

*A scientific communication model of the emergence of a hybrid research area was developed and tested in the field of developmental dyslexia, using multiple data sources concerning personal, professional, publication, and network aspects of seventy-four dyslexia researchers. Results suggest that societal concerns, federal research policy, and grant funding may play major roles in encouraging growth and change in a problem area, but that subject background and perceptions of past controversies also strongly influence researchers' involvement. The findings suggest the value of conceptualizing all of science communication, including the popularization of science, as a continuum within the larger society.*

## *Network Influences on Involvement in the Hybrid Problem Area of Developmental Dyslexia*

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*Growth, change, and progress* in science depend on the cumulative decisions of many individuals to study one problem area rather than another, as well as on their subsequent success in research. A *problem area* is an area of accepted knowledge associated with a substantive object of study (Gieryn 1978) and with a more or less interconnected group of researchers with shared disciplinary orientations. Established problem areas tend to be characterized by scientific consensus and predictability of results; emerging communities may offer opportunity to the scientist but also risk (Mulkay 1977; Ziman 1987).

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Ziman (1987) explores the many complicated issues surrounding "the problem of problem choice." He notes a strong tendency for scientists to persist in the same problem area, even in an established area that may yield diminishing scientific returns. Following the principle of homophily (Rogers 1983, 18), information clearly tends to circulate more easily within a research or problem area than across boundaries, although Crane (1972) suggests that "research areas are not closed communities, unresponsive to external influences" (p. 100). However, "[c]ognitive structure, of course, can both facilitate and impede, sometimes alternately, the flow of marginal and innovative ideas" (Chubin 1976, 460). And some individuals simply may be more open to change than others.

Involvement in emerging problem areas that cross disciplinary boundaries can be particularly refractory. A *hybrid problem area* can be thought of as a cognitive area that is investigated by individuals from a variety of backgrounds. Differences in training and language among investigators in a hybrid problem area may interfere with the emergence of a cohesive research community; competing interests, values, and methodological preferences may result in distinctly separate communities (Restivo and Loughlin 1987; Stewart 1990, 241). Communication and recruitment may be quite challenging. At the same time, researchers in a hybrid field may benefit from the insights of disparate others, resulting in innovative advances in research through a process of cross-fertilization. New research communities may arise from this creative tension.

These alternative possibilities raise the question of what factors encourage, or inhibit, cross-fertilization of ideas, and the possible relationship of such factors to the migration of researchers into an emerging hybrid problem area. The major focus of this article will be on a number of individual, contextual, and network factors that might affect researchers' *willingness to change* and *involvement* in an emerging area.

These issues will be explored within the context of selected groups with an interest in *developmental dyslexia*; specifically, those individuals with roots in the phonological deficit and visual perceptual deficit perspectives, and recent migrants from the neurosciences and other fields. Developmental dyslexia is an "unexpected difficulty in learning to read and spell" (Pennington 1991, 45). The dyslexia research community is of interest in part because of its hybrid composition, including researchers from a variety of professions, fields, and backgrounds. Dyslexia is considered to be a serious societal problem. It has been the focus of a good deal of federal funding, and it has received substantial attention in the media (e.g., see Roush 1995). In addition, certain aspects of its recent history have been well documented through highly visible exchanges in the literature debating alternative explanations about the

causes of dyslexia. Thus, dyslexia research appears to be an interesting area of ongoing growth and change.

The debate about causes appeared to have been largely resolved in the 1980s, with most researchers endorsing the view that differences in phonological abilities (a difficulty in decoding words) account for a large proportion of the variance in reading ability (Stanovich 1985). This perspective continues to be dominant in the 1990s (Lyon 1995; Shaywitz 1996, 1998). However, in the early 1990s, there began to be renewed interest in a less well accepted research tradition: the visual perceptual component to reading disability (involving problems in processing visual stimuli), following advances in related areas of dyslexia research (see Stein 1991). Recent findings in neuroanatomy, neurophysiology, and related fields suggest that underlying deficits in temporal processing may account for both phonological (linguistic) as well as visual and auditory perceptual problems in developmental disabilities (Galaburda, Menard, and Rosen 1994; Tallal et al. 1993). Such a theory of temporal information processing provides a possible integrating framework for research not only in dyslexia but also in developmental language disorders (dysphasia).

Events such as the September 1992 conference (Tallal et al. 1993) cosponsored by the New York Academy of Sciences and the Rodin Remediation Academy, and partially funded by several of the National Institutes of Health, have provided opportunities for researchers from diverse backgrounds to interact and learn from one another. These developments suggested the potential for reconciling opposing views and diverse research traditions within the broader problem area. They also suggested the possibility that more marginal researchers could become better integrated into the dyslexia research community than has traditionally been the case, or alternatively, the possibility of resistance and controversy.

### *Models of Scientific Change*

Scientific change may be viewed as a diffusion process in which individuals become aware of a new idea—in this case, an evolving intellectual problem area and its associated questions—and decide to “adopt” the innovation, by becoming involved in the research network and investigating relevant issues (Michaelson 1993; Rogers 1983). Valente and Rogers (1995) analyze the rise and fall of rural sociological diffusion research using a framework based on the work of Kuhn (1970) (as well as that of Crane 1972 and Price 1963). Kuhn’s (1970) well-known model emphasizes the “revolutionary” nature of change in science, in which incremental progress within “normal

science” is punctuated by violent upheaval and shifts between alternative “paradigms.” Valente and Rogers note that while the rural sociology case fits many aspects of Kuhn’s model, there are key exceptions. These include the important role of popularizers of the diffusion model in attracting funds and other support, and the impact of the policy environment as a crucial dimension in the growth and decline of the specialty area. Furthermore, they indicate that when the agricultural diffusion research front grew stale, it was not replaced by an alternative paradigm in a violent revolution. Instead, the diffusion model was adopted by other fields, ranging from communication to anthropology.

Although not specifically mentioned by these authors, the case of agricultural diffusion research appears consistent with the observations of others who have sought to amend and refine the Kuhnian model. Whitley (1984) comments that various scientific fields can be characterized by differences in intellectual structure and context that might be expected to affect the process of change. Both he and Restivo (1987) emphasize the problems associated with Kuhn’s unitary view of the mature sciences and the supposition that different fields will follow the same pattern of development. Less well developed fields may evolve in quite different ways than physics, the focus of Kuhn’s analysis.

Mulkay, Gilbert, and Woolgar (1975) propose instead a gradual model of scientific change, in which violent revolution may exist as a special case. In this view, researchers may migrate to an emerging area that is related to, but separate from, their initial area of research, to explore unsolved questions. Some scientists “begin working in a scientific specialty as critics or by contributing a modification of the paradigm” (Michaelson 1993, 221) and then continue to work in the emerging problem area. Such modifications are essential to the development of a new problem area. A period of exploration is followed by unification and then decline and displacement; reaction from neighboring communities may encourage relatively fluid interactions or hostile rejection. Rappa and Debackere’s (1995) description of the development of the neural network research community follows this pattern. Their account includes reports of opposition to neural network research from leading artificial intelligence researchers and of conflicts among different factions within the neural network community itself. This framework, and much related work, emphasizes the central importance of the research community in the development of science.

More recently, constructivists have shifted the emphasis of social studies of science from the macro level to the micro level. Knorr-Cetina (1982) criticizes the entire concept of scientific community as “a typical example of an outsider’s similarity classification” (p. 115), advocating instead a more

participant-centered perspective such as that provided by laboratory observation. Similarly, Latour (1987) asserts the importance of studying science "in action," observing scientists as they work and "construct" scientific facts. He persuasively stresses the collective nature of fact development ("the fate of a statement depends on others' behavior" [Latour 1987, 104]), the marshaling of resources to strengthen one fact claim over another, and the dependence of scientists on establishing and maintaining links with allies traditionally perceived as "outside" science. Constructivist studies have made a substantial contribution in extending the groundwork laid by Kuhn and others, emphasizing the social and cultural aspects of scientific development and counteracting the positivist view of science as a totally rational enterprise. However, the constructivist approach is not without problems or criticism.

While accepting many aspects of the constructivist perspective, Cole (1992) comments that Latour's arguments minimizing the role of the cognitive content of scientific ideas do little to explain why some scientific contributions (such as the structure of DNA) are accepted almost immediately, while others face a long, hard battle (p. 48). Like Cole, Rappa and Debackere (1995, 325), Stewart (1990, 205), and others assert that both cognitive and social variables can influence the evaluation of new scientific ideas. For example, complex ideas may require specialized training to be fully understood (Michaelson 1993). Pinch and Bijker (1984) further note that "[t]he laboratory location is a rather poor place in which to study the formation of scientific consensus" (p. 431), while Knorr-Cetina (1995) acknowledges that, by focusing on the laboratory environment, constructivist studies can be said to "ignore the societal context in which laboratories operate as well as the political aspects of science" (p. 162). Although Latour (1987) takes particular exception to the diffusion approach, he emphasizes its dissimilarities and points of conflict with constructivism while ignoring the extent to which the two approaches might be perceived as compatible. Investigation of scientists at more than one location and time would appear to be particularly necessary when studying the development of possible convergence or divergence in a hybrid problem area.

Consequently, like a number of the above-cited authors, the present study assumes that there is a useful, potentially complementary role for both micro- and macro-level (including diffusion) studies on the process of scientific change, and that both intellectual and social factors may affect the emergence of a new problem area. Like Lievrouw and colleagues (1987), the study incorporates a triangulation approach, using both qualitative and quantitative measures, in an effort to consider the various forces which may—directly or indirectly—influence the reception of developments in a field (developmental dyslexia) and subsequent patterns of growth and change.

### *Influences on Adoption and Diffusion*

*Diffusion* is "the process by which an innovation is communicated through certain channels over time among members of a social system" (Rogers 1983, 5), such as the adoption of family-planning methods in developing nations or the use of a specific research approach among social networking analysts (Michaelson 1993). Here, we follow Stewart's (1990) conceptualization of scientific specialty areas as social organizations. Although much diffusion research examines the adoption of innovations among individuals, Rogers (1983) observes that two main factors influence the innovation process in a social system such as an organization: organizational and network characteristics, and individual characteristics (p. 360). A third factor pertains to the attributes of the innovation (e.g., compatibility, complexity, or relative advantage). Individuals are less likely to adopt an innovation that is incompatible with previously held ideas or values. Compatibility is examined indirectly in this study, in terms of researchers' *perceptions* of attributes associated with a particular perspective.

Like organizations, scientific communities can vary greatly in such properties as *occupational diversity and stratification, professionalism, and external accountability*, each of which may affect the flow of information and the relative openness of a problem area to new ideas. Individuals also may differ in terms of their *knowledge, innovativeness, and expectations* concerning involvement in a problem area. Many other factors could be considered, but in view of this study's effort to examine a possible convergence between different perspectives in a hybrid problem area, those factors potentially influencing a willingness to change were emphasized.

*Diversity* refers to the number of different occupational specialties or countries of citizenship represented in a group. Once involved in a particular (especially an established) community, researchers engaged in the conduct of "normal science" tend to continue their association because of reduced diversity, such as similar education and professional socialization (Kuhn 1970) and persistence and commitment to the same problem area (Ziman 1987). Consequently, one would expect members of an *established* network to be relatively similar to one another in background and thus relatively resistant to innovation. Such researchers will tend to have accumulated a large number of citations to their work, to be well-known within the scientific community, and to cite each other and cocite similar sets of others. These cocitation patterns are indicators of the intellectual structure of a problem area (McCain 1990). Members of an established network may appear to be relatively self-sufficient, having relatively few connections with the broader scientific community.

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Rogers and Agarwala-Rogers (1976) define *external accountability* as the degree to which members of a network depend on, or are responsible to, their environment, such as in their degree of dependence on grant funding. This is similar to what Knorr-Cetina (1982) refers to as "resource-relationships—that is, relations to which one resorts or on which one depends for supplies or support" (emphasis in the original) (p. 119). External grant funding may explicitly influence the direction of proposed research, require the participation of selected specialists to ensure the availability of expertise, and ensure feedback to the granting agency. These interdependencies and requirements increase the potential flow of information and ideas and the potential for innovation. In addition, granting agencies may take a proactive role in recruiting scientists and pushing for research in support of a specific agenda. Ziman (1987) also emphasizes the profound influence that institutions which provide financial support can have on the problem choice of individual scientists (p. 106). This can, however, depend on the context: the impact of tenure status, country, type of scientific institution, and means of material support can vary substantially.

Both formal networks (as reflected in journal articles and citations) and informal social networks (e.g., meeting at conferences) are important sources of the *knowledge* required for innovation, such as changes in scientific problem areas (Rogers 1983, 166). Personal contacts may serve an alerting or document delivery function, as well as providing information (factual, interpretive, attitudinal) directly. Furthermore, the quality and dispersion of literature in an emerging problem area may make it difficult for potential recruits to encounter appropriate articles, ironically increasing the need for personal contacts and media coverage. Consequently, the two information sources are very likely interdependent.

Rogers (1983) notes that more is known about *innovativeness*, "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system" (p. 242), than about any other concept in research on diffusion of innovations. Innovativeness is considered to be a normally distributed, underlying personality characteristic independent of any particular innovation that has been measured using a reliable self-report scale (Hurt, Joseph, and Cook 1977). However, few studies have explicitly examined innovativeness or willingness to change as an individual attribute among scientists. The classic Columbia University drug diffusion study by Coleman, Katz, and Menzel (1957) found that the most socially integrated physicians were the first to adopt a drug, perhaps because of their greater awareness of the innovation.

Furthermore, there are various adoption motivations related to, but different from, innovativeness per se. Hagstrom (1965) notes that ongoing

competition for recognition in science results in numerous scientists seeking out new research areas just as they are opening up (p. 82). Migrating to a new problem area, then, depends somewhat on the *expectation* that the risk of doing research in a possibly unfamiliar area is worth the potential rewards (Mulkey, Gilbert, and Woolgar 1975). Researchers may anticipate that financial support will be available, that increased social status will follow from being perceived as innovative, that probable findings in the new field will be as important as those in the old, and that the new area will generate sincere intellectual interest (Rappa and Debackere 1995, 337).

As observed above, the emergence of a new perspective in a problem area from other preexisting perspectives may be reflected in changing perceptions of relevance (e.g., cocitation patterns), changing patterns of *intellectual involvement* (publication), and changing patterns of *social interaction* (informal communication, attending and meeting at conferences). Other individual-level measures of *involvement* in an emerging problem area include publication or presentation of research on relevant topics and collaboration with new colleagues. It is important to attempt to investigate these developments where possible, using multiple methods at multiple levels (e.g., individual, network) to permit triangulation of results.

In the problem area of dyslexia research, one of two alternative perspectives on the underlying causes of the disorder has been perceived or portrayed for some time as less credible and less well established than the other. The decision to become involved in the less prominent area of interest appears to be somewhat of a gamble, perhaps requiring marked personal innovativeness, differing expectations, or specialized knowledge and background. The two alternative communities (established vs. emerging) also might be expected to differ in characteristics associated with system norms favoring change, such as external accountability and professional activity. And researchers might be expected to differ in their *perceptions* of the importance of attributes associated with one or another theoretical perspective, such as language or visual processing skills. The next section summarizes these two perspectives in the dyslexia problem area.

### *The Case of Developmental Dyslexia*

*Developmental dyslexia* is an example of a hybrid problem area of wide-spread concern and interest. Also termed *specific reading disability*, dyslexia is an "unexpected difficulty in reading in children and adults who otherwise possess the intelligence, motivation and schooling considered necessary for accurate and fluent reading" (Shaywitz 1998, 307). Recent estimates of its

prevalence in the population range from 5 percent to 17.5 percent (Shaywitz 1998). News items concerning dyslexia have been widely reported in the lay press. Like the broader field of learning disabilities, it is considered "the proper and legitimate concern of many disciplines or professions (neurology, psychiatry, psychology, education, ophthalmology [*sic*], optometry, and occupational therapy, speech/language pathology to name a few) [that] . . . have historically focused on different aspects of problems in development" (Lyon 1991, 7).

As noted earlier, the two most generally accepted explanations for dyslexia have involved a linguistic, or phonological, deficit (a difficulty in decoding words) and a visual perceptual deficit (involving problems in processing visual stimuli). However, the use of labels for different theoretical approaches implies an overly simplistic intellectual structure within a complex and constantly changing problem area (Stanovich 1993, xxiii). These theories were vigorously debated in the *Journal of Learning Disabilities* in the late 1970s (Fletcher and Satz 1979a, 1979b; Vellutino 1979; Vellutino et al. 1977). However, by the mid-1980s, a small set of conclusions was generally accepted by most researchers in the field. The most basic is that word-decoding ability, primarily the result of differences in phonological abilities, accounts for a large proportion of the variance in reading ability at all levels (Stanovich 1985, 67). Although Lovegrove, Martin, and Slaghuis (1986) made a concerted effort to show that a visual deficit exists in a large percentage of specifically disabled readers, the phonological perspective was widely disseminated through a *Scientific American* article (Vellutino 1987), among many other publications.

In the 1990s, however, the visual perceptual aspects of reading disability attracted renewed attention from researchers (e.g., Boden and Brodeur 1999; Cornelissen et al. 1995; Demb, Boyton, and Heeger 1997; Eden et al. 1995; Kruk, 1991; Lehmkuhle et al. 1993) following advances in the cognitive, genetic, neurobiological, and neuropsychological aspects of dyslexia (Galaburda 1993). It appears likely that a major increase in federal funding of research into the biological basis of learning disabilities also played a role in this renewal of interest. For example, funding for learning disabilities from the National Institutes of Health (NIH) increased from \$1.75 million in 1975 to \$10.42 million in 1990, for a cumulative total of \$76 million (Lyon 1991). Although the phonological perspective continues to be accepted by most researchers as the primary explanation for the disorder (Lyon 1995), the temporal processing theory mentioned previously provides a possible integrating framework for research. These developments suggested the possibility of convergence between alternative perspectives in the problem area. Alternatively, this new theory could be rejected or totally ignored.

In this study, the *neuroscience-vision group* will refer to researchers whose work has been concerned chiefly with topics related to visual or spatial and/or neuroscientific processes in the developmentally reading disabled (e.g., see Lovegrove et al. 1986). The *phonological dyslexia group* will designate those whose work has been concerned primarily with the role of linguistic processing in developmental reading disability (e.g., see Vellutino 1987). A particular focus of the study is on the role of the *emerging neuroscience-vision group*, in view of its more controversial, "outsider" status, as compared with the more *established* phonological group. The *emerging hybrid group* will denote those whose work accepts aspects of both perspectives.

### Overview of Cocitation and Communication Patterns in Developmental Dyslexia Research

Cocitation data can be used to indicate the intellectual structure of a problem area; the aggregate results of two authors being jointly cited by substantial authors are taken as a measure of perceived similarity or conceptual linkage (McCain 1990; White 1990). Relative numbers of cocitations may be viewed as a measure of influence, and similar patterns of citation indicate shared research focus and interest, providing evidence "beyond the knowledge and insights available from even the most knowledgeable, well-connected single researcher in the field" (McCain 1989, 677). Cocitation analysis has been used to investigate possible changes in the intellectual structure of disciplines over time in a number of studies (e.g., McCain 1984, 1989; Paisley 1990; Rice 1990), although Edge (1979), Knorr-Cetina (1982), and others have criticized the frequent reliance on citation studies to portray the structure of social relationships in a problem area. This points to the need to investigate social networks as well as intellectual or citation networks.

A prior network analysis of the dyslexia researchers using cocitation and sociometric data found two distinct groups, corresponding to the phonological and neuroscience-vision perspectives (Perry and Rice 1998). Various measures were used to validate group labels and characterizations. The cocitation groups identified grew in numbers and influence during a seventeen-year period, analyzed in three time segments (1976-81, 1982-87, and 1988-93). It had been expected that cocitation patterns would reveal two distinct groups at the earliest period that would gradually converge over time. In contrast, cocitation groups were relatively mixed in membership at the outset and became more divergent over time. However, in a sense there appear to have been three alternative groups at the earliest period: phonological, neuroscience, and outsiders, with the latter including those with an interest in

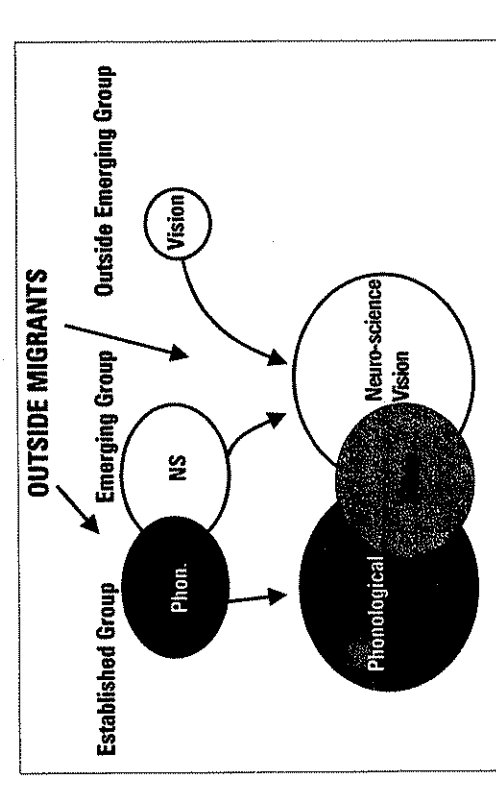


Figure 1: Preliminary Model of Hybrid Change in a Scientific Problem Area, Using the Case of Developmental Dyslexia

vision. The results suggested a convergence between the neuroscience and vision/outsider blocks, and a divergence between the phonological and neuroscience-vision blocks, each of which became more distinctly characterized and more closely connected with similar others. Cocitation data also revealed a system of stratification within the overall network, with an "insider" subset within each of the larger groups identified. Overall, the individuals associated with the phonological perspective could be characterized as more established "insiders" than those associated with the neuroscience-vision perspective in terms of cocitation patterns.

However, a network analysis using self-reported social contacts (e.g., phone calls, letters, conferences, e-mail) indicated a fair degree of social interaction between and among the different groups of researchers. This suggests that several lines of research may be going on within one or more social networks, a pattern similar to that described by Lievrouw and colleagues (1987) in their study of lipid-metabolism researchers. The most highly connected dyslexia researchers ("elites") especially reported interaction with individuals identified with both perspectives (the neuroscience-vision and phonological). Figure 1 illustrates these findings graphically.

Given these findings, what other measures of involvement might characterize the network groups identified? Do the groups hold different perceptions of

the importance of key processing skills as an underlying cause of dyslexia? Do these perceptions differ at different time periods? And what group and individual characteristics—especially those associated with a positive attitude toward change—might contribute to the patterns observed? Research questions and hypotheses derived from the prior discussions follow.

### **Research Questions and Hypotheses**

The time periods examined correspond to identifiable periods of change in the problem area: T1 = 1976-81, T2 = 1982-87, and T3 = 1988-93. The establishment of the Colorado Reading Project in 1979 marked the beginning of major federal funding of learning-disabilities research. This was followed by the funding of additional multidisciplinary projects in 1986, 1987, 1989, and 1990. Allowing two years for funding to have some impact, one might anticipate an increasing impact of the funded research in each of the three time periods. In addition, specific clusters of relevant publications were published in each of the three time periods: a series of debates in T1 (Fletcher and Satz 1979a, 1979b; Vellutino 1979; Vellutino et al. 1977), position papers on alternative perspectives in T2 (Lovegrove, Martin, and Slaghuys 1986; Stanovich 1985), and publications concerned with neuroscientific aspects of learning disabilities in T3 (e.g., Lehmkuhle et al. 1993). Finally, the years included in T3 happened to coincide with the subset of the SciSearch database available at the time of the analysis. Only results from T1 and T3 will be presented here, to highlight the most explicit differences.

### **Research Question 1—Network Involvement**

*Are Social and Intellectual (cocitation) Structures Related to Other Measures of Involvement in a Scientific Problem Area?*

**Hypothesis 1:** Compared with members of alternative groups, members of (a) the neuroscience-vision cocitation group rate the importance of non-language-processing skills to the study of dyslexia more highly (T1, T3), (b) the neuroscience-vision social group rate the importance of non-language-processing skills to the study of dyslexia more highly (T3), (c) the neuroscience-vision cocitation group at T1 and T3 are more likely to publish in support of the emerging hybrid perspective (T3), (d) the neuroscience-vision social group are more likely to publish in support of the emerging hybrid perspective (T3), (e) the neuroscience-vision cocitation group at T1

and T3 are more likely to attend conferences associated with the emerging hybrid perspective (T3), and (f) the neuroscience-vision social group are more likely to attend conferences associated with the emerging hybrid perspective (T3).

### **Research Question 2—Network Structure**

*How Are Measures of Network Structure (professional activity, diversity, and external accountability) Related to Alternative Intellectual Perspectives in a Scientific Problem Area?*

**Hypothesis 2:** Compared with the phonological dyslexia cocitation group, the neuroscience-vision cocitation group is (a) more active in outside professional organizations (T1, T3), (b) more diverse (T1, T3), and (c) has greater external accountability (T1, T3).

### **Research Question 3—Individual Characteristics**

*Are Individual Characteristics Related to Involvement in Alternative Perspectives in a Scientific Problem Area?*

**Hypothesis 3:** Compared with members of the alternative groups at T3, members of the neuroscience-vision (a) cocitation group and (b) social group are more innovative, (c and d) hold different expectations concerning their involvement in the problem area, and (e and f) have greater knowledge of new research developments relating to the emerging perspective.

### **Method**

#### *Network Identification*

The target networks of researchers were selected in part because of a series of published exchanges in the literature and the existence of substantial papers reviewing the case for alternative perspectives (both cited above), which made the proponents of alternative research approaches easy to identify. The published perspectives reflected a broad controversy within the problem area, rather than personal disagreements of a few individuals or a highly specialized research topic.

The study used multiple indicators in an effort to ensure that individuals selected were considered central to the broadly construed problem area, where possible both in a social (communication) and citation (intellectual) sense. These included (a) presence in appropriate bibliographies from the 1970s through the 1990s, (b) lists of principal investigators of funded research pertaining to reading disabilities, (c) presence on relevant editorial or advisory boards, and (d) participation in conferences on learning disabilities. This resulted in an initial composite list of 924 names. The analysis used the sixty-nine individuals mentioned in four or more sources, plus an additional 5 names added to the master list following review by two knowledgeable informants. Table 1 presents the names of the seventy-four researchers selected, along with their three-letter codes.

### Questionnaire

A questionnaire was developed and pretested, then revised following reviews by several individuals knowledgeable about dyslexia research. Components included a sociometric roster, an innovativeness scale (Hurt, Joseph, and Cook 1977), questions on the nature of problem area(s) of current research activity, expectations regarding that activity (Rappa and Debackere 1995), and assessments of the importance of various processing skills to the study of dyslexia. Respondents also were asked about their familiarity with four recent, highly visible publications in major scientific outlets on neuroscientific aspects of developmental dyslexia research (the emerging hybrid perspective) (Cardon et al. 1994; Galaburda, Menard, and Rosen 1994; Lehmkuhle et al. 1993; Tallal et al. 1993). Three of the four had been reported in the national press (e.g., Blakeslee 1994a, 1994b; Reading problems 1993). Phillips et al. (1991) have noted that coverage of medical research in the popular press appears to enhance the transmission of research findings to the medical community.

Other items in the questionnaire requested basic biographical data, as well as information on grant funding and professional activity (e.g., serving on editorial boards). A curriculum vitae (CV) was requested and was designed to substitute for much of the questionnaire if the respondent so chose. To complete each researcher's record, lists of editorial boards, published biographical sources (e.g., *Who's Who*), and a search of the CRISP database (a database of research projects funded by NIH) were consulted in conjunction with the survey data. A copy of the questionnaire is available from the first author.

Vigorous efforts were made to maximize the return rate (telephone calls; the inclusion of U.S. currency, postage, or international postal orders;

TABLE 1  
Codes and Names of Dyslexia Researchers Included in the Study

No.	Code Name	No.	Code Name	No.	Code Name
1	Bak Bakker DJ	26	Joh Johnson DJ	51	Rou Rourke BP
2	Ben Benton AL	27	Jor Jorm AF	52	Rum Rumsey JM
3	Bla Blachman BA	28	Kvl Kavale KA	53	Rut Rutter ML
4	Bod Boder E	29	Kvn Kavanagh JF	54	Sat Satz P
5	Bos Bos CS	30	Kim Kinsbourne M	55	Sei Seidenberg MS
6	Bra Brady CS	31	Laj Larsen JP	56	Shd Shankweiler D
7	Bre Breitmeyer BG	32	Las Larsen S	57	Shb Shaywitz BA
8	Bry Bryant BR	33	Leo Leong CK	58	Shs Shaywitz SE
9	Chf Chalfant JC	34	Lia Liberman AM	59	She Sherman GV
10	Chi Chall JS	35	Lit Liberman IY	60	Sie Siegel LS
11	DeF DeFries JC	36	Liv Livingstone M	61	Smi Smith SD
12	Den Denckla MB	37	Low Lovegrove WJ	62	Sig Stanley GV
13	DiL DiLolla V	38	Lun Lundberg O	63	Stk Stanovich KE
14	Doe Doshier DG	39	Lyo Lyon GR	64	Ste Stein JF
15	Dua Duane DD	40	Maf Manis FR	65	Tal Tallal PA
16	Duf Duffy FH	41	Mav Mann VA	66	Tor Torgesen JK
17	Ede Eden G	42	Mar Martin F	67	Udd Udden P
18	Fis Fisher DF	43	McC McConkie GW	68	Vel Vellutino F
19	Fie Fletcher JM	44	McK McKinney JD	69	Vog Vogel SA
20	Gal Galaburda AM	45	Mor Morrison F	70	Von Von Euler C
21	Gib Gibson EJ	46	Ols Olson RK	71	Wim Williams MC
22	Hal Hallahan DP	47	Pav Pavlidis GT	72	Wid Willows DM
23	Ham Hammill DD	48	Pen Pennington BF	73	Won Wong BYL
24	Hug Hugdahl K	49	Pir Pirozzolo FJ	74	Woo Wood FB
25	Hyn Hynd GW	50	Ray Rayner K		

NOTE: Names are generally coded by the first three letters of the researcher's last name. In cases where this would lead to duplicate codes, the third letter reflects either the researcher's first name (e.g., Laj = J. Larsen) or a subsequent letter in the researcher's last name (e.g., Kvl = Kavale).

follow-up letters with postage; mailing of second copies of the questionnaire; and reminder postcards). Seven individuals did not respond, due to illness, incorrect address, or not being actively involved in dyslexia research. These nonrespondents did not differ significantly from respondents in citizenship, number of NIH grants reported in CRISP, mean coccitedness at T3, or cocitation group membership at T3. There was a significant difference in professional age (years since doctoral degree) between respondents (younger) and those nonrespondents for whom degree date was available. Since it is probable that older, better-known researchers are more likely to be listed in biographical sources than are younger researchers, it is not clear whether this relationship would hold for all nonrespondents if data on degree date were more complete.

The final database included fifty-four sociometric rosters, fifty-five complete or partial questionnaires, and thirty-seven CVs. Information from biological sources was available for an overlapping twenty-five individuals. Available response data thus varied from measure to measure.

#### *Coding of Self-Reported Problem Areas*

On the questionnaire, the responding researchers reported up to three current problem areas along with a more specific research focus. These included a wide range of topics such as "autism," "brain injury," "handedness," "neuro-imaging," "phonological decoding," "reading and developmental disorders," and "word recognition." Given the prevalence of a psychology background in the problem network and the nature of reported responses, a scheme for coding the problem areas was adapted from the Content Classification System used by the PsycINFO database (Walker 1994, xxi). Topics that fell logically into more than one category were coded as present in both. For example, an interest in the neurobehavioral basis of dyslexia was coded as both "Disabilities" and "Neuropsychology." Additional code groups included "Developmental Psychology," "Education/learning," and "Language."

#### *Results: Description, Research Questions 1-3, Comparing Networks*

##### *Descriptive Overview*

All researchers in the study sample for whom data were available hold the doctoral degree, with nearly 75 percent holding the Ph.D. The mean year in which the doctorate was awarded was 1968. Most researchers have a background in psychology or clinical psychology; the next most common background is in medicine. Researchers reported an average of slightly more than four institutional affiliations following receipt of the doctorate, such as postdoctoral work, visiting appointments, concurrent appointments, or serial work history.

A majority of researchers in the study were citizens of the United States at the time they began work on dyslexia. Other countries with more than one researcher represented in the problem network include Australia, Canada, the United Kingdom, and Sweden. In addition, at the time of the survey, three U.S. citizens worked in Canada, while one Canadian and two citizens of the United Kingdom worked in the United States.

As noted earlier, analysis of cocitation and social interaction data revealed two groups: a neuroscience-vision group and a phonological dyslexia group.

The coded self-reported research interests were used to validate group labels: members of the neuroscience-vision group for both the cocitation (100 percent) and social network (90 percent) were significantly more likely to report an interest in neuropsychology topics than were members of the phonological group (40 percent and 50 percent, respectively,  $p < .0001$ ,  $p < .001$ ). (One-way analysis of variance [ANOVA] with  $p < .05$  is used for assessing the significance of differences between groups throughout the article; ANOVA is equivalent to a  $t$ -test for two means.) Significant differences between the neuroscience and phonological groups also exist for other self-reported areas of interest (e.g., education/learning) in the cocitation network (20 percent vs. 60 percent,  $p < .005$ ). Consistent with archival reports and expectations regarding members of a more established group, individuals associated with the phonological perspective in the T1 and T3 cocitation groups (2.3 vs. 0.5 and 7.8 vs. 5.4, respectively,  $p < .0005$ ,  $ns$ ), and the T3 social group (7.9 vs. 5.2,  $p < .05$ ), also were more highly cocited than those associated with the neuroscience-vision group. The rise in cocitedness over time is consistent with growth in the problem area and with the greater visibility of the work of its researchers.

#### *Research Question 1: Measures of Involvement*

*Hypothesis 1(a and b): Members of the Neuroscience-Vision Dyslexia Cocitation Group and Social Group Rate the Importance of Non-Language-Processing Skills to the Study of Dyslexia More Highly Than Do Members of the Alternative Group(s) (T1, T3) (partially supported).*

The survey asked respondents to rate the importance of a number of cognitive processing areas to the study of dyslexia (1 = *not important* to 7 = *very important*). The four primary areas were rated in this order: language processing (mean = 6.6), auditory processing (5.9), integration skills (5.0), and visual processing (4.6). ANOVA at the two-group level shows no significant differences for any of the various skills except the importance of visual processing at T1 (5.3 for the neuroscience cocitation group compared with 4.3 for the phonological,  $p < .05$ ) and for social groups at T3 (5.3 compared with 4.1,  $p < .005$ ). Similar results hold at the subgroup level of analysis at T3: neuroscience-vision cocitation subgroup 1B rated the importance of visual processing significantly higher (6.5) than other cocitation subgroups (4.1 for neuroscience 1A, 4.3 and 4.2 for the two phonological subgroups,  $p < .05$ ).

These findings suggest the continued outsider status of the concept of visual processing skills in the research network as a whole over time, except among those for whom research in the visual aspects of dyslexia is a

particular interest and concern. The concept of auditory processing skills does not seem to suffer the same lack of esteem with regard to its importance, although some research suggests that similar mechanisms may apply for the impact of both auditory and visual processing skills on the development of dyslexia (e.g., Farmer and Klein 1995; Sherman 1995; Tallal et al. 1993). The visual component to the temporal processing theory may evoke unfortunate reminders of relatively simplistic theories from the 1920s involving a visual deficit explanation for dyslexia, especially among those less familiar with the latest research, and consequently may contribute to a greater resistance among dyslexia researchers to the acceptability of any theory associated with the visual system.

*Hypothesis 1(c and d): Members of the Neuroscience-Vision Cocitation Group at T1 and T3 and Social Group at T3 Are More Likely to Publish in Support of the Emerging Hybrid Perspective at T3 Than Are Members of the Alternative Group(s) (not supported).*

Overall, more than 67 percent of responding researchers reported having published on topics relating to vision and reading. Although a slightly higher proportion of researchers in the neuroscience group reported having published on these topics in all analyses (T1 and T3 cocitation groups as well as groups identified using social interaction data), the differences between groups were not significant. This finding suggests a problem with the wording of the questionnaire; respondents were asked whether they had published on the topic, not whether they had published in support of the topic. One phonological researcher, in fact, commented that she had recently written an article rejecting the connection between dyslexia and the processing of visual information in the brain. Consequently, the indication of fairly widespread publishing activity is presumed to be due to some possibly negative articles, reflecting ongoing negotiation within the area. Ironically, given that much published research receives little if any notice and is never cited at all, negative attention in its own way is an interesting indicator of the visibility of the neuroscience-vision perspective.

*Hypothesis 1(e and f): Members of the Neuroscience-Vision Cocitation Group at T1 and T3, and Social Group at T3 Are More Likely to Attend Conferences Associated with the Emerging Hybrid Perspective at T3 Than Are Members of the Alternative Group(s) (supported at T3).*

Conference attendance was measured by an additive index consisting of attendance at one specific conference, later published as *Temporal Information*

*Processing in the Nervous System* (Tallal et al. 1993), and reported attendance at any other conferences associated with dyslexia and the processing of visual information in the brain. Differences in attendance were not significant for cocitation groups at T1, when group membership was somewhat intermingled. However, as hypothesized, differences between groups were significant for both the cocitation (neuroscience-vision = 1.2; phonological = 0.6) and social (1.1, 0.7) groups at T3 ( $p < .0005$ ,  $p < .05$ , respectively), suggesting that involvement in a particular perspective is associated with one's professional activities.

### *Research Question 2: Characteristics of Groups*

*Hypothesis 2a: The Neuroscience-Vision Cocitation Network Is More Active in Outside Professional Organizations Than Is the Phonological Dyslexia Cocitation Group (T1, T3) (not supported).*

The activity index with the most cases was a two-item additive index consisting of (a) editorial board activity (mean percent yes = .91) and (b) review committee activity (.81), in any year ( $n = 48$ ;  $\alpha = .67$ ; variance explained by a single principal component = 75 percent).

ANOVA for the two-item scale at T1 was significant at the two-group level, although in the *opposite* direction from that predicted. Members of the phonological cocitation group were significantly more likely (mean = 1.8) to have served on an editorial board and/or on a review committee than were members of the neuroscience-vision cocitation group (mean = 1.4,  $p < .05$ ). Comparisons of the professional activity index for T3 at the two-group level showed no significant differences. However, the results for the four cocitation subgroups at T3 parallel those reported for the T1 structure: neuroscience-vision researchers (subgroup 1B) are less likely to have been appointed to editorial boards or review committees (mean = 1.0) than those in other subgroups (1.8, 1.9, 1.8,  $p < .05$ ). Again, this suggests their continuing outsider status for at least these measures of activity. Both editorial board activity and service on review committees may be considered appointments related to one's prestige and less apt to be offered to those in an emerging perspective.

*Hypothesis 2b: The Neuroscience-Vision Cocitation Group Is More Diverse Than Is the Phonological Dyslexia Cocitation Group (T1, T3) (general support).*

The diversity of institutions represented in the problem area over time is remarkable. The sixty individuals for whom at least partial data were

collected have been affiliated with more than 170 institutions. Also, except for certain centers of research activity—chiefly at those sites with substantial NIH grant support (e.g., Colorado, Harvard, the Haskins Lab in Connecticut, Yale), at NIH itself, and at the Ontario Institute for Studies in Education (OISE)—there appears to be no obvious pattern of affiliation in training or research collaboration. Nor, with a few exceptions, are many of the individuals in the sample connected by a former adviser-advisee relationship. Nearly all such ties that do exist appear to be among those in the neuroscience-vision cocitation group at T3; this may be an artifact of the study's effort to include a reasonable sample of those involved with the visual perspective. This finding is counter to the widely accepted assumption that "most scientists have been educated at a relatively small number of prestigious graduate departments where they studied with eminent scientists" (Cole 1983, 136). The perception one gains is of "Little Science," involving numerous distributed sites of research, rather than a limited number of dominant centers involving large numbers of researchers doing "Big Science."

The best supporting evidence for Hypothesis 2b concerns citizenship at the time a group member began doing research on dyslexia. There was no significant difference in citizenship patterns between cocitation subgroups at T1. But by T3, neuroscience-vision cocitation subgroup 1B members were significantly more likely (70 percent) to be citizens of countries other than the United States than were members of either subgroups 1A (neuroscience: 20 percent) or 2B (phonological: 18 percent,  $p < .05$ ). Members of the neuroscience-vision group in the social network also were significantly more likely to be citizens of countries other than the United States (67 percent) than were researchers in the phonological group (24 percent,  $p < .05$ ).

As noted earlier, a Ph.D. degree and a major in psychology characterize the backgrounds of a majority of problem area researchers, with no significant differences among groups or subgroups. However, members of the neuroscience cocitation group were significantly more likely to hold the M.D. degree (36 percent vs. 9 percent,  $p < .01$ ) or to have a graduate background in biology (28 percent vs. 0 percent,  $p < .001$ ) than were members of the phonological cocitation group at T3. In contrast, phonological group members were more likely to have a graduate background in education (32 percent vs. 8 percent,  $p < .05$ ) than were neuroscience group members at T3. Members of a cocitation subgroup identified more closely with the phonological perspective have been affiliated with significantly fewer institutions than those in a neuroscience cocitation subgroup at both T1 (2.7 compared to 5.6,  $p < .05$ ) and T3 (3.2 compared to 5.8,  $p < .05$ ), although this relationship did not hold for all subgroups. Affiliation with a larger number of institutions could

reflect a greater tendency of physicians and biologists to obtain postdoctoral training as compared with those with a background in education. Such affiliations might be expected to expose researchers to a greater diversity of viewpoints, to make them accountable to a larger number of individuals or groups, and possibly to result in a greater willingness to accept change. An alternative possibility is that individuals associated with a less well-accepted perspective have had greater difficulty obtaining tenure or tenure-track positions than those affiliated with the phonological perspective. This experience could make them more cautious and more likely to conform to established views.

*Hypothesis 2d: The Neuroscience-Vision Dyslexia Cocitation Group Has Greater External Accountability Than Does the Phonological Dyslexia Cocitation Group (T1, T3) (greater support at T3 than at T1).*

Of fifty-nine researchers for whom data were available, 81.4 percent had received external grant funding at some point in time for research related to dyslexia. Groups did not differ significantly from one another in their receipt of any grant funding. In fact, no significant differences were found among groups—at any point in time—using any of the self-reported data concerning external accountability. These measures include the number of institutions represented by coinvestigators (mean = 1.5,  $n = 50$ ) and the number of different grant agencies (mean = 2.4,  $n = 54$ ).

The data also were analyzed according to total number of NIH-funded projects or subprojects related to reading disorders reported in CRISP, as well as by total subproject dollar amounts between the years 1976 and 1993. Non-United States citizens were excluded from the analysis since no U.S. funding had been awarded to citizens of other countries. There were no significant differences between cocitation groups at T1, although total number of grants at this time is significantly correlated with professional age (years since professional degree,  $r = .39$ ,  $p < .005$ ). The pattern of significant correlation between receipt of grants and professional age is not sustained in later years. This suggests that following the increased availability of research funding on reading disabilities in the mid-1980s, younger researchers and those new to the problem area were as successful in attracting federal grant dollars as those with a longer history in the field.

At T3 the neuroscience-vision cocitation group showed significantly higher grant activity than did the phonological cocitation group (7.7 projects/subprojects compared to 2.3; \$851,830 compared to \$313,439; both  $p < .05$ ). This suggests that the emerging group of researchers with a neuroscience-vision focus competed successfully against researchers with

an interest in phonological research for scarce funding dollars, perhaps through more aggressive efforts to attract such funding. Three other factors also may help to account for this finding.

1. Awards for Learning Disability Research Centers (LDRCs), established in 1987 by the National Institute of Child Health and Human Development (NICHD), required a substantial neuro-imaging capability (e.g., spectroscopy, magnetic resonance imaging [MRI], functional MRI). Such capabilities imply a neuroscience orientation.
2. Most of the program projects and intervention/treatment centers funded by NIH that focus specifically on reading disability are concerned with more neuroscientific topics (e.g., Yale, Harvard, and the Bowman Gray School of Medicine, Winston-Salem, North Carolina).
3. Perceptions of NIH funding priorities may have influenced R01 grants. R01 grants are "field-initiated" grants, presumably reflecting the interests of individual researchers. The focus of these grants might be expected to vary widely across the range of topics investigated in the literature and to be distributed more equally between groups than either the LDRCs or program projects would be.

There were no significant differences between cocitation groups at T1, when network structure was relatively less distinct. The ten researchers receiving NIH funding at T1 were evenly split between the two cocitation groups at T3, suggesting a relatively even distribution of grants to alternative perspectives in the 1970s. The number of grants a researcher received at T1 was significantly correlated with the individual's mean cocitation levels at that time period ( $r = .54, p < .0001$ ). However, following the substantial increase in NIH funding during the decade and the increase in numbers of investigators funded, this relationship no longer held by T3. A knowledgeable informant formerly at the NICHD noted that, by the agency's making the area of reading and reading disabilities "attractive," researchers were possibly induced to shift their own research priorities to an area of strong emphasis within NIH. A dramatic increase in the number of individual grant applications at NICHD reported by a second source provides further support for this interpretation: R01 grant proposals increased by an estimated 120 percent between 1990 and 1995.

### Research Question 3: Individual Influences

*Hypothesis 3(a and b): Members of the Neuroscience-Vision Cocitation Group and Social Group Are More Innovative Than Are Members of the Alternative Group(s) at T3 (not supported).*

Four items from the ten-item short form of the Innovativeness Scale described by Hurt, Joseph, and Cook (1977) were used to measure individual innovativeness. Responses were submitted to unrotated principal components analysis; all four items loaded highly (.68 or above) on a single factor. Rice and Tyler (1995) studied the influence of innovativeness on use and evaluation of voice mail in two organizations. They reported that their measure of innovativeness used these same four items (Rarely trust new ideas until others do; First to accept something new; Reluctant until see innovation work from others; Must see others using innovation; all measured from 1 = *strongly disagree* to 7 = *strongly agree*). These loaded on a single principal component (57 percent variance explained) with a Cronbach's reliability alpha of .74. Their results are almost exactly the same as our results for this scale. Scoring was reversed so that a higher value indicates greater personal innovativeness. The mean score was used ( $m = 5.6$ ). Despite differences in diversity and external accountability that suggest the potential for encouraging a greater willingness to change among members of selected groups, there were no significant differences in innovativeness among groups at either T1 or T3 for either cocitation or social network structure.

*Hypothesis 3(c and d): Members of the Neuroscience-Vision Cocitation Group and Social Group Hold Different Expectations Concerning Their Involvement in the Problem Area Than Do Members of the Alternative Group(s) (T3) (not supported).*

To measure expectations influencing researchers' entry into their current problem area, eleven of the twelve scientific motivation items examined by Rappa and Debackere (1992, 1995) were used (including opportunity to solve societal problems, potential for peer recognition, dissatisfaction with one's prior research agenda, availability of research funding, success of others in the field, etc., with 1 = *very unimportant* to 7 = *very important*). Statements concerning the "intellectually compelling nature of the problem area" and the "opportunity to solve an important societal problem" received the highest mean responses (6.4 and 5.9, respectively). All other items were rated as essentially unimportant (where 4 = *neutral*). The responses suggest a relatively idealistic, proactive selection of dyslexia research as a problem area, rather than an arbitrary migration to the field due to a lack of any better alternatives or the attraction of research dollars. For example, availability of research funding was the third-lowest ranked choice ( $m = 3.0$ ) selected by researchers as a reason for entering the problem area. There were no significant differences between the cocitation groups or between the social groups for any of the self-reported reasons for entering the problem area.

*Hypothesis 3(e and f): Members of the Neuroscience-Vision Cocitation Group and Social Group Have Greater Knowledge of New Research Developments Relating to the Emerging Perspective Than Do Members of the Alternative Group(s) (supported).*

Knowledge of current developments in neuroscientific aspects of dyslexia research was assessed by asking respondents to indicate their familiarity with four recent publications pertaining to neuroscientific aspects of dyslexia research: genetics of dyslexia (Cardon et al. 1994), neuroanatomy (Galaburda, Menard, and Rosen 1994), visual temporal processing (Lehmkühle et al. 1993), and visual and auditory temporal processing (Tallal et al. 1993). Choices were 1 = *don't know this reference*; 2 = *have heard of or seen it, but haven't looked at the article or abstract*; 3 = *have skimmed paper, read abstract*; 4 = *have read full paper (or many of the proceedings papers)*. Unrotated principal components analysis resulted in all four items loading highly (.74 or above) on one factor (eigenvalue = 2.4, 61 percent of variance explained,  $\alpha = .78$ ). The mean across the four publications was 2.7, suggesting a low degree of familiarity with the papers referenced.

Members of the neuroscience-vision group at the two-group level for both the T3 cocitation (mean = 3.2) and social networks (mean = 3.1) were significantly more familiar with new research developments on neuroscientific aspects of dyslexia research than were members of the phonological group (means = 2.3, 2.4,  $p < .001$ ,  $p < .01$ ). This is consistent with diffusion theory: "Individuals generally tend to expose themselves to ideas that are in accordance with their interests, needs, or existing attitudes" (Rogers 1983, 166). Recall that members of the neuroscience-vision group for both cocitation and social networks at T3 also were significantly more likely to report an interest in neuropsychology topics than were members of the alternative group. Furthermore, members of the neuroscience-vision group in the cocitation network were significantly more likely to hold a degree in medicine or biology than were members of the phonological group, although these differences were not significant for the social network. The latter point suggests the importance of interpersonal ties for encouraging both interest in and knowledge of subject-related developments, even if one's initial training was in a somewhat different field.

## Discussion

### Summary of Results

Despite initial expectations of two distinct groups of researchers converging over time under the umbrella of a unifying theoretical perspective, results

were somewhat more complex. The mere existence of a theory (temporal processing) with a potential for integrating disparate approaches was clearly not a sufficient inducement to bring about convergence. In fact, papers on both sides of the controversy discussing the relative merits and criticisms of temporal processing continue to appear (e.g., Farmer and Klein 1995 and associated commentaries; Mody, Studdert-Kennedy, and Brady 1997). Rather, analyses of cocitation and social networks in the problem area of dyslexia suggest that separate lines of research are becoming more distinct within a somewhat more fluid social structure, although there is some evidence of convergence between the neuroscience and vision groups. Highly connected dyslexia researchers especially reported interaction with individuals identified with both perspectives (the neuroscience-vision and phonological). Furthermore, cocitation patterns indicate a fair degree of intermingling over time. This suggests the possibility of greater similarities among group members than was first anticipated.

Results were relatively consistent across measures: there were few significant differences between groups. In particular, neuroscience-vision researchers were not more open to change than were individuals associated with the more established phonological perspective. As a whole, researchers in the problem area indicated both a moderately high willingness to consider change and similar reasons for becoming involved in their areas of research (primarily its intellectual interest and their concern about an important societal problem). This level of interest in the intrinsic intellectual appeal of the problem area is similar to that found by Debackere and Rappa (1994) for academics who were early entrants to the emerging field of neural networks research, as compared with later academic entrants or those employed in commercial settings. Although in this study there was no separate analysis by researchers' time of entry to the field, nearly all the dyslexia researchers investigated hold appointments at academic or research institutions. Marked societal needs for a better understanding of dyslexia, the many difficulties involved in researching specific reading disability, and the persistent controversy over alternative perspectives may continue to provide a sense of challenge to researchers. These factors also may work to sustain researchers' strong intellectual interest in the problem area, although selected individuals reported leaving the field because of frustrations due to lack of progress. A positive attitude toward change also may be a widely shared personality characteristic of academics, although further comparison across disciplines will be necessary to confirm this assumption.

Despite these similarities, significant differences were found between the alternative groups identified for a number of measures of involvement, as well as for selected items that had been proposed as leading to a greater

willingness to change. While neuroscience-vision researchers were more likely than phonological researchers to be citizens of a country other than the United States, among U.S. citizens, those in the neuroscience-vision group were more likely to receive grants from the NIH than were phonological group members. In general, individuals in the neuroscience-vision group also were more likely to (a) hold more similar perceptions on the importance of research approaches, such as visual processing skills; (b) attend conferences related to the emerging perspective; (c) be aware of recent research publications pertaining to neuroscientific aspects of dyslexia; and (d) have a background in medicine or biology than were members of the phonological group. This is consistent with the principle of homophily in diffusion theory—the transfer of ideas occurs more easily among those with similar beliefs and education (Rogers 1983, 274)—and “selective exposure” as a necessary survival mechanism for scientists trying to cope with information overload. The results also support Mulkey, Gilbert, and Woolgar’s (1975, 193) contention that entrants to an emerging field are likely to have special competence in knowledge or techniques which may be applicable within the new area (see also Ziman 1987, 102).

Figure 2 attempts to summarize the findings of the study graphically, although the bidirectional arrow between the more highly connected, highly cocited researchers (“elites”) and the public policy “box” represents a speculative relationship that requires further investigation. Indeed, the more one looks at the multifaceted nature of this controversial hybrid problem area, the more intriguing issues arise. The study’s most useful contribution may lie in its identification of possible directions for future research.

#### *Temporal Factors and the Impact of Lingering Perceptions*

Perceptions of the relative importance of visual processing skills may reflect differences between the research community’s views of what Cole (1992) refers to as “core” knowledge as compared with knowledge produced at the “frontier,” or research front (p. 230). He notes that only a very small body of knowledge is accepted by the community of science as true and important, and that there is extremely low consensus about contributions made at the frontier, despite commonly held views of the nature of scientific knowledge. The practice of teaching science as a series of “great discoveries” reported in textbooks tends to seriously understate the lack of consensus in science as it evolves.

In the dyslexia problem area, the view that developmental dyslexia primarily reflects a language deficiency now appears to be widely accepted as

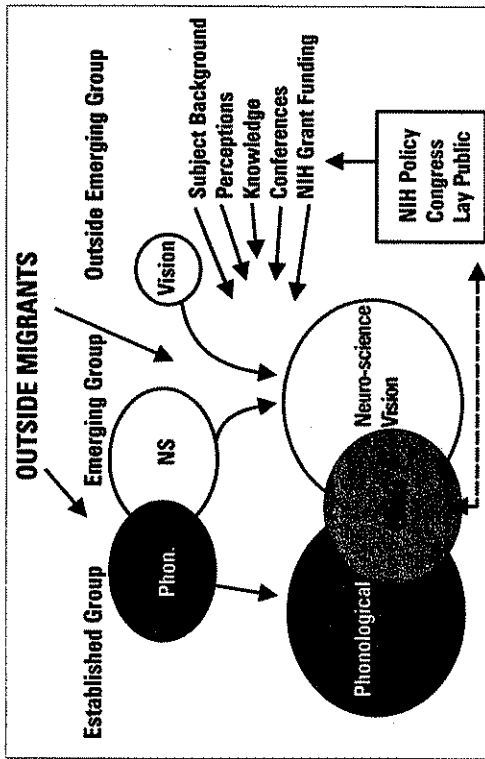


Figure 2: Revised Model of Hybrid Change in a Scientific Problem Area, Using the Case of Developmental Dyslexia

core knowledge (e.g., see Beitchman and Young 1997; Shaywitz 1998), while controversy continues regarding the role of visual factors. However, the situation seems to be complicated by the cyclic nature of prevailing views on the underlying causes of dyslexia, which Rayner, Pollatsek, and Bilksky (1995) liken to the swing of a pendulum, and by temporal factors in the acceptance of knowledge contributions in general. The situation is further complicated by the important policy implications of what comes to be accepted wisdom regarding the underlying causes of dyslexia, the resulting impact on educational remediation efforts, and the effects of remediation approaches on public knowledge.

Clearly, researchers at the frontier will be most informed about new developments directly relating to their work, and other researchers, even in a closely related area of research, will take a longer time to become aware of them. Quite apart from questions regarding the validity of an idea or theory, which may be difficult to determine (Cole 1992; Lievrouw and Carley 1990), subject background and expertise are likely to affect reactions to new knowledge contributions in terms of their utility and compatibility. Those with similar backgrounds may find these contributions more interesting, understandable, and useful than those with training in different fields and may begin incorporating them into their own work. The diffusion of this information to practitioners and to the broader public takes an even longer period of

time, so that it may not be uncommon for public and scientific views of core knowledge to be out of sync, especially in a rapidly changing field.

This may account for the introduction to a *Scientific American* article in 1996, which rather oddly asserts that "a new model of this reading disorder emphasizes defects in the language-processing rather than the visual system" (Shaywitz 1996, 98). The language deficit perspective was hardly a "new" model in 1996 (Vellutino's 1987 article in the same popular science journal also emphasized the language deficit aspects of dyslexia), but in view of the persistence of older visual models in the general public's understanding of dyslexia, readers might still have found it to be so. Emphasizing the novelty of the phonological model in 1996 may have been a rhetorical strategy to heighten readers' interest in the ideas presented or an attempt to bring the public's understanding of dyslexia in line with current scientific consensus. Alternatively, it may have been an editorial strategy to make the article (and the issue) appear more interesting for marketing purposes.

Simplistic interpretations of early theories regarding the role of visual factors in dyslexia had a strong influence on the education of reading disabled children during much of the century. Benton (1985) notes that methods to improve a child's spatial ability and visual-motor skills, often in preference to continued drill in reading itself, became widely adopted up until about 1970, when the approach began to lose popularity because of questions about its effectiveness (p. 88). As noted earlier, the rejection of these early theories may continue to have a lingering impact regarding the acceptability of any theory associated with the visual system. In essence, even though current theories on visual processing deficits are quite distinct from earlier work, they appear to be tarred by association, except for those with a particular interest in this work.

While this study found that the neuroscience-vision group as a whole has grown in numbers and visibility during the seventeen-year period and that individuals in this group were especially successful in obtaining NIH grant funding in the T3 period, other evidence suggests that the subgroup most closely identified with the visual perspective can still be characterized as outsiders. They have been more isolated (or more excluded) from such professional activity as editorial boards, review committees, and external committees in general. Analysis of social-interaction patterns indicates that they also are less connected with others in the larger problem area than any other subgroup. Reports in the literature since data collection was completed suggest that the visual processing perspective continues to face opposition regarding its acceptance in the broader problem area (e.g., Mody, Studdert-Kennedy, and Brady 1997; Shaywitz 1998; Skottun and Parke 1999), although efforts to make a case for the viability of the perspective continue (e.g., Eden et al.

1996; Farmer and Klein 1995). Articles on both sides of the controversy have appeared not only in the research literature but also in more popular periodicals such as *Scientific American*, as noted above, and in the journals of professions concerned with the implications of treating dyslexics (e.g., American Academy of Optometry and the American Optometric Association 1997; American Academy of Pediatrics 1992). (See Collins and Pinch 1979 for an interesting analysis of tactics used to gain recognition in a discipline, and implicit and explicit approaches to the rejection of knowledge claims.) This suggests the value of continuing to track developments in the problem area prospectively and to analyze in more detail the rhetorical strategies used by various groups in efforts to persuade the wider community of the "rightness" or "wrongness" of a particular perspective in a scientific issue.

Temporal issues apply not just to apparent differences between accepted knowledge in the scientific community and the general public, but also potentially to differences between the measures used to analyze changes in a problem area. The use of cocitation data to track developments in a problem area provides a valuable perspective of changes over time, but mismatches between cocitation and social network structure, and between cocitation patterns and archival reports, give rise to a number of alternative interpretations (Perry and Rice 1998). For example, mismatches may be due to temporal lags in the cocitation data or to inherent differences between intellectual and social structure. These questions also make it difficult to investigate the relationship of funding patterns to progress in dyslexia research. The ongoing nature of change in the dyslexia problem area provides a useful opportunity to explore these alternative possibilities. A follow-up analysis of cocitation data using the target researchers for the period 1994-99 is currently under way and should provide better insight into these questions.

### Diversity

The finding that the neuroscience-vision group is more diverse in terms of nationality is intriguing and merits further follow-up. In his study of competing paradigms in the geosciences, Stewart (1990) noted how "localism" or "provincialism" was related to the reaction to more global theories (pp. 240-41). North Americans tended to focus on their own continent and were unaware of evidence in support of continental drift theory from other continents; specialists focused on questions within their own areas of expertise and often did not recognize the integrating ability of drift theory. The fact that a number of recent review articles on the topic of auditory or visual temporal processing have been authored by individuals from outside the United States (e.g., Farmer and Klein 1995; Canada; Greatrex and Drasdo 1995; UK; Leppanen

and Lyytinen 1997; Finland; and Walsh 1995: UK) provides interesting preliminary evidence that the trend toward greater diversity in the temporal processing perspective may be continuing. Further investigation is of course necessary to confirm this observation.

### *Grant Funding*

Concerns by legislators, scientists, and laypersons about the lack of progress in learning disabilities research, exacerbated by the fact that the learning-disabled population appears to have grown rapidly, have led to substantial expenditures in support of research on learning disabilities during the past two decades (Lyon 1991; Roush 1995). Analysis of CRISP data indicates a major increase in funding of reading-disabilities research in particular, with a special emphasis on neurobiological topics. Although one cannot assert a cause-and-effect relationship based on these analyses, the data suggest an intriguing interaction between and among societal concerns, federal research policy, funding patterns, growth in the problem area, and changes in the emphasis of reading-disabilities research. Valente and Rogers (1995) similarly note the importance of popularizers of the diffusion model in attracting funds and other support and of the impact of the policy environment in the growth and ultimate decline in agricultural diffusion research from the 1940s through the late 1960s.

Increases in federal grant funding in reading-disabilities research appear to closely parallel indications of the expanding influence of dyslexia researchers with a neuroscientific focus, in terms of numbers, cocitation patterns, and interpersonal contacts but raise an interesting lead-lag question. Preliminary indications suggest that progress followed the awarding of grants, but alternative relationships between growth and funding are also possible. For example, Hufbauer's (1986) study of federal funding into sudden infant death syndrome (SIDS) indicates that targeted federal funding "provided little support for the initial insights, [but] . . . fostered much of the follow-up work" (p. 74).

Availability of grant funding may not be a primary reason for a scientist's involvement in a given area of research (this choice was the third-lowest mean response provided by researchers in the present study as a reason for entering the problem area), and certainly research can take place without external funding. In fact, one researcher in the study stated that he or she deliberately avoids the accountability associated with grant funding: "being involved in more than one research at a time, I needed to remain independent." However, the availability of substantial grant funding certainly is likely to affect the scale of research that can be undertaken and may be

sufficient to inspire, to renew, or to redirect attention to an area closely related to one's present or primary sphere of interest, despite self-reports that suggest otherwise (Ziman 1987, 106).

Furthermore, involvement in any research program may lead one to related research questions, not all of which can be explored at once. Grant funding may be the deciding factor in terms of determining relative priorities for such competing research problems. Researchers in the current study reported a mean of 2.4 broadly coded research topics, suggesting that involvement in several related areas (e.g., disabilities, neuropsychology, education/learning) may be characteristic of a hybrid field, as it is with other fields (Gieryn 1978; Ziman 1987). Involvement in more than one research project may be a strategy employed to reduce the risk involved with any single project, or it may be a characteristic associated with more eminent researchers because of their greater access to research funds, colleagues, and students (Hagstrom 1965; Mulkey et al. 1975). Alternatively, this finding may simply reflect the interdisciplinary nature of research topics within a hybrid problem area.

### *Federal Funding and the Communication of Scientific Information*

In addition to supporting research projects and programs, federal funding can be used specifically to encourage interaction among researchers representing diverse backgrounds and to disseminate the results of research (e.g., see Hufbauer 1986). Furthermore, the federal government has made concerted efforts to disseminate the results or status of federally funded research proposals, and scientific information in general, to the scientific community and to the lay public. Increasingly, these efforts (e.g., the CRISP database, PubMed, MEDLINEplus) rely on electronic technologies such as the Internet to expedite this and other scientific communication processes. Lievrouw and Carley (1990) note that widespread use of such technologies can help to increase the overlap in stages of the cycle of science communication, perhaps bringing about a closer correspondence in the level of understanding held by specialists, generalists, and the general public. Similarly, the work of Phillips and colleagues (1991) suggests that popular coverage of medical research works in multiple directions, not only reaching the general public but also amplifying the transmission of medical information back to the research community. These types of developments may help to reduce the problems of temporal lag mentioned earlier.

Lievrouw and Carley (1990) further observe that the popularization of scientific ideas can do much to increase the visibility of those ideas and their

chances of securing public funding, and that the popularization of science remains an understudied aspect of the study of science communication. Those scientists who are most successful in communicating the importance of their work to others may be more likely to ensure the continuity of funding and potentially the progress of research in their area of interest. In essence, this doubles the communication burden on researchers seeking to be successful. Not only must they try to stay current with information relevant to their own research but they also must attempt to perform a teaching or public relations role and to lobby in favor of societal priorities for science. At least one of the researchers in this study provides telephone callers with an automated selection of choices, one of which relates to obtaining copies of press releases concerning his or her recent research. Another researcher provides links from his or her site on the World Wide Web to a site of another researcher in the problem area, suggesting to others the interrelatedness of their work, even though they do not appear to collaborate in their research.

These observations suggest that success in research may increasingly involve interpersonal, public speaking, computer, and public relations skills not generally associated with the traditional image of an ivory-tower academic. Successful "tele-scientists" may be able to more rapidly and effectively popularize their work, collapse formerly discrete phases in the communication cycle, and potentially make faster progress than the more traditional scientist, with predictable results (Lievrouw and Carley 1990). These developments also suggest the value of conceptualizing all of science communication as a continuum within the larger society (see also Lewenstein 1995), with the popularization of science as one component in the overall process.

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