; Emde, Gainsbauer, and Harmon, 1976; Spitz, 1965; Sroufe, 1979) and is homologous in other mammalian species (Cardinal, Parkinson et al., 2002; Rolls, 1999; Schneirla, 1959). Core affect is universal to all humans (Russell, 1983; Wierzbicka, 1992; Scherer, 1997; Mesquita, 2003), is evident in all instrument-based measures of emotion (for a review, see Barrett, 2006b), and forms the core of emotion experience (Barrett et al., 2007; Russell, 2003). Core affect (i.e., the neurophysiological state) is available to consciousness, and it is experienced as feeling pleasant or unpleasant (valence) and, to a lesser extent, as activated or deactivated (arousal) (for a review, see Russell and Barrett, 1999). If core affect is a neurophysiologic barometer that sums up an individual's relationship to the environment at a given time, then self-reported feelings are the barometer readings. Feelings of core affect provide a common metric for comparing qualitatively different events (Cabanac, 2002). Core affect is a precondition for first-person experiences of the world, language fluency, and memory; it modulates sensory processing to influence what people actually see, and in doing it so forms the core of conscious experience (for a review, see Duncan and Barrett, 2007).

A person's core affective state is largely, although not exclusively, influenced by a process that has been called evaluation (Bargh and Ferguson, 2000; Brendl and Higgins, 1995; Tesser and Martin, 1996), appraisal (Arnold, 1960) or primary appraisal (Lazarus and Folkman, 1984), or valuation (Barrett, 2006c). Valuation can be thought of as a simple form of meaning analysis in which something is judged as helpful or harmful in a given instance, producing some change in a person's core affective state. Judgments about whether stimuli or events are helpful or harmful or rewarding or threatening (whether those judgments are fleeting and automatic or more deliberate and effortful) help to influence the valence property of core affect. There is consensus across a broad swath of psychological research that humans evaluate and that the process of valuation is a basic aspect of mammalian functioning. People continually and automatically evaluate situations and objects (Bargh and Ferguson, 2000, but see Storbeck and Robinson, 2004) for their relevance and value—that is, whether or not object properties signify something important to well-being, leading to moment-to-moment fluctuations in core affect. An object is valuable when it is important to survival (Davis and Whalen, 2001) or when it is relevant to immediate goals (Rogers 1959; Smith and Kirby, 2001). Valuation largely occurs outside of awareness and conscious control (for a recent review, see Moors and De Houwer, 2006).

Summary

Overall, the available evidence suggests that there is no clear objective way to measure the experience of emotion. Emotion categories—such as anger, sadness, and fear—have thus far not clearly and consistently revealed themselves in the data on feelings, facial and vocal behaviors, peripheral nervous system responses, or instrumental behaviors. It has not yet been shown whether there are distinct brain markers for each emotion, but so far the available evidence does not encourage a commonsense view. However, scientists are able to assess a person's affective state (i.e., pleasure and displeasure) by indirect (see Berridge and Winkielman, 2003), experiential (Russell and Barrett, 1999), and objective means (in the face or body, e.g., Cacioppo et al., 2000). This affective state is a basic and core element in emotional responding.

THE EMOTION PARADOX

The evidence presented thus far frames a fundamental emotion paradox: people seem compelled by their own experiences to believe that emotions are biological categories given by nature, but objective, instrument-based measures of emotion provide evidence only of a person's core affective state. How this dilemma is resolved depends on how seriously the evidence that is inconsistent with the commonsense view is treated.

One way to resolve the emotion paradox is to assume that the data are flawed or otherwise not sufficient for testing the hypothesis that discrete emotions have distinct biobehavioral signatures. Social factors, such as display rules (cf. Ekman, 1972) or other regulation processes, might mask or inhibit prepotent responses that would otherwise be easy to measure. Response systems differ in their temporal dynamics, sensitivity, and reliability of measurement, and this might obscure the measurement of any patterns that exist (cf. Bradley and Lang, 2000). Moreover, laboratory studies of emotion do not use emotion-eliciting stimuli that are strong enough to produce prototypical emotional responses and this may be why they are not observed (cf. Tassinary and Cacioppo, 1992).

In any of the research areas reviewed thus far, it is possible to find additional caveats to explain why the expected results have not been found. Self-reports are flawed, and experience may be epiphenomenal to emotion. Facial muscle measurements are too coarse-grained to capture complex sets of facial movements, and perceiver-based judgments of facial movements provide stronger evidence for the commonsense view. Most psychophysiological studies measure only a few output channels, providing a less than optimal test of the question of autonomic specificity. And neuroimaging investigations of emotion are just beginning, tend to confuse emotion perception with emotion induction, and do not give sufficient spatial resolution (not to mention the fact that people must lay immobilized inside a scanner). In sum, it is possible that distinct, natural kinds of emotions will reveal themselves in the brain and body if only scientists could find the right eliciting stimuli, have better measurement tools, or use more sophisticated and precise research designs.

Although any of these explanations may be correct, an equally plausible explanation is that scientists have failed to observe stable and reliable biobehavioral patterns for each emotion because they are not there. If the commonsense view is held to the same empirical standard as other emotion models, then it is fair to say that the supporting evidence is equivocal at best. The evidence suggests the real possibility that there are no emotion mechanisms in the brain waiting to be discovered, producing a priori packets of outcomes in the body. Emotions may not be given to humans by nature, which raises the question of whether they are the appropriate categories to support a cumulative science.

SUGGESTIONS FOR A NEW PARADIGM

For the most part, the field of emotion has accepted the first solution to the emotion paradox by explaining away disconfirming evidence as the result of imprecise measures, flawed experimental designs, and so on. This solution comes with large price tag: some of the most fundamental questions about human emotion remain unanswered, and the majority of the empirical findings related to emotion do not seem to produce cumulative knowledge in the procrustean process of trying to fit the data into discrete categories. To be sure, better research about emotion means conducting better studies with better research tools. But it may also require a fundamental change in the way that researchers ask and answer questions about emotion. In essence, progress may require crafting a new scientific paradigm for the study of emotion.

Asking Better Questions

First and foremost, a better science of emotion means asking different sorts of questions. Instead of asking "Is 'X' a real emotion?," one might ask "How can science account for the richness and variability in emotional life?" Rather than asking why physiology, behavior, and experience fail to correlate when emotion is measured, scientists might ask what is important about the instances when they do correspond. Rather than asking about whether people are accurate in decoding the emotional displays of others, scientists might ask "What is the function of perceiving emotion in others?" and "What does it mean to get this perception 'right'?" Rather than asking "How do we evoke pure instances of emotion, uncontaminated by contextual influences or language?," scientists might ask "Do context and language have an intrinsic role to play in shaping the form and function of an emotional response?" And finally, rather than asking "How can scientists conduct better studies, with better methods and tools, to empirically locate the biobehavioral signatures for anger, sadness, and fear?," perhaps scientists should think about why scientists typically theorize about and focus their empirical efforts on caricatured emotional episodes when they are, in the best scenarios, rare.

The barriers to asking better questions are mainly psychological. The commonsense view is compelling. It fits with the way people talk about emotion everyday. A person says "You made me angry," as in "You triggered my anger reflex." Anger explains why someone yelled and perhaps even justifies it. This idea underlies, often implicitly, people's construal of emotions in themselves and others. Experiences of anger, fear, etc., feel like they erupt or "happen," as the causal entity—the emotion—hijacks a person's mind and body. Sometimes people behave in ways that they would rather not—in ways that do not correspond to more reasoned responses that they identify as part of their human self.

Denying a commonsense view of emotion means that people must accept that their perceptions of the world are not a valid indicator of how the world works. Because people perceive *anger* in themselves and in others, they believe *anger* exists as an entity to be discovered somewhere in the brain or body. People believe that their experiences reveal reality. In evolutionary biology, this is called the "error of arbitrary aggregation" (Lewontin, 2000). In social psychology, we call it "naïve realism."

Abandoning a commonsense view would mean being free from a basic form of essentialism that captures well how people think about the events and objects in their everyday lives (Bloom, 2003). People's naïve intuition that emotions have essences may be an example of psychological essentialism (Medin and Ortony, 1989). People need not have even the foggiest idea what the essence of a category is to continue believing in it. It has been argued that psychological essentialism is an adaptive and universal way of parsing the world (Gelman and Hirschfeld, 1999; see also Quine, 1977). But as Quine points out, psychological essentialism may produce a bias in how people—including scientists—formulate ideas about the world.

An Inductive Approach

As a second step, a new paradigm for the scientific study of emotion might take a more inductive approach. Rather than beginning with an abstract, theoretical construct (e.g., anger) that researchers try to identify in human behavior, perhaps researchers could concentrate their empirical efforts on identifying which observable or measurable phenomena (e.g., cardiovascular changes, facial expressions, startle responses, EEG recordings, subjective experience, conscious thoughts) are implicated across instances of emoting and observe, rather than prescribe, their relationships in varying circumstances and time frames. If instances of emotion can be characterized by empirical coherences, then observations should eventually demonstrate reliable patterns of relationships among the necessary components of emotion. Alternatively, new constructs may emerge, and they may have little resemblance to folk or commonsense categories of emotion.

The barriers to an inductive science of emotion are practical, technological, and ethical. First, no one scientist can be an expert in every scholarly domain that includes emotion, nor can he or she have expertise in every measurement method that is used. As a result, interdisciplinary approaches to the study of emotion are necessary, with scientists from different domains of expertise working together to craft a multidisciplinary measurement environment. This means that scientists from different disciplines must craft a common scientific language. Second, there are technological challenges involved in an inductive approach to studying emotion, such as the ability to capture and integrate measurements of the face, the body, the brain, and experience, in real time. Third, there are ethical considerations, because it is generally considered unethical to expose people to stimuli that will lead to an intense or dramatic emotional episode. In most current research, emotion is induced in rather limited circumstances, such as having participants view pictures, watch movies, or relive prior experiences of emotion. Typically, participants are sitting still throughout an entire experiment. Creating more naturalistic laboratory environments in which participants can interact with one another and move around (e.g., using immersive virtual environments) or crafting devices to allow real-world capture of experiential, physiological, and social interaction data (e.g., context-sensitive experience-sampling) would be necessary for an inductive science of emotion.

A Specific Theoretical Framework: The Conceptual Act Model

A third requirement for a new scientific paradigm for the study of emotion is a model with a clear and simple research agenda for understanding emotional responding that rivals the commonsense paradigm. One reason for the success of the commonsense model is that it is simple to state: emotions are packets of responses that result from mechanisms in the human brain and body that derive from the evolutionary past. It is this simplicity that has led to elegant and clear hypotheses that have guided emotion research for almost a century. There are several modern models that might serve to inspire a new paradigm grounded in the idea that emotions are not biologically given, however (e.g., Averill, 1980; Clore and Ortony, 2000; Mesquita, 2003; Ochsner and Barrett, 2001; Owren, Rendell, and Bachorowski, 2005; Rolls, 1999; Russell, 2003; Shweder, 1993, 1994; Smith and Ellsworth, 1985; Solomon, 2003). Although these models differ from one another in their surface features, they all assume, as did Wundt (1897), that emotions are events that are constructed from more basic psychological processes, and it is the processes themselves that are given. The goal of science should be to understand the more basic psychological and neurobiological processes involved in the construction of emotion

The model that I have crafted takes its lead from the emotion paradox discussed above. If the clearest evidence for the distinctiveness of anger, sadness, and fear is in perception, then perhaps these categories exist in the perceiver. Specifically, I hypothesize that the experience of feeling an emotion, or the experience of seeing emotion in another person, occurs when conceptual knowledge about emotion is used to categorize a momentary state of core affect (Barrett, 2006b; Barrett et al., 2007).

Categorizing is a fundamental cognitive activity. To categorize something is to render it meaningful; it is to determine what something is, why it is, and what to do with it. Then, it becomes possible to make reasonable inferences about that thing, predict how to best to act on it, and communicate it to others. In the construction of emotion, the act of categorizing core affect performs a kind of figure-ground segregation (Barsalou, 1999, 2003), so that the experience of an emotion will stand out as a separate event from the ebb and flow of an ongoing core affect (the core affect is associated with the direction and urgency of initial behavioral responses). In doing so, people divide ongoing changes in core affect into meaningful experiences. Conceptualizing core affect renders it intentional (about something), leading a person to experience the world in a particular way (consistent with the views of Ortony, Clore, and Collins (1988), Frijda (2006), and Smith and Ellsworth (1985). Conceptualizing also allows people to make reasonable inferences about what to do next and to communicate their experience to others in an efficient manner. The conceptual knowledge that is called forth to categorize core affect is thought to be tailored to the immediate situation, represented in sensory-motor cortices, acquired from prior experience, and supported by language. Categorizing the flux and flow of core affect into a discrete experience of emotion corresponds to the colloquial idea of "having an emotion."

When combined, core affect and conceptual knowledge about emotion produce a highly flexible system that can account for the full richness and range of experience that characterizes human emotional life, including the appearance of distinct biobehavioral profiles of emotional response when they occur. The ability to categorize confers some adaptive advantage, and so it is likely to have been evolutionarily preserved, even if the specific categories are not. Many cultures may share the basic-level emotion concepts in Western culture, including anger, sadness, and fear, undoubtedly because these concepts are optimal tools for coping in the typical human environment: living in large groups with complicated relational rules.

Taken together, the basic propositions of the conceptual act model of emotion map a novel research agenda for the psychological construction of emotion with several distinctive features. First, it hypothesizes that the basic building blocks of emotional life are conceptual and affective, and so understanding each of the processes and how they constrain one another would be central to the study of emotion. The evolutionary legacy to the newborn is not a set of modular emotion circuits that are hardwired into the brain, but rather a set of mechanisms that compute core affect, as well as those that allow category learning. It is also possible to use this approach to examine how affective and conceptual changes configure to produce the effect of emotion on such diverse outcomes as economic decisions (Loewenstein and Lerner, 2003), stereotyping (Bodenhausen and Moreno, 2000; DeSteno and Dasgupta, 2004), and moral reasoning (Haidt, 2001; Greene, Nystrom et al., 2004), as well as how each contributes to emotional change, as in the treatment of emotional disorders. Some treatments (such as pharmacotherapy) may be more effective at producing affective change; others (such as the emotion resocialization that is thought to occur in some forms of psychotherapy) might be more likely to produce conceptual change, leaving affective responding untouched (Quigley and Barrett, 1999).

Second, the conceptual act model focuses on the need to understand the richness and diversity of emotional life in humans that was highlighted by William James. In doing so, the model will move the science of emotion away from its current focus on a small set of canonical forms that are seen rarely in everyday life. Specifically, it will lead scientists to expect, rather than to treat as error and explain away, variations in the form and functions of emotional responses. The conceptual act model not only helps to explain why some individuals are better able to distinguish between discrete emotional states than are others (i.e., why they differ in emotional granularity), but it also predicts that any emotion will differ from one instance to the next, even in the same person.

Third, the conceptual act model suggests an intrinsic role for language in perceiving emotions in the behaviors of other people (see Lindquist et al., 2006). It is consistent with the linguistic relativity hypothesis (Whorf, 1956), which states that language forms the basis of experience. In the case of emotion, language shapes core affective phenomena into the emotional reality that people experience. Language not only enters into the categorization process, but it also directs the development of knowledge about emotion categories in the first place. Language guides what nonlinguistic information is included in an emotion category as it is being constructed during the learning process. As a result, the conceptual act model provides a means for understanding the role of language in cultural, as well as in individual, differences in the experience of emotion.

Fourth, the conceptual act model rescues the experience of emotion from obscurity. Some models treat experience as epiphenomenal to the scientific study of emotion (e.g., LeDoux, 1996); in the conceptual act model, it is given a central place in characterizing what emotions are and how they function in the economy of the mind and behavior. At its core, the conceptual act model of emotion assumes that emotions do not have an ontological status separate from people's perception of them.

Fifth, the conceptual act model suggests that conceptualizing core affect is a skill. Some people may be better than others at tailoring conceptual knowledge to meet the needs of situated action (Barsalou, 2003). This skill for wielding conceptual knowledge about emotion might be considered a core aspect of emotional intelligence. If conceptualizations of a given emotion category lead to the experience of emotion, then constructing such an experience is also a skill. Presumably, there is not one experience of anger, but many, and the one that emerges in a given instance depends on the content of the simulation. It is a skill to simulate the most appropriate or effective representation or even to know when to inhibit a simulated conceptualization that has been incidentally primed. Presumably, this skill can be both measured and trained.

Finally, the conceptual act model leads to reflections on why scientists typically theorize about and focus their empirical efforts on prototypical emotional episodes, that is, what most people consider the clearest cases of emotion that necessarily have all of the component parts (Russell, 2003; Russell and Barrett, 1999), even though such episodes are quite rare and the nonprototypical cases are more frequent in our everyday lives. The answer may be that it is a natural consequence of the way that categories work. Emotion categories can be thought of as goal-directed categories that develop to guide action. The most typical member of a goal-directed category is that which maximizes goal achievement not that which is most frequently encountered (Barsalou and Ross, 1986; Barsalou, 2003). As a result, the most typical instances of a category contain properties that represent the ideal form of the category—that is, whatever is ideal for meeting the goal that the category is organized around—not those that most commonly appear as instances of the category.

Research Implications

The research agenda motivated by the conceptual act model can be framed as two broad of domains of inquiry, each of which contains several different questions. Many of these would be relevant to research that may be of interest to the military; this section discusses several examples.

To understand what emotions are and how they function in the economy of the mind and behavior, it would be important to better understand the structure and function of core affect. There are a number of important questions that can be addressed in this regard. For example, what is the neurobiology of the core affect system and how does it influence other processes, such as attention to and sensory processing of threatening or rewarding objects? The classic amygdala-centric view of affective processing (largely derived from animal models) is incomplete, and the affective circuitry is better thought of as a distributed set of circuits that constrain one another and other aspects of cognitive processing in a deeply intrinsic fashion (Barrett et al., 2007; Duncan and Barrett, 2007). For example, there are neuroanatomical reasons to hypothesize that affective states not only influence how people interpret what they see, but also literally *what* they see (Duncan and Barrett, 2007). Some preliminary research suggests that affect can modulate processing in the ventral stream (the system involved in object perception and awareness) as far back as V1 (Stolarova, Keil, and Moratti, 2006). It would also be important to understand how people can better use their affective reactions as a source of information to make judgments in uncertain conditions. There is ample evidence that people can use their affective reactions as a source of information in both explicit (Schwarz and Clore, 1983) and implicit ways (Bechara, Damasio et al., 1994; Bechara et al., 1996, but see Dunn, Dalgleish, and Lawrence, 2006); however, it is also possible for people to misattribute their affective reactions (Payne et al., 2005) or to experience a "false alarm" and see threat where none is present (Quigley and Barrett, 1999). A better understanding of when affect helps (and hurts) the perception of threat and reward in conditions of uncertainty seems warranted.

Another important question involves how people learn about threat and reward. Humans are born with the ability to have pleasant and unpleasant reactions to certain "prepared stimuli"—stimuli that evoke a response in the absence of previous experience with or exposure to them (for a discussion, see Öhman and Mineka, 2001)—but for the most part, people have to learn whether objects in the world are helpful or harmful. An object's value is determined by its ability to change a person's affective state. At least three questions seem important: What are the fast, rule-based and slow, associative mechanisms by which such learning occurs (see Bliss-Moreau, Barrett, and Wright, 2007; De Houwer, Thomas, and Baeyens, 2001; De Houwer, Baeyens, and Field, 2005)? How malleable is such learning (see Bouton, 2005)? Are there individual differences in such learning (see Bliss-Moreau et al., 2006)? It would also be beneficial to study the processes involved in overcoming such learning in the moment. For example, it is well documented that there are individual differences in the capacity to use controlled processing to overcome a prepotent or habitual response (Barrett, Tugade, and Engle, 2004).

A second set of questions involve the conceptual processes that contribute to the construction of emotion out of the more basic and primitive form of affective responding. For example, little is known about how language and conceptual knowledge for emotion lead people to see "anger" or "fear" in another person. Presumably, this distinction is important, because it will determine what sort of behavior the perceiver anticipates in the target person (e.g., aggression or withdrawal) and therefore what the perceiver does next. There is growing evidence from both social psychology and cognitive neuroscience research that language and conceptual information influence the perception of emotion in others. Biological measures of semantic processing (the N400 ERP signal and increased activity in the inferior frontal cortex) indicate that conceptual knowledge participates in emotion perception as early as 200 milliseconds after the presentation of an emotional face (Balconi and Pozzoli, 2005; Nakamura et al., 1999; Streit et al., 1999, 2003). Furthermore, when words for emotion are temporarily taken offline (using a behavioral paradigm called semantic satiation, which is the opposite of priming), judgments of emotions in the faces of other people are impaired (Lindquist, Barrett, Bliss-Moreau, and Russell, 2006), as is the ability to literally construct an image of a face as emotional (Gendron, Lindquist, Barrett, and Barsalou, 2006).

The link between conceptual knowledge and emotion perception suggests that what people know about emotion will influence the emotions that they perceive in others (and in themselves). Yet scientists know very little about the content and structure of the conceptual system for emotion that plays a role in emotion perception. As children, people are socialized to learn the semantic, interpersonal, and behavioral scripts associated with specific emotion labels in their culture (Harris, 1993). Children as young as 2 readily label their emotional experiences (Bretherton, McNew, and Meeghly-Smith, 1981), but how they use such labels is another story (Widen and Russell, 2003). They rapidly learn the type of psychological events and abstract situations that are associated with particular emotion labels (e.g., fear, sadness, happiness, anger, guilt; see, e.g., Harris et al., 1987), and they are also aware of the typical actions and expressions that are supposed to accompany a particular emotional state (Trabasso, Stein, and Johnson, 1981). However, there may be significant variation in terms of how those rudimentary concepts are elaborated on the basis of episodic experience later in life. When individuals do not learn from experience, their emotion knowledge may be more stereotypic and less sensitive to changing contexts. Those individuals who do learn from experience will have more complex emotion representations and will have a greater range of personal cues to activate those representations and produce discrete emotional experiences. Presumably, the more that knowledge about the situation in incorporated in understanding what anger (or fear or sadness) is and what to do about it, the more precisely tailored an emotional response will be to the situation, resulting in more effective behavior and decision making.

It is not just what a person knows, but how he or she uses that knowledge that determines whether an emotion perception is adaptive and effective. The conceptual act model suggests that functional emotional behavior will depend in part on the resources that people have to use the conceptual knowledge they possess, especially when emotion perception is occurring in stressful situations (i.e., under cognitive load). A number of studies show that knowledge structures that are activated outside of awareness can have a profound influence on people's subsequent thoughts, feelings, and behaviors (for a review, see Bargh and Chartrand, 1999). When the concept "old" is activated, college-aged participants walk slower (Bargh, Chen, and Burrows, 1996). When the concept "African American" is activated, European American participants act more aggressively (Bargh, Chen, and Burrows, 1996). These effects can be overcome with more controlled processing, but only when sufficient cognitive resources are available. A similar result may occur with emotion knowledge. As a result, it is reasonable to hypothesize that executive resources (such as working memory capacity) will influence the modularity of emotion perception and emotional action. A cognitive module is defined as a fast, domain-specific set of processes that have evolved to handle particular types of information. Modules are assumed to be encapsulated and impenetrable (activities and outputs cannot be influenced by other classes of information, such as expectations or beliefs), reflexive (they provide predetermined outputs when predetermined inputs are present), and unconscious (it is impossible to reflect on the operations of a module). Working memory capacity can produce a kind of "functional modularity," however, when a system appears modular but only because of insufficient attention (rather than because of the architecture of the brain; see Barrett, Tugade, and Engel, 2004). Individuals who are lower in working memory capacity, or in situations that require intensive attentional resources, may produce functionally modular or reflex-like responses that will be less strategic and flexible, and therefore less functionally effective.

Theoretical Implications

The conceptual act model not only suggests novel and innovative avenues of research for understanding what emotions are and how they function, but it emphasizes several broader themes that are important when understanding social behavior. First, the model emphasizes the *relativity of emotion perception*. Context influences the emotions that are perceived in both ambiguous (Carroll and Russell 1996; Fernandez-Dols, Wallbott, and Sanchez, 1991) and in nonambiguous (Trope, 1986) circumstances. For example, people of non-Western cultures have a more difficult time than those in Western cultures in categorizing facial behaviors into Western categories (Elfenbein and Ambady, 2002). Although people categorize facial behaviors effortlessly and often without awareness, this does not constitute evidence that categorization is a matter of merely "decoding" innate information that is "encoded" into the face.

Second, the conceptual act model also has important psychological and philosophical implications for the *relativity of social perception*. If conceptual knowledge of categories shapes the perception of social reality, and if learning shapes conceptual development, then learning may play a much larger role in shaping social reality than previously assumed. The malleable nature of category knowledge suggests that the construction of people's social worlds may be vastly more culturally and individually determined than commonsense implies.

Finally, the conceptual act model emphasizes *the malleability of emotion perception*. If conceptual knowledge intrinsically shapes the emotion that people see in others, then acquisition and elaboration of culturally bound emotion categories may influence people's perceptual capacities. Knowing about a person's culture will help to identify that person's emotional state and therefore better predict his or her behavior. It may be that people can be taught to become better emotion perceivers and, hence, better communicators. In this way, cultural competence should contribute to cross-cultural relations and international diplomacy. Recent research has focused on the role of transnational competence (e.g., Koehn and Rosenau, 2002) in the development of successful transnational networks, projects, and diplomatic efforts. Training people to understand the fundamental differences in people's experiences of the world might allow for better communication and collaboration in today's global society.

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Neurophysiological Approaches to Understanding Behavior

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A biological revolution is occurring in the behavioral and social sciences, with an increasing emphasis on the use of neuroscience methods to understand human behavior, especially across the various subareas of psychology. The field of neuroscience reflects the interdisciplinary effort to understand the structure, function, physiology, biology, biochemistry, and pathology of the nervous system. From a psychological perspective, however, the term neuroscience typically is used to refer primarily to the study of the brain. Of interest is how the brain gives rise to learning, cognition, and behavior. Since the late 1980s, there has been dramatic growth in the field of cognitive neuroscience, which combines cognitive psychology, computational sciences, and neuroscience to examine how brain activity gives rise to cognitive abilities (e.g., memory, emotion, attention, language, consciousness). Indeed, this approach has been quite successful in providing new insights into many of these mental functions (Gazzaniga, 2004).

Most recently, social neuroscience is an emerging field that uses the methods of neuroscience to understand how the brain processes social information. It involves scholars from widely diverse areas—such as social psychology, neuroscience, philosophy, anthropology, economics, and sociology—working together and across levels of analysis to understand fundamental questions about human social nature. Social neuroscience merges evolutionary theory, experimental social cognition, and neuroscience to elucidate the neural mechanisms that support social behavior. From this perspective, just as there are dedicated brain mechanisms for breathing, walking, and talking, the brain has evolved specialized mechanisms for processing information about the social world, including people's ability to know themselves, to know how others respond to them, and to regulate their own actions in order to live and interact with other people in society. The problems that are studied by social neuroscience have been of central interest to behavioral and social scientists for decades, but the methods and theories that are being used reflect recent discoveries in neuroscience. Although the field is in its infancy, there has been rapid progress in identifying the neural basis of many social behaviors (Adolphs, 2003; Heatherton, Macrae, and Kelley, 2004).

We begin this paper with a brief review of the intellectual history of examining behavior from a biological perspective. We then describe the major neurophysiological and neuroimaging methods being used to understand behavior, with examples of how specific methods have provided key insights about important aspects of psychological functioning. The third short section considers conceptual and practical concerns in using the methods, and the final section presents our conclusions. Throughout this paper we focus on the vexing issue of the extent to which psychological functions are localized in discrete brain regions, which can be considered one of the major challenges in much contemporary brain research.

INTELLECTUAL HISTORY

By the beginning of the 19th century, anatomists had a reasonably good understanding of the basic structures of the brain. What was unclear, however, is how those structures worked to produce thought and behavior. The key question was whether different parts of the brain did different things or whether the entire brain acted in unison to perform its vital functions. Some of the earliest proponents of functional localization were the phrenologists, such as Franz Gall and Johann Spurzheim. Although their theory that brain functions were associated with specific patterns of bumps on the skull is now discredited, the idea that discrete regions of the brain are specialized for different tasks was quite insightful. Early case histories of individuals with brain damage—such as Broca's patient, Tan, whose left frontal lobe damage left him unable to speak or Phineas Gage's frontal injury that led to dramatic changes in personality while leaving his intellectual faculties intact—provided considerable evidence for localized functions. The evidence from these early reports seemed clear: localized brain damage causes specific impairments.

Yet psychologists such as Karl Lashley in the early 20th century continued to argue that all parts of the cortex contributed equally to mental abilities through mass action, an idea known as equipotentiality. In a series of learning studies, Lashley removed cortical tissue from rats to see if he could disrupt their ability to remember how to navigate through mazes. He found that it was the amount of tissue removed rather than where it was located that impaired learning. However, had Lashley removed subcortical tissue he would have come to a much different conclusion: it is now well established that subcortical structures such as the hippocampus and the amygdala are critical to learning and memory.

One reason the debate about whether psychological processes are located in specific parts of the brain or distributed throughout the brain continued so long was because researchers did not have methods for studying ongoing mental activity in the working brain. The first noninvasive method of brain mapping developed for humans, electroencephalography (EEG), was used as early as the 1920s by Hans Berger, but its signals were not clear or specific enough to answer questions about the location of psychological processes. That situation changed swiftly and decidedly with the invention of brain-imaging methods in the 1970s and 1980s. Positron emission topography (PET) was invented by a team led by Michael Ter-Pogossian at Washington University in 1973, whereas magnetic resonance imaging (MRI) was invented by Paul Lauterbur in the early 1970s at the State University of New York at Stony Brook and further developed by Peter Mansfield of the University of Nottingham, for which they shared the Nobel Prize in physiology or medicine in 2003.

Functional brain imaging, the use of imaging techniques to observe ongoing mental activity, was pioneered in the mid 1980s by Marcus Raichle and his colleagues (including Peter Fox, Michael Posner, and Steven Petersen). Although early imaging work used PET, functional MRI (fMRI) was developed in the early 1990s and now serves as the dominant brain imaging method. In the past decade there has been an explosion of research linking specific brain areas with particular behaviors and mental processes (for reviews, see Posner and DiGirolamo, 2000; Gazzaniga, Ivry, and Mangun, 2002). It is now clear that there is some localization of function, but that many different brain regions participate to produce behavior and mental activity. That is, although there is considerable support for the general idea of specialization, virtually every behavior involves the joint activity of many brain regions. As we discuss below, identifying specific functions for discrete brain structures remains an ongoing challenge for neurophysiological approaches to studying behavior.

The ability to study the working mind through neurophysiological methods relies on understanding how the nervous system works. In the late 19th century, Santiago Ramón y Cajal proposed that individual neurons are genetically and metabolically distinct units that serve as the building blocks of the nervous system. This neuron doctrine was a challenge to the prevailing belief that the nervous system was a continuous mass of connected tissue. By using staining methods developed by Camillo Golgi, Ramón y Cajal not only was able to visualize neurons, but also went on to discover that electrical signals moved along the neuron from the dendrites down to the axon. That neurons operate by electrical activity allows one way to examine the working brain, namely by recording the electrical activity of neurons, either singularly or collectively.

Although it was initially believed that communication between neurons also occurred electrically, in the early 20th century it was discovered that chemical signals sent across the synapse in the form of neurotransmitters formed the basis of neuronal communication. It was initially and long believed that no more than a handful of neurotransmitters were involved in brain activity, but it is now known that hundreds of different substances act in diverse ways to affect mental activity and behavior. Interestingly, it is now known that cells other than neurons also affect thought and behavior. For instance, glial cells that were once considered little more than part of the physical structure of the brain have been found to modulate neural activity.

Understanding the chemical processes of the brain has provided many new insights into mental activity and behavior and has also been useful for developing treatments to help people with various psychological disorders. Some recent methods for understanding brain function capitalize on their ability to measure the actions of specific neurotransmitters within the nervous system.

NEUROPHYSIOLOGICAL METHODS

The principles of how cells operate in the brain to influence behavior have been studied with great progress for more than a century, but it is only recently that researchers have been able to study the working brain as it performs its vital mental functions. Although a multitude of different methods have been developed, they tend to group into two categories. The first group relies on measuring the electrical activity (and its associated magnetic consequences) in the brain. These methods are optimized for assessing the timing of brain activity (i.e., they are high in temporal resolution), but they are limited in their ability to localize the origins of the brain activity (i.e., they are low in spatial resolution). The second category is based on tracking blood flow (and its correlates) that accompanies neuronal activity. Methods such as PET and fMRI are relatively high in spatial resolution, but because of the rather sluggish nature of blood flow, they are low in temporal resolution. This section describes the major neurophysiological and neuroimaging techniques.

Electroencephalography (EEG) and Event-Related Potential (ERP)

Electroencephalography (EEG) is based on the principle that neural activity produces electrical potentials that can be measured and that the sum of these potentials indicates the relative activity of the brain. EEG records these electrical signals in real time through electrodes that are strategically placed on the scalp (with an additional reference electrode placed on an electrically neutral area, usually the earlobe). Electrical potentials from the electrodes are expressed in terms of the difference between the scalp electrodes and the reference electrode.

EEG provides a wealth of information about global brain activity and is therefore commonly used in clinical settings to study sleep cycles and diagnose neurological disorders, such as epilepsy. However, because EEGs register all brain activity, the signal is noisy, and it cannot provide information about specific changes in brain activity in response to a stimulus or cognitive task. This problem is remedied by using event-related potentials (ERP), an offshoot of EEG. During ERP experiments, the time period following the onset of a stimulus or cognitive task is extracted from the ongoing EEG signal. In order to reduce background noise, the trials are repeated numerous times, and the EEG signals that follow those trials are averaged together in order to create an average waveform of the brain's response to the experimental event. ERPs are expressed in terms of the polarity of their signal (P for positive deflecting ERPs and N for negative), and the latency at which they are expressed. That is, a negatively deflecting ERP occurring 400 milliseconds after an event is termed an N400. Perhaps the most important feature of ERP is that it provides a relatively precise record of brain activity.

The majority of ERP research has focused on categorizing ERPs elicited by visual, auditory, and verbal stimuli. Recently emerging ERP research has begun to consider more socially relevant stimuli, such as identifying ERPs that are uniquely responsive to human faces (e.g., N170) (Bentin, Allison, Puce, Perez, and McCarthy, 1996) and human bodies (N190) (Thierry et al., 2006). However, these findings are not without controversy. For instance, although the typical N170 response for face recognition is absent in patients with face recognition disorders such as prosopagnosia (Bentin and Deouell, 2000), emerging evidence suggests that the N170 may reflect expert object recognition, of which face processing is only one example. Indeed, animal experts have been shown to elicit an N170 to images of their favored animal (Tanaka and Curran, 2001). Nonetheless, the use of ERP methods has provided psychologists with insights about a number of important social behaviors, including identifying unique patterns that are associated with perceiving members of an outgroup, at least for those who score high on measures of racial prejudice (Ito, Thompson, and Cacioppo, 2004).

An interesting application of ERP has been to investigate the neural correlates of deception. The majority of research in this area focuses on two ERP components: the P300, which typically indexes the subjective novelty of an item (Friedman, Cycowicz, and Gaeta, 2001), and another component commonly referred to as the "parietal old/new effect," which distinguishes true from false recognition (Curran, Schacter, Johnson, and Spinks, 2001). For instance, Rosenfeld and colleagues (1999) have demonstrated that differences in the amplitude of the P300 can be used to distinguish between truly novel items and previously seen items in people who are feigning amnesia. More recently, Johnson, Barnhardt, and Zhu (2003) conducted a deception study in which participants were asked to provide truthful responses on some trials and deceptive ones on others. Interestingly, the authors found that the amplitude of the parietal old/new effect was largest for previously seen stimuli regardless of whether the participant responded truthfully or deceptively. The authors argue that this parietal old/new effect can be used as an objective measure of true recognition that is independent of a person's behavioral response, thereby providing a measure of guilty knowledge.

Magnetoencephalography (MEG)

EEG and ERP have the advantage of being relatively inexpensive, and they have submillisecond temporal resolution. Their potential for localizing function, however, is severely limited due to the possibility that there are multiple generators of the ERP signal that cannot be distinguished. A technique related to ERP that also provides better spatial resolution is magnetoencephalography (MEG), which measures magnetic fields that are produced by the electrical activity of the brain. Unlike EEG, MEG does not require electrodes; rather, it uses special sensors that detect magnetic fields. MEG has the same temporal resolution as ERP because it is basically measuring the same neural activity measured by EEG; however, because magnetic signals are not distorted by the skull, as are EEG signals, the MEG signal localization is far superior. In fact, MEG can localize the magnetic current within 2-3 millimeters under favorable conditions (e.g., when the target cortical structure is near the scalp). The one disadvantage of MEG is that it is much more expensive than ERP.

Despite its superior spatial resolution, MEG does not provide structural or anatomical information. It is therefore predominantly used to provide temporal information about known cortical structures. Language research, for instance, has relied on MEG to provide information about the time course of events by which speech is generated (which occurs in Broca's area) and understood (which occurs in Wernicke's area). In one study, participants were presented with pictures of simple objects (e.g., a house, dog, or cat) that they were told to identify silently in their minds (Kober et al., 2001). They then read simple words silently. The results suggested that, for most participants, activation in Wernicke's area occurred before activation in Broca's area in both the silent naming and reading tasks. Not only has MEG provided insight about the time course of language comprehension, it also has contributed to understanding how quickly and effectively the brain processes visual cues. For instance, Amano, Nishida, and Takeda (2006) asked participants to attend to a visual target and press a button when its velocity changed. The authors found that the faster that participants were able to press a button to indicate that the target's velocity had changed, the higher their MEG responses.

As these examples show, MEG provides useful information about the time course of neural activity and even about specific anatomical regions when that region is known. In many studies, however, the underlying cortical structure that gives rise to a specific cognition or behavior is unknown. MEG is thus often combined with imaging techniques, such as fMRI, that identify the discrete cortical regions engaged in specific cognitive tasks. MEG can then glean temporal information about those regions. For instance, research on the fusiform face area, a region of the temporal lobe, has benefited greatly from both fMRI and MEG research (Downing, Liu, and Kanwisher, 2001). First, fMRI studies are used to identify the fusiform face area as an area that responds selectively to faces (Kanwisher, McDermott, and Chun, 1997). Subsequently, MEG is used to map the time course of face recognition (Liu, Harris, and Kanwisher, 2002). This combination of techniques has provided insights into the psychological processes underlying face perception.

Positron Emission Tomography (PET)

The brain imaging methods that have produced the greatest scientific enthusiasm in recent times measure metabolic processes rather than electrical activity. Brain activity is associated with changes in the flow of blood as it carries oxygen and nutrients to activated brain regions. Brain imaging methods track this flow of blood to understand which areas of the brain are most active for a given task. Positron emission tomography (PET), the first imaging method developed, involves a computerized reconstruction of the brain's metabolic activity by using a relatively harmless radioactive substance that is injected into the blood stream. A PET scanner detects this radiation as blood travels through the brain and therefore can be used to map out brain activity in real time in three-dimensional space. The resulting image identifies the neural structures engaged in specific cognitive tasks.

One of the primary functions of PET was to isolate neural regions that are involved in certain physical or cognitive processes. One such interesting application of PET was to identify the extensive neural network involved in perceiving pain. Coghill, Sang, Maisog, and Iadarola (1999) administered thermal stimulation to participants during a series of PET scans to isolate the global organization of brain mechanisms involved in processing pain. The authors identified an extensive network in pain perception that includes the anterior cingulate cortex, insula, and cerebellum.

In addition to identifying the specific underlying mechanisms that motivate physical and psychological processes, PET provided investigators with a powerful method for addressing research questions that are difficult to study using behavioral methods. Memory researchers, for instance, long debated whether different forms of memory (e.g., encoding new memories or retrieving old ones) originate from the same or different neural systems. This debate was intensified by the famous case of patient H.M. In 1953 H.M. underwent a radical surgery in which his hippocampus was removed bilaterally in an attempt to cure his severe epileptic seizures. Following the surgery, H.M. suffered from profound amnesia and was unable to form new memories (Scoville and Milner, 1957). The surgery sparked a debate over whether the removal of the hippocampus impaired H.M.'s ability to form memories, retrieve memories, or both. Results from PET studies resolved this issue by demonstrating that different cortical networks are engaged during encoding and retrieval (Fletcher et al., 1995; Kapur et al., 1995). Using a classic memory paradigm, Tulving et al. (1996) had participants evaluate photographs during a PET scan that they had either previously viewed (old) or were novel (new) to identify neural regions involved in encoding (e.g., viewing a novel stimulus) and retrieving (e.g., viewing a previously presented photograph) information. For encoding, the researchers found that greater activation occurred in the hippocampus; for retrieval, they found greater activation in the prefrontal cortex.

PET has one major disadvantage. The use of radioactive substances places an inherent limitation on the number of trials and accordingly tends to have low power. Moreover, it can take a long time to image the entire brain and so trials need to last for an extended period. These features of PET require modification of many of the standard paradigms used in cognitive psychology. Thus, for reasons of safety as well as the ability to use many trials, most current brain imaging is conducted using fMRI.

Functional Magnetic Resonance Imaging (fMRI)

Functional magnetic resonance imaging (fMRI), like PET, measures brain activity by tracking metabolism associated with blood flow, but it does so noninvasively (i.e., nothing is injected into the blood stream). Thus, a single fMRI study can contain hundreds of trials, thereby greatly enhancing the power of the study. For instance, in fMRI it is possible to alternate continuously between experimental and control conditions. (In PET, a break is needed between conditions in order for the radioactive tracer to clear the system.) Moreover, fMRI provides superior spatial resolution, 1-2 millimeters in comparison with PET's resolution of 5-10 millimeters; thus, fMRI permits exploration of smaller brain structures (e.g., the amygdala) that tended to be overlooked in PET research.

In fMRI, blood flow is not measured directly. Rather, fMRI uses a strong magnetic field to assess changes in the blood-oxygen level dependent (BOLD) response at particular cortical sites after they have become active, which is an indirect measure of blood flow. Specifically, the BOLD signal is derived from the ratio of oxygenated to deoxygenated blood at cortical locations throughout the brain. Neural substrates that are active during a cognitive task have a greater repository of oxygenated hemoglobin than regions that are at rest. Deoxygenated hemoglobin is paramagnetic and distorts the magnetic field created by fMRI. Oxygenated hemoglobin, however, is diamagnetic and thus does not distort the magnetic field. The degree to which the magnetic field is distorted at a given location forms the fMRI image.

During the past decade, the advent of fMRI has led to increased research on cognition, behavior, and emotion. The superior spatial resolution of fMRI enables researchers to investigate smaller, subcortical regions, such as the amygdala. Indeed, a wealth of information has become available on the amygdala, implicating it in such tasks as perceiving emotion (Whalen, 1998), emotional memory (LeDoux, 1993), and evaluating stigmatized others (Krendl et al., 2006; Phelps et al., 2000). Research using fMRI has provided insight on the modulatory role of the prefrontal cortex over subcortical regions, such as the amygdala. For instance, Ochsner, Bunge, Gross, and Gabrieli (2002) provided compelling evidence that the prefrontal cortex increases activation during tasks that require overriding prepotent responses. In their study, the authors showed participants highly negative scenes and asked them either to attend to the pictures or to reappraise them so that the pictures became unemotional. During the reappraisal trials, the authors observed heightened activation in the medial and lateral prefrontal cortex and decreased activation in the amygdala and orbitofrontal cortex (regions implicated in processing emotion).

The use of fMRI has also proven effective for resolving conflicting theories that cannot be addressed by traditional behavioral methods. One example is the use of brain imaging to understand the self-reference memory effect. In the realm of cognition, one's self receives preferential access to attentional resources, and there is a selective advantage for remembering stimuli evaluated with reference to the self (Rogers, Kuiper, and Kirker, 1977). However, the basis of this advantage was long debated in social psychology, with the argument that either the self is somehow special or that the self is not special but simply encourages more elaborative encoding (Greenwald and Banaji, 1989; Klein and Kihlstrom, 1986). Which view is right? A frustrating feature of these competing accounts is that they are difficult to evaluate using purely behavioral measures as they make identical predictions—enhanced memory for self-relevant material. Herein lies the tremendous advantage of using brain imaging. An initial attempt to examine the neural substrates of the self-reference effect used PET. Unfortunately, there is a limit to the number of trials that can be presented using PET, and the researchers did not obtain a statistically significant self-reference effect (Craik et al., 1999). Nonetheless, their results were intriguing in that during self-reference processing trials, they did find distinct activations in frontal regions, notably the medial prefrontal cortex (MPFC) and areas of right prefrontal cortex.

Observing the limitations of PET, Kelley et al. (2002) used fMRI in an attempt to identity the neural signature of self-referential mental activity. In the task, participants were asked to judge 270 trait adjectives in one of three ways: self ("Does the trait describe you"?); other ("Does the trait describe George Bush"?); and case ("Is the trait presented in uppercase letters"?). Following two encoding runs, participants were given a "surprise" recognition memory test: participants viewed both trait adjectives that had been presented during the encoding scans and novel trait adjectives that had not been presented. The large number of trials (an advantage of fMRI over PET) allowed for the replication of previous behavioral findings that trait words encoded for one's self were better remembered than trait words encoded for George Bush or words for which participants made case judgments. More importantly, a direct comparison revealed that "self" trials produced significantly greater activation than "other" trials in a number of different brain regions, most notably the MPFC.

These findings provide preliminary evidence that the MPFC is involved in self-referential processing, but a question remains: How can one determine if this brain activity is responsible for the increase in memory for material encoded with reference to self? That is, activity in the MPFC accompanies self-referential processing, but does this activity contribute to the formation of memories in the brain? To investigate this question, Macrae et al. (2004) measured brain activity while participants judged the relevance of a series of personality characteristics. Afterwards, memory for the items was tapped in a surprise recognition task. By contrasting brain activation elicited by items that were later remembered with those that were later forgotten, it was possible to identify brain regions that predict successful recognition. Importantly, this research showed that the level of activity in the MPFC during self-referential judgments predicted which items would be remembered on the surprise memory test (i.e., the greater the MPFC activity, the more likely an item was to be remembered). Thus, not only does activity in the MPFC track with self-referential processing, but it also contributes to the formation of self-relevant memories. The important point for this paper is that brain imaging allowed researchers to test competing hypotheses that could not be discriminated by standard behavioral testing.

Although fMRI has advanced scientific research in many domains, it is important to note that, like PET, fMRI is not without its limitations. Primarily, fMRI sessions are expensive (costing at minimum several hundred dollars per participant). Furthermore, fMRI has inferior temporal resolution, particularly in comparison with ERP and MEG. An fMRI detects cortical activation on the basis of changes in the BOLD signal, but the BOLD signal changes only after a cortical region has become active. In an attempt to circumvent this limitation, many researchers have begun to conduct fMRI studies in conjunction with ERP and MEG to minimize the temporal limitations of fMRI (Foucher, Otzenberger, and Gounot, 2004). To date, much of the initial research has focused on validating the method, and it remains to be seen whether it will prove more useful in studying cognition than either technique alone. There are also interpretive issues related to brain imaging in this work, which we discuss below.

Morphometry

In the above sections we have explored methods that index brain activity; however, with the advent of high resolution MRI, it has also become possible to noninvasively measure the shape, size, and orientation of white and gray matter in the brain. The study of brain morphometry allows for the identification of structural features of the brain that can be correlated with pathology or behavior. The study of morphometry has had a tremendous impact on identifying brain abnormalities associated with neuropathological conditions, such as autism, Parkinson's disease, and epilepsy (Abell et al., 1999; Bernasconi et al., 2004; Nagano-Saito et al., 2005). For instance, two recent morphological studies of autism revealed reduced grey matter volume and cortical thickness in areas of the brain known to be important for social and emotional functioning: this finding may help explain the well known social and empathetic deficits characteristic of autism (Hadjikhani, Joseph, Snyder, and Tager-Flusberg, 2006; McAlonan et al., 2005). Research has also demonstrated direct links between brain morphometry and experience. For instance, Maguire et al. (2000) found that the posterior hippocampus, an area important for spatial memory, was larger in a population of London taxi drivers than in matched controls; in addition, the size of this area correlated with driving experience.

An early limitation of morphometry was that it relied on manually segmenting brain regions, a method that is prone to subjective bias or error. As morphometry becomes increasingly popular, numerous automated segmentation techniques for measuring grey and white matter have developed. The main advantage of such an automated approach is that analyses are not restricted to easily segmentable structures or prior regions of interest. By far the most common of the automated methods is voxel-based morphometry (VBM). In this method, MRI images of the brain are submitted to an automated segmentation algorithm that classifies grey and white matter on the basis of the intensity differences in the images. The resulting grey and white matter maps can then be evaluated for group differences in grey and white matter (e.g., healthy controls and patients) or to measure correlations of grey and white matter density with a continuous variable (e.g., test performance, personality measures). For instance, Sluming and colleagues (2002) used VBM to show that experienced musicians have increased grey matter density in Broca's, an area of the brain important for language.

Another popular method for studying cortical structures is analyzing cortical thickness (Fischl and Dale, 2000). This method measures the distance between segmented white and grey matter borders along the cortex. The primary difference between this and VBM is that statistical differences can be expressed in terms of the millimeter thickness of the cortex. Research using cortical thickness analysis has spanned a broad range of topics. For example, Lazar and colleagues (2005) found that experienced meditation practitioners displayed increased cortical thickness in brain areas involved in attention. In two recent studies, Rauch and colleagues (2005) measured the correlation between cortical thickness, extroversion, and ability to modulate fear. Interestingly, they found that the capacity to extinguish memory for conditioned fear was correlated with increasing cortical thickness in the orbitofrontal cortex. These findings were consistent with previous work by Rauch et al. (2003) showing that patients with posttraumatic stress disorder have reduced grey matter volume in this area of the brain, which may lie at the root of their difficulty in extinguishing fearful memories.

Although the application of morphometric techniques in nonclinical populations is still in its infancy, recent research has been successful in highlighting specific brain structures that are correlated with individual differences in personality. In one of the first studies of its kind, Pujol and colleagues (2002) used manual segmentation to measure the volume and symmetry of the cingulate cortex so that they could assess its relation to personality traits. They found that the size of the right anterior cingulate was correlated with measures of proneness to worry, shyness, and fear of uncertainty. These findings are intriguing in light of the anterior cingulate cortex's role in cognitive control and suggest that increased right anterior cingulate volume is related to a fearful temperament. More recently, a morphometric study by Pruessner and colleagues (2005) examined the relation between individual differences in stress response, self-esteem, and hippocampal volume. Interestingly, they found decreased hippocampal volume in participants with low self-esteem. Finally, Wright and colleagues (2006) found reduced cortical thickness in the inferior frontal cortex (IFC) in participants who scored high in extraversion. These results suggest that the IFC may be an area involved in social inhibition and that the reduced thickness of this area may reflect relative disinhibition in highly extraverted persons.

Diffusion Tensor Imaging (DTI)

Despite numerous technical advances in morphometry research, it is only able to provide information about the size and location of grey and white matter regions. To understanding how different brain regions are connected, it has proven useful to examine white matter fiber tracks, which are bundles of myelinated axons that connect brain regions. The advent of diffusion tensor imaging (DTI) in the late 1990s provided researchers with the ability to detect directionality of these white matter tracts (see Basser, Mattiello, and LeBihan, 1994). DTI is based on MRI: it maps the location of white matter tracts by applying magnetic gradients to water molecules that diffuse across myelinated neuronal axons. DTI provides invaluable information about neurodegenerative disorders that target white matter (e.g., schizophrenia, Alzheimer's, stroke, and dyslexia (see Le Bihan et al., 2001)). Alzheimer's, for instance, is a disease that can only be officially diagnosed after death. However, DTI research has begun to identify differences in white matter tracts that may allow for accurate diagnosis of Alzheimer's much earlier. A recent DTI study found that 11 patients with probable Alzheimer's showed significant reduction in the integrity of certain white matter fiber tracts associated with cognitive performance, specifically, the splenium of the corpus callosum, superior longitudinal fasciculus, and cingulum (Rose et al., 2000). Interestingly, no decay was observed in white matter fiber tracts involved in motor performance, which supports the observed finding that Alzheimer's affects cognitive, not motor, ability.

DTI has also been used extensively to study schizophrenia. In the first study using DTI to examine schizophrenic brains, the researchers found that people with schizophrenia had significantly less white matter anisotropy (not having properties that are the same in all directions) in comparison with the controls, despite having equivalent white matter volume (Lim et al., 1999). Additional studies have found differences in the corpus callosum such that people with schizophrenia displayed significantly greater diffusivity, but decreased anisotropy, in the splenium than controls (Foong et al., 2000).

Transcranial Magnetic Stimulation (TMS)

It is commonly known that functional neuroimaging data only "suggest" brain regions that may be engaged during a given behavior; correlations between behavior and localized brain activity cannot establish a causal brain–behavior linkage. One way to test for a causal link would be to conduct a virtual lesion study in which specific brain regions were damaged while leaving other areas relatively intact. Traditionally the establishment of causal brain-behavior links in humans has relied on the neuropsychological study of patients with damage to specific brain regions. Because head trauma or neurological disease generally causes such damage, our ability to experimentally control the location and extent of damage is severely limited. Transcranial magnetic stimulation (TMS) allows for the reversible experimental disruption of neural activity in relatively circumscribed cortical regions while study participants engage in a cognitive task (Jahanshahi and Rothwell, 2000; Walsh and Cowey, 2000; Wig, Grafton, Demos, and Kelley, 2005). Since its introduction in the mid-1980s (see Barker and Jalinous, 1985), TMS research has investigated a wide range of theoretical questions, from memory and language to epilepsy and schizophrenia. Recently, researchers have also begun investigating its therapeutic potential in treating mood-related disorders, such as depression (Loo and Mitchell, 2005).

During transcranial magnetic stimulation, a powerful electrical current flows through a wire coil that is placed on a person's scalp over the area to be stimulated. As electrical current flows through the coil, a powerful magnetic field is produced (commonly 2 Tesla or 40,000 times the earth's magnetic field), which, when rapidly switched on and off, induces an electrical current in a circumspect region of brain directly below the coil. The application of TMS interferes with neural function in discrete regions of the brain. In single-pulse TMS, the disruption of brain activity occurs only during the brief period of stimulation. If multiple pulses of TMS are given over extended time (known as repeated TMS), the disruption can carry over beyond the period of direct stimulation.

Much of the early use of TMS was in studying the motor and visual cortices. For example, TMS has been used to show a causal relationship between disruption of a region of the parietal cortex (the anterior intraparietal sulcus) and participants' ability to form the proper hand configuration for grasping an object (Tunik, Frey, and Grafton, 2005). In visual cognition, TMS has been used to selectively disrupt the perception of motion. By applying TMS over area V5 (an area of visual cortex important for processing visual motion), researchers have been able to temporarily reduce participants' ability to detect a moving stimulus (Beckers and Homberg, 1992). Recently, researchers have begun to use TMS to study the brain basis of complex social cognitive phenomenon, such as face perception and empathy for pain. Past neuroimaging research has shown that a region of the brain known as the superior temporal sulcus (STS) is often activated in the perception of biological motion (such as body movement and eye gaze). However, it has not yet been determined whether this region is necessary to perceive biological motion. Recent studies using TMS to create a virtual lesion in the STS have demonstrated interference in the perception of eye gaze direction (Pourtois et al., 2004) and reduced accuracy in detecting biological motion from point light displays (Grossman, Battelli, and Pascual-Leone, 2005).

Although many TMS studies have sought to disrupt brain activity through repetitive stimulation, researchers have also explored the capacity of TMS to stimulate brain activity in order to improve function. An area of the brain known as the frontal eye field (FEF) has been implicated in the control of eye movements and, more recently, has been shown to be involved in the conscious detection of stimuli in primates (Moore and Fallah, 2001; Thompson and Schall, 1999). Using TMS to stimulate the FEF in humans, Grosbras and Paus (2003) were able to demonstrate increased detection of an otherwise subliminal stimulus. Thus, it seems that stimulation of FEF increases cortical excitability in the visual system and can consequently reduce the threshold needed for detecting a stimulus. More recently, Kim et al. (2005) were able to show that TMS can facilitate visual attention in one side of visual space by inhibiting brain activity in areas responsible for attending to the opposite side of visual space. By applying repetitive TMS over the posterior parietal cortex of the left or right hemisphere, thereby disrupting activity in that area, the researchers were able to show a concomitant increase in visuospatial attention in the opposite visual field. This finding demonstrates that visual attention is a resource that is shared between brain areas responsible for the left and ride side of visual space and that by inhibiting activity in one region, competition for attentional resources is eliminated and attention to the noninhibited side of visual space is increased. Whether these TMS-induced facilitation effects can exist without detriment to other facets of visual perception remains to be studied.

CONCEPTUAL AND PRACTICAL CONCERNS

In spite of the enthusiastic adoption of the methods of neuroscience to study psychological constructs, there remain important conceptual issues regarding this approach. Space limits preclude a full discussion of such concerns, but we provide a few examples in this section.

Perhaps the most central issue is that scientists do not yet fully understand the specific neural basis of brain imaging signals. Although several explanations have been proposed for the BOLD response, the precise mechanism remains unspecified at the neuronal level. Another problem (discussed above) is that most imaging methods are necessarily correlational and therefore prone to all the inherent limitations of all correlational methods. The advent of such tools as TMS may allow for examining causality, but TMS is limited to cortical areas near the skull and therefore will not be useful for many mental processes that involve subcortical structures. Assessing patients who have brain injuries can provide complementary evidence for the causal involvement of a brain region for a given psychological function.

Another conceptual issue is the difficulty in localizing specific psychological functions to discrete brain regions. There have now been several thousand imaging studies of a variety of psychological functions. What is clear is there is no one-to-one mapping between brain region and psychological function. Indeed, some brain regions are activated across numerous cognitive tasks. Thus, when a researcher finds a particular activation in an imaging study, it is not always obvious what that activation reflects. Although the literature contains sufficient evidence that there is specialization of brain function, it can be challenging to determine the specific function associated with a particular activation. An area may be activated across a broad array of disparate cognitive tasks because those different tasks share some common psychological process (e.g., semantic processing, memory, selecting among competing stimuli). In these cases, the activation may have little to do with the research question of interest to the investigator. As in all areas of science, the value of any imaging study depends on the care with which the experimental tasks are designed. In an ideal world, the comparison conditions that are used differ from the experimental conditions in as few dimensions as possible. Researchers also have to be vigilant to the possibility that their manipulations may be confounded with other psychological processes.

Consider the following example. Given the fundamental importance of social inclusion, it was perhaps not surprising that a recent study implicated brain regions commonly associated with physical pain as crucial for the experience of social pain. Specifically, Eisenberger, Lieberman, and Williams (2003) found that a region of the dorsal anterior cingulate cortex (dACC) was responsive during a video game designed to elicit feelings of social rejection when virtual interaction partners suddenly and surprisingly stopped cooperating with a research participant. Although these findings are intriguing, they clash with prior research and theorizing on the anterior cingulate cortex. In numerous prior studies, the dACC has been most closely associated with cognitive conflict, such as occurs when expectancies are violated (Bush, Luu, and Posner, 2000), while activity in the ventral ACC (vACC) is more typically associated with social and emotional processes. The literature also indicates that the vACC is implicated in emotional disorders, such as depression (Buchsbaum et al., 1997; Drevets, et al., 1997; George et al., 1997). Indeed, in a particularly striking study, Mayberg and colleagues (Mayberg et al., 2005) demonstrated that deep brain stimulation in vACC was effective in alleviating depression in treatment-resistant patients. Hence, the findings of Eisenberger and colleagues are intriguing, but viewed in this light somewhat surprising.

One complication in interpreting those findings is whether the method used to induce social rejection also likely violated research participants' expectations. Put simply, the participants expected to participate. When this did not happen, it violated expectancies, producing cognitive conflict. So, left unanswered is whether the activation patterns they observed in that study were produced by cognitive conflict or social rejection.

Recently, researchers sought to address that question by designing a study that allowed for an independent examination of the neural underpinnings of social rejection and expectancy violation (Somerville, Heatherton, and Kelley, 2006). Results revealed a double dissociation between dorsal and ventral ACC regions. The dACC was uniquely sensitive to expectancy violations, with greater response when feedback was inconsistent with participants' impressions. This result held regardless of whether the feedback was a rejection or an acceptance. Conversely, a region in vACC was uniquely sensitive to social feedback, with significantly greater response to negative feedback than positive feedback, irrespective of expectancy violations. The lesson from this study is that simply observing activation in a specific brain region does not necessarily identify the psychological processes that underlie that activation. An editorial in the leading journal *Nature Neuroscience* stressed that all imaging studies should be driven by hypotheses in terms of testing discrete cognitive constructs (e.g., "Is the hippocampus involved in memory?"), rather than simply brain mapping (e.g., "What happens in the brain during social influence?").

In addition to the conceptual concerns, a practical limitation to using neurophysiological methods to study behavior needs to be mentioned: the inadequacy of training opportunities to educate students about the rich traditions of psychological science along with a rigorous education in neuroscience. Consider the topic of social neuroscience. Many of the social psychologists who wish to use neurophysiological methods receive little formal training in neuroscience. At the same time, much of the work in social neuroscience is being conducted by researchers who have little awareness of the vast social psychological literature that is prized for its methodological rigor. There is a pressing need for cross-disciplinary training to facilitate theory-driven research that is methodologically sound.

CONCLUSION

The use of neurophysiological methods allows researchers to watch the working brain in action as it performs mental activities. These methods have enabled scientists to study important questions that were previously intractable, as well as to test competing theories that cannot be distinguished based on behavioral evidence. The use of these methods in psychology is still in its early days, and there remains a great deal to be learned. It is likely that technical advances will allow researchers to better understand the significance of functional brain activity (i.e., what causes it). At the same time, there is an urgent need for cross-interdisciplinary training that allows social and behavioral scientists to use these methods in constructive and productive ways.

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