FAST MAPPING AND EXCLUSION (EMERGENT MATCHING) IN DEVELOPMENTAL LANGUAGE, BEHAVIOR ANALYSIS, AND ANIMAL COGNITION RESEARCH

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Researchers from behavior analytic, developmental, and comparative perspectives have all investigated the conditions under which new arbitrary (symbolic) stimulus-stimulus relations are acquired. For example, young children, people with severe mental retardation, and several species of nonhuman mammals all exhibit emergent matching (EM) in the context of a well-established matching-to-sample baseline: When presented with an undefined sample stimulus and a comparison array that includes one undefined comparison and one or more baseline comparisons, participants select the undefined comparison. Further, subsequent testing may show a learning outcome: Exposure to EM trials may result in a new defined relation involving the formerly undefined stimuli. Between 1974 and the late 1980s, emergent matching and learning outcomes were described independently by behavior analytic, child language, and animal cognition researchers. Cross-literature citations were virtually absent, however. More recently, crossdisciplinary citations have begun to appear. This article briefly reviews the history of EM research, emphasizing the independent development of research programs, methods, and terminology in the three disciplines. We then identify several research areas where a multidisciplinary approach may benefit all concerned.

For many years, psycholinguists, behavior analysts, and animal cognition researchers have investigated processes by which their respective participant populations learn new arbitrary relations without explicit training. Psycholinguists have studied young children's "fast mapping" of new words, a phenomenon that likely underlies the virtual explosion of word learning that occurs in the preschool years (e.g., Carey & Bartlett, 1978; Golinkoff, Mervis, & Hirsh-Pasek, 1994).

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Behavior analysts have studied so-called “exclusion” performances, in which participants immediately display arbitrary matching relations without explicit differential reinforcement (Dixon, 1977; McIlvane, Kledaras, Lowry, & Stoddard, 1992). Animal cognition researchers have used similar methods to examine the behavior of higher primates, dolphins, and sea lions (e.g., Premack, 1976; Schusterman & Kreiger, 1984). Despite well-known differences in philosophy and terminology, the programs have developed similar procedures and reported similar behavioral outcomes (Huntley & Ghezzi, 1993; Wilkinson, Dube, & McIlvane, 1996). These convergences suggest that the programs are studying the same phenomena. If so, we suggest that all areas of research may benefit from considering and adapting the best ideas and methods currently available, regardless of source.

To promote interdisciplinary discourse, this paper will (1) review the development of the research in each discipline and the converging outcomes reported, and (2) outline several research questions in which the same issues have been of interest to each. These analyses, particularly the latter, will provide a foundation for illustrating how interdisciplinary communication might benefit research in each of the respective disciplines.

**Exclusion and Fast Mapping Procedures**

Exclusion or fast mapping typically occurs in the context of a well-learned matching-to-sample (MTS) baseline. For example, an experimenter may display an array of familiar items and speak the name of one; the participant indicates which one was named. The top two rows in Figure 1 show examples of MTS trials that would be appropriate for a young child, and which are considered to represent tests of receptive language (e.g., *Peabody Picture Vocabulary Test-Revised*; Dunn & Dunn, 1981) or the repertoire of the listener (Skinner, 1957). With appropriate training procedures, most humans and many nonhuman animals demonstrate MTS performances (e.g., Carter & Werner, 1978).

**Emergent matching.** Given a set of defined relations in a MTS baseline, the experimenter, without any special instruction, may display an unfamiliar item in the array and give an unfamiliar name. The examples in the upper portion of Figure 2 illustrate such a task, where the participants might be asked “Which one is the symu?” or “Which one is the breel?” Virtually all published research thus far has reported that participants select the unfamiliar item in this situation. This performance has been called *exclusion* by behavior analysts (Dixon, 1977) and nonhuman animal cognition/language researchers (Schusterman, Gisiner, Grimm, & Hanggi, 1993) and, often, the *disambiguation effect* in psycholinguistics (Merriman & Bowman, 1989). For our present purposes, we shall henceforth use another, more neutral term—emergent matching (EM)—which is descriptive, makes no assumptions about the basis for the participant’s selection, and is not associated with any particularly theoretical position. The term “emergent
symbolic mapping" has also been used (Wilkinson et al., 1996) to emphasize that exposure to EM trials may establish mapping relations (i.e., equivalence relations) between undefined sample and comparison stimuli.

EM has been documented in 2- and 3-year-old children (Dollaghan, 1985; Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Kagan, 1981; Markman, 1989; Merriman & Bowman, 1989), children with specific language impairments (Dollaghan, 1987), people with severe mental retardation (McIlvane et al., 1992; McIlvane & Stoddard, 1981, 1985), and marine mammals (Herman, Richards, & Wolz, 1984; Schusterman & Kreiger, 1984; Schusterman et al., 1993).

Naming outcomes. Some studies have been limited to the initial EM demonstration that asks only how participants respond when presented with a single new sample. Other studies have gone on to ask whether the participants have learned anything from the EM task. One way of doing this is to ask the participants to name the new item after some number of EM trials. This can be called a naming outcome assessment. For example, after a certain number of trials on which the participants have selected a novel form upon hearing the word "breel," the participants could be presented with that new form and asked to produce the word. Naming outcomes have been reported for normally developing children (Dollaghan, 1985), children and adolescents with cognitive and/or language impairments (Chapman, Kay Raining-Bird, & Schwartz, 1990; Dollaghan, 1987), and individuals with moderate and severe mental retardation (McIlvane, Bass, O'Brien, Gerovac, & Stoddard, 1984).
Learning outcomes. A second way of testing whether participants have learned anything about the new relation during EM testing is to evaluate MTS performance with more than one novel relation. For example, the participants might be introduced to two new, undefined dictated word-picture relations, each on different exclusion trials. Then, the participants might be presented with both new pictures at the same...
time. Such a procedure is illustrated in the lower portion of Figure 2. These learning outcome trials ask if the participants will match the first new picture to "symu" and the other new picture to "bree!." Loosely speaking, he or she is asked to tell which picture is which. Learning outcomes have been documented in young children (Wilkinson & McIlvane, 1997; cf. Rice, 1990), in individuals with severe mental retardation (Wilkinson & McIlvane, 1994a, 1994b), and in marine mammals after extensive training (Schusterman et al., 1993). As we will discuss below, however, exclusion training does not always lead to learning outcomes (Dixon, 1977; McIlvane & Stoddard, 1981, 1985; Schusterman & Gisiner, in press).

Early Experimental History of EM Research

Figure 3 shows some of the early experimental reports on the EM phenomenon. What they have in common is that they all described essentially the same procedure. The arrows indicate citations where the author(s) explicitly related the work to a paper in another column. The earliest experimental report of the EM phenomenon was contributed by Vincent-Smith, Bricker, and Bricker (1974) as part of an effort to further research on language comprehension. Most of the developmental language research up to that point had focused on the acquisition of expressive language. Vincent-Smith and her colleagues were interested in developing methods to study the development of receptive language. By the age of 6 years, children's vocabularies grow to about 14,000 words by one estimate (8000 root words; Templin, 1957), mostly without formal or explicit instruction (Rice, 1989). Children's first exposure to many new words comes by listening to what others say while observing relevant objects and events. Vincent-Smith and her colleagues adapted the Wisconsin General Test Apparatus for MTS procedures. Stimuli were small objects and spoken names. In a two-choice format, with differential reinforcement, their 2-year-old participants demonstrated EM immediately. When the rate of learning new word-object relations via EM was compared to learning by trial and error, the children learned faster following the former.

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Figure 3. Selected examples of pre-1987 empirical studies of EM phenomena in developmental language, behavior analytic, and animal cognition/language research literature. Cross literature citations are indicated by arrows pointing to cited study.
Behavior-analytic EM research, and the term “exclusion,” made its first appearance in 1977. Dixon (1977) was interested in a stimulus control analysis of EM and consequent learning outcomes. The participants were teenagers with mild mental retardation. The stimuli were Greek letters and their spoken names. Dixon found that all participants immediately demonstrated EM, but only one of the eight participants immediately demonstrated the learning outcome. Learning outcomes were eventually demonstrated with all participants following additional practice or with new stimulus sets.

At about the same time, the first paper that included the term “fast mapping” was published in the developmental language literature (Carey & Bartlett, 1978). Fast mapping, as it has come to be defined, is a “quick, initial, partial understanding of a word’s meaning” (Rice, 1989, p. 152) derived from the context in which the new word is used by others. Carey and Bartlett (1978) studied EM within the course of natural language acquisition in a nursery school classroom. For example, a teacher introduced the new name “chromium” for the color olive by saying “You see those two trays over there. Bring me the chromium one. Not the red one, the chromium one.” Virtually all children selected the undefined item (in this case, on the basis of color) and, later, some children gave evidence of having learned the new name-color relation.

The next reports on EM were published shortly thereafter. One was a behavior analytic study of matching-to-sample performances of a nonverbal individual with severe mental retardation (McIlvane & Stoddard, 1981). This was the first of a series of behavior-analytic papers that showed that EM was reliable in people with mental retardation if MTS baselines could be established (e.g., McIlvane et al., 1984; McIlvane & Stoddard, 1981, 1985). The other report was Kagan’s (1981) description of the developmental course of EM in his book The Second Year, using the term linguistic inference. He wrote:

The purpose of this procedure was to determine if the child would infer that an unfamiliar linguistic term referred to an unfamiliar object . . . The experimenter placed two namable objects . . . and one unfamiliar object that had no name . . . in front of the child . . . and said, ‘Give me the zoob.’ (pp. 26-27)

By the age of 22 months, most children selected the unfamiliar object. Kagan’s study was the first demonstration of the development of EM in young children.

Finally, at about the same time, Schusterman and his colleagues were teaching two California sea lions gestural signals that corresponded to objects (e.g., ball, water wing), object modifiers (e.g., large, black), and actions to be performed on the objects (e.g., tail touch, toss). The program was modeled after one developed by Herman (1980) with dolphins, which itself followed up on work with chimpanzees (e.g., Premack, 1976) and used EM-like training methods. Schusterman and his colleagues taught the first object and action signals by careful
response shaping and differential reinforcement. After initial repertoires were established, Schusterman and Kreiger (1984) introduced new items in the EM format, and they were the first to clearly and unambiguously describe the phenomenon in nonhumans:

New object names were introduced by pairing the novel, and as yet unnamed object with an old, and already named, object. Under these conditions, both sea lions learned to associate or match the unfamiliar gesture with the unfamiliar object quite rapidly. Indeed, depending on the familiar-unfamiliar pairing, the match between a novel gesture and a novel object was frequently immediate as reflected by errorless performance. (p. 13)

The studies described above represent the foundation of the experimental analysis of EM. Although the research programs in behavior analysis, developmental psycholinguistics, and animal cognition were conducted independently, there were obvious similarities in the behavior that was described. Perhaps as a result of the methodological convergences, all three disciplines have also examined many of the same research questions, which we will consider below.

**N3C / Sample-S+ Control**

Undefined $\rightarrow$ "pafe"

Undefined $\rightarrow$ "pafe"

**Mutual Exclusivity / Sample-S- Control**

Undefined $\rightarrow$ "pafe"

**Figure 4.** A contrast between the N3C versus mutual exclusivity accounts of EM.
Research Questions

What is the basis for EM? This question has generated great interest in both behavior analysis and psycholinguistics. Rephrased, this question asks why participants, without special instruction, virtually always select a new comparison item upon hearing a novel dictated word or other undefined sample stimulus. In child language research, there is currently a debate on which of two contrasting principles account for EM (fast mapping). These are Golinkoff and colleagues' novel name - nameless category principle (N3C) (Golinkoff et al., 1992), and Markman's (1989) mutual exclusivity (ME) principle.

As Figure 4 suggests, advocates of the N3C position propose that hearing a novel name encourages a search for an as yet unnamed item, because children have learned that new names are likely to refer to items that do not yet have a name (i.e., are undefined). As Mervis and Bertrand (1993a) pointed out recently, N3C is an active search for an unnamed item—not a "process of elimination." By contrast, advocates of the ME principle propose that a child assumes that a single item can not have more than one name (Markman, 1989). Therefore, they reject a named item as a match for the new, undefined dictated name. Consequently, after a process of elimination, they assign the new name to an available unnamed item.

Behavior analysts also have identified two possible bases for EM: relations involving the undefined sample word and the comparison item selected, termed a sample-S+ relation, and those involving the undefined sample and the comparison item rejected, termed a sample-S- relation (McIlvane et al., 1987). The sample-S+ and sample-S- relations directly parallel N3C and ME, respectively. McIlvane and colleagues (1984, 1987) reported a blank comparison procedure that was used to measure sample-S+ and sample-S- control independently. Figure 5 shows an example, taken from a study with three participants with severe mental retardation (McIlvane et al., 1992). After a dictated word-picture MTS baseline was established, the blank comparison was introduced via programmed teaching. When the teaching program was completed, participants selected the appropriate picture on half of the trials and the blank comparison on the other half, as suggested in the upper portion of Figure 5.

McIlvane and colleagues (1992) then inserted several types of unreinforced probe trials (depicted in the lower portion of Figure 5) into the blank comparison baseline. CONTROL trials presented a defined sample word with its corresponding picture, a novel, undefined comparison picture, and the blank. These trials provided a control for general preference for novel stimuli. All participants selected the defined picture on CONTROL trials. TEST-1 trials presented an undefined name with an undefined picture, a defined picture, and the blank. Two of the three participants always selected the undefined picture, and the third did so reliably after some initial variability. The TEST-1 data indicate sample-S+ control—selecting undefined pictures when given undefined
TEST-2 trials presented an undefined name with two defined pictures and the blank. Here, two participants consistently touched the blank, and the third did so after initial inconsistency. These results indicate sample-S- control, that is, rejecting or excluding the defined comparisons.

Figure 5. Examples of a blank comparison trial types, including baseline trials and EM probes.

Variants on these methods have recently been implemented in an initial analysis involving word learning in normally developing preschoolers (Wilkinson & McIlvane, 1997). Like the studies involving individuals with mental retardation, typical children also demonstrated
both sample-S+ and sample-S- control in their fast mapping performances. These studies suggest an experimental approach that may prove useful to help resolve basic issues in both developmental language and animal cognition research. It is possible, for example, to use them to determine whether young children and nonhumans will routinely relate undefined stimuli, as suggested in the N3C principle.

_Does stimulus type affect learning by exclusion?_ Rice and colleagues (Rice, 1990; Rice, Buhr, & Nemeth, 1990) recently reported that EM by 3-year-old children occurs more readily with object labels than with action labels (also see Merriman, Marazita, & Jarvis, 1993). Historically, analyses of this issue have been hindered by the oft-discussed difficulties of depicting actions with still photographs (Benedict, 1979). Ongoing developments in microcomputer-based MTS technology, however, are likely to open up this research area for laboratory analyses by allowing digitized video stimuli to show actions. The depiction of action through this technology is one area in which MTS methods and procedures worked out in behavior-analytic and comparative research might be useful in addressing current questions in developmental language research.

In a related study, Wilkinson and Mcllvane (1994a) reported differences in learning outcomes as a function of the physical characteristics of the items to be learned. Better EM learning occurred when the newly introduced words were related with pictures of objects rather than to more abstract stimuli such as letters. Although that research did not explain why picture names might be easier to learn than letter names, these data seem to have implications both for psycholinguistics and behavior analysis. For psycholinguists, the procedures provide an experimental protocol for extending analyses from those referents that traditionally appear in word learning (objects or pictures) to other types of referents. For example, the role of the letter as an abstract symbol, as compared to a symbol for a potentially concrete referent, remains to be explored within the psycholinguistic framework.

For behavior analysis, these results are interesting because they are not predicted by extant studies of contextual effects. In conditional discrimination procedures, the conditional stimuli are sometimes characterized as providing the context under which discriminative stimuli exert their control (cf. Cumming & Berryman, 1965). Such an analysis applies to contextual effects within discrimination trials, but tell us less about across-trial effects. A few studies have examined across-trial effects, for example, Neef, Iwata, and Page's (1977) demonstration that certain baseline conditions could help to reduce competition from undesirable stimulus control topographies. There are also studies of more general contextual effects, for example, the arbitrary-assignment phenomenon (Stromer, 1986) or the analyses of relational frames (Steele & Hayes, 1991). Although these studies are helpful in a general way, a richer, more detailed analysis seems necessary to help us understand why superficially similar, comparably accurate letter vs. picture baselines did not comparably encourage accurate mapping. Perhaps the psycholinguist's
EMERGENT MATCHING

analysis might inspire stimulus class research to illuminate the behavioral processes by which such learning is encouraged.

How is the rate of introducing new stimuli related to learning outcomes? Most fast mapping research has focused on how participants learn a single new word at a time (although multiple words may be introduced over the course of the study). As noted above, however, Mervis and Bertrand (1993a, 1993b) suggest that emergence of fast mapping may be correlated with the onset of the rapid vocabulary expansion documented in early language, at least in typically developing children. If fast mapping is instrumental in the vocabulary explosion, it will be necessary to evaluate how children map not just one new word, but multiple words (each to its own referent) in rapid succession. Because few fast mapping studies have examined how the introduction of multiple relations might affect learning, it is unclear whether the processes involved in mapping a single new relation are the same as the processes involved in maintaining that relation in the presence of other new words.

By contrast, the behavior-analytic program has had a continuing interest in mapping multiple new relations through EM (McIlvane & Stoddard, 1981; Stoddard, 1982). Two procedures have been used, and our interdisciplinary program has recently initiated a formal evaluation of them. The first is a concurrent introduction procedure, where two new relations are introduced in the same block of trials. The second is successive introduction, where a second stimulus pair is introduced after some number of exclusion trials with the first. Ongoing research suggests that participants with mental retardation who have difficulty learning and maintaining new relations introduced concurrently can show significantly improved learning when the relations are introduced successively (Wilkinson & Green, in press; Wilkinson & McIlvane, 1994b). Although preliminary, these data suggest that the ability to learn a single new relation may be slightly different than the ability to maintain that relation while learning other new relations. In light of these data, one future research direction is to examine the widely held psycholinguistic assumption that fast mapping involves an "insight," and to probe whether there may instead be a more gradual developmental progression, at least for certain individuals. These methods are clearly of interest to developmental language researchers who are interested in characterizing the onset of the vocabulary spurt.

A second question related to the rate of introducing new stimuli concerns the amount of EM exposure necessary to produce positive results on learning outcome tests in different populations. Schusterman and his colleagues (1993) have reported that California sea lions failed outcome tests introduced relatively early in training, and that "about 100 to 200 reinforced pairings using an errorless 'exclusion' technique" were required to learn new relations (Schusterman & Gisiner, in press). Although less exposure seems necessary for human participants, studies with individuals with mental retardation have also reported learning-outcome test failures early in training, followed by improved
performance after additional exposure to exclusion training (Dixon, 1977; McIlvane & Stoddard, 1981, 1985). We are aware of no published studies that have included formal learning outcome tests, as we have defined them, with very young children. Preliminary research in our laboratory indicates that normally developing 3- and 4-year-old children pass learning outcome tests in the concurrent introduction procedure after as few as three exclusion exposures for each relation. Systematic analysis of the mechanisms underlying the onset and progression of mapping in normal development awaits future research (Merriman, 1991; Woodward & Markman, 1991).

Recent Trends in Crossdisciplinary Citation

Figure 6 updates Figure 3 by including major empirical studies that appeared in the 20 years following Vincent-Smith's first report. Although the listing is selective (because of the high volume of papers in each discipline that contain no cross-citations), it does suggest the time course of the development of routine interdisciplinary citations. Mervis and Bertrand (1993b), for example, have referred to behavior-analytic studies in mental retardation in a discussion of the relation of language ability and fast mapping. Within the nonhuman animal cognition/language literature, it has become commonplace to see citations of EM work in behavior analysis, as exemplified in papers by Schusterman and his colleagues (1993) and Tomanaga (1993). Behavior analysts in turn are increasingly citing developmental language research, as exemplified by the Lipkens, Hayes, and Hayes (1993) study of the development of EM in a toddler-aged child. We have omitted from Figure 6 the many recent papers from our own research program, which makes explicit efforts to integrate psycholinguistic and behavior-analytic perspectives, and now routinely cites research from all relevant perspectives. For instance, our recent theoretically oriented papers (e.g., Wilkinson et al., 1996; Wilkinson & McIlvane, 1997) have been dedicated to identifying specific topics in which cross-disciplinary research might be uniquely suited to addressing questions of language development.

Given the striking conceptual and procedural parallels in much of the work, it is unclear what accounts for the disciplinary isolation that characterized the first 15 years of EM research and still continues to some degree today. Perhaps it was inevitable with a subject matter as widely defined and studied as behavior. One likely obstacle was the language barrier: Not only were the terms referring to the phenomena themselves different, but many of the technical terms within each discipline can be opaque for outside readers.

What can be done to reduce the problem of discipline isolation? First, we believe that a few well-publicized examples of successful interdisciplinary studies would go a long way toward reducing the isolation. An observation of parallels across independent disciplines is not simply a matter of academic interest. Rather, as Whitehurst recently (1996) pointed out, a full account of developmental phenomena may not


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Figure 6. Selected examples of all empirical studies of EM phenomena in developmental language, behavior analytic, and animal cognition/language research literature. Cross literature citations are indicated by arrows pointing to cited study. Not shown are Wilkinson and colleagues' recent papers in which interdisciplinary linkage is a major focus of activity.

be possible without an explicit attempt to merge contributions from multiple sources. We have committed ourselves to accomplishing such empirically based studies (e.g., Mcllvane, Dube, & Serna, 1996; Wilkinson & Mcllvane, 1997) and encourage others to do the same. Second, we believe that clear examples of disciplinary isolation must be documented, if only to give some incentive to broaden the scope of one's scientific vision. In retrospect, the history of EM research is somewhat embarrassing for all concerned. Very similar work was carried out over a fairly long period by researchers representing three important subdisciplines of psychology, but without the communication and cross-fertilization that might have produced more rapid advances in both disciplinary and interdisciplinary efforts. Connecting the behavior analytic program on "learning by exclusion" with "fast mapping" research would have been particularly helpful. Behavior analysts on the one hand would have been directed to the neglected area of early child development (cf. Mcllvane & Dube, 1996; Whitehurst, 1996). Language researchers, on the other hand, would have been directed to the behavior-analytic concerns about multiple word learning and to methodology for distinguishing among controlling relations in MTS procedures. We are hopeful that the present paper will help in encouraging an end to the intellectual isolation that all too frequently characterizes disciplinary research in psychology.
References


