INFANCY, 2(4), 451–467

The Salience of Multimodal Sensory Stimulation in Early Development: Implications for the Issue of Ecological Validity

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Studies of infant development concerned with the emergence of specific perceptual or cognitive abilities have typically focused on responsiveness in only one sensory modality. Research on infant perception, learning, and memory often attempts to reduce multimodal stimulation to "noise" and to control or omit stimulation from other sensory modalities in experimental designs. This type of unimodal research, although important, may not generalize well to the behavior of infants in the multimodal context of the everyday world. Research from animal and human development is reviewed that documents that significant differences in infants' perceptual skills and abilities can be observed under conditions of unimodal versus multimodal stimulation. These studies provide converging evidence for a functional distinction between unimodal and multimodal stimulation during early development and suggest that ecological validity can be enhanced when research findings are generalized appropriately to the natural environment and are not overgeneralized across stimulus properties, tasks, or contexts.

A persistent concern in the study of behavioral development is the extent to which data obtained via experimental manipulations explain the normal course of devel-

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opment in the species under study (Miller, 1981; Valsiner, 1987). As pointed out by a number of psychologists over the last 50 years, the extent of deviation from species-typical conditions associated with laboratory-based experimentation can limit the interpretation and generalizability of the behavioral outcomes that are measured and also contribute to potential variability in these outcomes (Brunswik, 1956; J. J. Gibson, 1979; Neisser, 1976). Broadbent (1987) referred to this as the "problem of observational fragility" (p. 170), the fact that relatively small variations in experimental conditions can change the behavioral outcome in question. The phenomenon of observational fragility is well known to students of infant development and contributes to an ongoing concern with the generalizability and ecological validity of laboratory-based research findings.

As demonstrated by the companion articles on this thematic topic, there is continuing controversy regarding the operational definition of ecological validity and the criteria for determining how the ecological validity of a study or experiment is to be evaluated. Although ecological validity is a multidimensional concept (see Schmuckler, this issue), one aspect that is often emphasized is the relevance of research to the understanding of activities and events of everyday life. Neisser (1976) highlighted this perspective several decades ago:

> Demands for ecological validity are only intelligible if they are specific. They must point to particular aspects of ordinary situations that are ignored by current experimental methods, and there must be good reason to suppose that those aspects are important. (p. 34)

In addition to this concern, we believe that a related key factor in addressing the relevance of research lies in the way that research is generalized. In our view, the ecological validity of research is enhanced if the findings are generalized appropriately and are neither overgeneralized nor undergeneralized across stimulus properties, organismic characteristics, and developmental contexts.

Since the influential writings of Lewin (1946) and Brunswik (1952, 1955, 1956) some 50 years ago, a growing number of investigators have become sensitive to the fact that most research designs in psychological sciences involve the use of atypical stimuli or contexts for the behaviors under examination. Of course, it is well known that psychologists make experimental settings artificial or atypical for good reason—to control for extraneous variables and to permit the separation of factors that do not normally occur separately in the natural world. This methodological approach is a cornerstone of scientific reductionism, which attempts to explain how systems function by finding out what the components of the system in question are and how those components fit together (Cohen & Stewart, 1994; Stewart & Cohen, 1997). For example, psychophysics has a long and successful history of employing single-factor designs in which all variables but one are eliminated or controlled and the variable under examination is systematically varied (see Mook, 1983, for a compelling argument for the value of such artificial settings).

Despite the success of the reductionistic approach in the behavioral sciences, there is increasing recognition within developmental psychology of the need to employ conceptual strategies, research methods, and data analyses that have greater fidelity to the dynamic and multidetermined nature of developmental phenomena as they occur in the everyday world (Bronfenbrenner & Morris, 1998; Fischer & Bidell, 1998; Ford & Lerner, 1992; Richters, 1997; Valsiner, 1987, 1998; Wapner & Demick, 1998). Development occurs "in the middle of things" and the everyday world presents the young organism with physical, biological, and social environments that are structured, organized, and often specific to the organism. There is growing appreciation that the single-factor designs common to a reductionistic approach are not sufficient for the investigation of the process of development, nor do they allow for generalizations beyond the specifics of their particular research context (Wachs, 2000). This insight has been fueled in large part by evidence that complicated systems such as behavior are characterized by features that cannot be reduced to their individual components. This phenomenon is typically referred to as *emergence* and suggests the conceptual and methodological value of some form of *contextualism,* the attempt to explain how a system functions in terms of the circumstances or contexts in which it operates. The importance of a contextualistic approach to the study of behavior was punctuated clearly by Petrinovich (1979) some 20 years ago: "If we are interested in explaining how organisms behave in their environment and how the two systems—distal and organismic—interact, we will have to study the environment as carefully as we do the organism" (p. 378).

This concern with the relation between the organism and the set of physical, biological, and social factors with which it interacts over the course of development is at the heart of what has come to be known as an ecological approach to developmental issues (Dent-Read & Zukow-Goldring, 1997; E. J. Gibson, 1991; E. J. Gibson & Pick, 2000; Reed, 1996). This approach acknowledges the richness of the stimulation provided by the everyday world and argues against extreme forms of theoretical reductionism by functionally interrelating the organism and its environment. From this view, behavioral development depends on coactions involving the organism and its context, and the task of defining the relevant developmental resources of an organism becomes critical to any systematic description and analysis of the development of behavior. In particular, the ecological approach asks investigators to reconsider their unit of analysis, arguing for a shift to the relation between the organism and its context rather than simply the organism itself.

This shift in emphasis toward a more ecologically grounded approach to infant research has become more evident over the last decade in several areas, including motor development (Adolph, 1997; Goldfield, 1995; Thelen & Smith, 1994), language development (Dent, 1990; Locke, 1993; Zukow-Goldring, 1997), and social development (Fogel, 1993). Although the ecological approach has also been successfully applied to the study of perceptual development (L. E. Bahrick & Pickens, 1994; E. J. Gibson & Pick, 2000; Rochat & Morgan, 1995; Schmuckler, 1996; Walker-Andrews, 1997), we find it surprising that apart from studies such as those just cited, a majority of developmental psychologists have tended to study the development of specific perceptual abilities in only one sensory modality at a time. Rarely have perceptual or cognitive abilities been studied as multimodal processes in the context of the multimodal environment in which they typically develop. Despite the fact that the environment of the young infant is inherently multimodal in nature, with objects and events typically experienced through several sensory systems simultaneously, the large majority of infant studies concerned with perceptual or cognitive development have conceptually reduced multimodal input to noise and attempted to control experimentally or even omit such stimulation from their experimental designs. Thus, studies of speech perception typically focus on infants' attention and responsiveness to the speech stream presented only to the auditory system; studies of memory development often focus on responsiveness to a unimodal visual display.

Given that the development of perception, learning, memory and other complex skills occur in the context of a multimodal environment, there is an obvious concern that developmental timelines and processes inferred from studies of infant responsiveness to unimodal information may not generalize to the behavior of infants in the multimodal context of the everyday world. A focus on the single sensory system runs the risk of distorting normally occurring patterns of sensory experience and may result in obscuring how specific stimulative events coact with organismic factors to exert particular effects at particular times in early development. This potential lack of generalizability from unimodal to multimodal responsiveness is, in our view, an important issue in discussions of the ecological validity of infancy studies. As pointed out by Bronfenbrenner (1977), "the properties of the environmental context in which research is carried out influence the processes that take place within that context and thereby affect the interpretation and generalizability of the research findings" (p. 516).

In this article, we review several lines of evidence drawn from both animal- and human-based research documenting that different outcomes in infants' emerging perceptual skills and abilities can be observed under conditions of unimodal versus multimodal stimulation. These comparative and human studies provide convergent results suggesting a functional distinction between unimodal and multimodal stimulation during early development and point to the dividends of a greater empirical concern with the specific types and amounts of sensory stimulation routinely available in the young organism's typical developmental context. The lack of congruence sometimes obtained between unimodal and multimodal research raises important questions regarding how we draw conclusions and make extrapolations based on our research designs. If findings regarding infants' perceptual skills and abilities drawn

from unimodal research do not in fact generalize well to infants' multimodal responsiveness, we must reexamine the nature of our generalizations? What are the constraints or boundary conditions for useful extrapolations across stimulus conditions? How do we generalize appropriately to the way in which development occurs in the everyday world and prevent the overgeneralization or undergeneralization of empirical findings? Although we have no simple answers to these challenging questions, a brief review of what is known about the relative effects of unimodal versus multimodal sensory stimulation provides a useful forum for exploring the related issues of ecological validity and generalizability in infant research. In particular, we examine how the nature of the stimuli under examination and the nature of the task required of the infant (see Schmuckler, this issue) can influence the conclusions drawn from research findings.

COMPARATIVE RESEARCH ON UNIMODAL VERSUS MULTIMODAL SENSORY STIMULATION

Given that most objects and events in the world are multimodal and evoke a diversity of visual, auditory, tactile, and olfactory impressions simultaneously, how does the young infant determine which patterns of sensory stimulation belong together and originate from a single object or event and which patterns are unrelated? What causes some stimulation to be salient, attended to, processed further, and remembered, and other stimulation to be ignored? Addressing these fundamental questions of perceptual development is a challenging task, particularly because studies that manipulate the amount or type of sensory experience available during early development are difficult to undertake with human infants. Comparative research involving nonhuman animals has provided a useful step in experimentally examining such issues at both the neural and behavioral levels of analysis (Lewkowicz & Lickliter, 1994; Lickliter & Bahrick, 2000).

Beginning more than a decade ago, a number of neuroanatomical and neurophysiological studies appeared indicating that the appropriate pairing of stimuli from different sensory modalities can elicit a neural response that is greater than the sum of the neural responses to the unimodal components of stimulation considered separately (Meredith & Stein, 1986; Stein, Meredith, & Wallace, 1994). For example, the effectiveness of a visual stimulus in eliciting attentive and orientation behaviors in cats was found to be dramatically affected by the presence of a temporally congruent and spatially collocated stimulus in the auditory modality (Stein, Meredith, Honeycutt, & McDade, 1989). Stein and Meredith (1993) proposed that multimodal stimulus combinations produce significant increases over unimodal responses in an array of extracellular measures of neural activity including response reliability, number of impulses evoked, peak impulse frequency, and duration of the discharge train. Stein and Meredith (1993) concluded that the neural consequences of pairing two stimuli from different modalities is greater than what would be expected by adding the consequences of each cue separately. This multiplicative nature of bimodal stimulation, in which the magnitude of neural effects resulting from bimodal stimulation consistently exceeds the level predicted by adding together responsiveness to each single-modality stimulus alone, suggests that multimodal and unimodal stimulation are often responded to differently and highlights the potential importance of multimodal information in facilitating selective attention and perceptual learning during infancy.

Comparative research at the behavioral level of analysis has likewise punctuated the important role of multimodal sensory stimulation in the emergence and maintenance of normal or species-typical patterns of perceptual organization. Beginning with the pioneering work of Gottlieb (1971) on species identification in birds, a large body of research has accumulated indicating that multimodal (i.e., auditory and visual or auditory and tactile) experience in the period following hatching is a key component in the development and maintenance of the early perceptual and social preferences underlying species identification (Gottlieb, 1973; Johnston & Gottlieb, 1981; Lickliter, Dyer, & McBride, 1993; Lickliter & Gottlieb, 1988). More recently, studies of precocial bird embryos and hatchlings have consistently demonstrated that subjects denied normal levels of multimodal stimulation during the early postnatal period show impaired perceptual responsiveness to both multimodal and unimodal maternal stimulation. For example, quail chicks receiving only maternal visual or maternal auditory input in the period following hatching fail to show species-typical perceptual responsiveness to unimodal and multimodal maternal cues when compared to chicks receiving multimodal maternal experience (Columbus, Sleigh, Lickliter, & Lewkowicz, 1998; Lickliter, Bahrick, Sleigh, & Columbus, 1997; Sleigh, Columbus, & Lickliter, 1998). Specifically, chicks provided only unimodal (i.e., auditory or visual) maternal experience during the early postnatal period showed delayed patterns of visual responsiveness to maternal information and reduced sensitivity to the spatial collocation of auditory and visual stimulation when compared to control chicks. The finding of delayed visual responsiveness is particularly surprising given that one group of experimental chicks received ongoing experience with maternal visual cues in the period from hatching to testing (Sleigh et al., 1998). Related work with both quail chicks and ducklings on the effects of limitations of multimodal stimulation following hatching has demonstrated altered patterns of auditory learning (Gottlieb, 1993; Lickliter & Hellewell, 1992) and intersensory functioning (Columbus & Lickliter, 1998). Similar findings (King, Hutchings, Moore, & Blakemore, 1988; Knudsen & Brainard, 1991, 1995; Withington-Wray, Binns, & Keating, 1990) also illustrating that the uncoupling of multimodal experience can lead to changes in the young organism's normal developmental trajectory have been reported in several other species of birds and mammals examined at the neural level of analysis. This further highlights the functional distinction between unimodal and multimodal sensory stimulation for developing perceptual systems.

INSIGHTS ON IMPORTANCE OF MULTIMODAL STIMULATION FROM HUMAN INFANT RESEARCH

Although work with human infants has rarely taken this unimodal versus multimodal distinction into account, several investigators have reported findings that support the view that multimodal stimulation has greater perceptual salience than unimodal stimulation early in development. In a series of related studies, Lewkowicz (1988a, 1988b, 1992, 1996) showed that regardless of the specific nature of the information specifying multimodal stimulation (e.g., flashing checkerboards and pure tones, moving objects and punctate sounds, human faces and voices), human infants consistently exhibit the capacity to discriminate changes in stimulation when those changes occur in two modalities concurrently. In contrast, when changes in stimulative features are unimodal (e.g., a change in the temporal rate of one component or a change in the gender of the speaker), discrimination is not always observed. L. E. Bahrick (1988, 1992, 1994) likewise provided evidence for the power of redundant information in guiding and constraining early intersensory responsiveness. In a series of related studies, amodal information—that is, information redundant across two or more senses—was found to direct infants' early perceptual learning and buffer them against learning incongruent or arbitrary intersensory relations. For example, following a training session infants were able to learn to pair an object and a sound together when they were united by the amodal properties of temporal synchrony and object composition but not when the amodal information was made incongruent (L. E. Bahrick, 1988). Similarly, infants as young as 3 months showed significant visual recovery to a change in two amodal relations, audiovisual synchrony and composition, but not until 7 months did they detect a change in unimodal relations (the color and shape of the visual stimuli and the pitch of their sounds; L. E. Bahrick, 1992, 1994).

The results of an earlier study (L. E. Bahrick, Walker, & Neisser, 1981) of infant selective attention to audiovisual information also illustrates the salience of multimodal stimulation for attentional deployment. Infants viewed films of two superimposed events (a toy slinky moving and a hand clapping game). For the adult viewer, when the two superimposed events were viewed silently, they appeared to be an amalgamation of ghostly images passing through one another. However, when the soundtrack to one event was turned on, the sound-specified event seemed to stand out from the other event, creating a strong impression of figure and ground. Infants also appeared to be affected this way by the addition of the soundtrack. By playing the synchronous soundtrack to one of the superimposed events, infants' attentional selectivity was directed to that event and caused them to ignore the silent one. This was apparent because after the soundtrack was turned off and the films were separated (i.e., appearing side by side) infants consistently preferred to look at the novel, previously silent film. Control studies confirmed this interpretation, in that when infants were presented with only one centrally projected event with sound followed by silent trials of the two events side by side, they preferred to look at the novel (not previously visible) film (L. E. Bahrick et al., 1981). Taken together these results demonstrate that the intersensory redundancy provided by the natural, synchronous soundtrack to a visible event can guide infants' visual selectivity, even when another visual event occupies the same spatial location.

These convergent findings from research concerned with the effects of multimodal stimulation on nonhuman animals and human infants highlight the notion that overlapping or redundant sensory information is particularly salient to infants and can elicit enhanced responsiveness. Reactions to the presence of one stimulus can be significantly altered by the presence of a stimulus presented to another modality. It is important to note, however, that much of what we know regarding infant attention, perceptual responsiveness, and information processing is based on unimodal research designs. These unimodal studies provide important information about the perception of modality-specific properties and provide a basis for comparisons with multimodal conditions, thereby making differences apparent. The way in which the findings of unimodally based research generalize to the everyday, real-world activities of the young infant remains an important and relatively unexamined question.

SALIENCE OF INTERSENSORY REDUNDANCY TO INFANT ATTENTION

In light of the research concerning the functional distinction between unimodal and multimodal stimulation, we (L. E. Bahrick & Lickliter, 2000) recently proposed an intersensory redundancy hypothesis, which attempts to synthesize knowledge gained from studies of both nonhuman animals and human infants. *Intersensory redundancy* refers to spatially coordinated and concurrent presentation of the same information (e.g., rate, rhythm, intensity) across two or more sensory modalities. For the auditory and visual modalities, this also entails the temporally synchronous alignment of the bimodal information. For example, the sight and sounds of hands clapping share a synchrony relation, a common tempo of action, and a common rhythm. The same rhythm and tempo can be perceived visually or acoustically. In brief, the intersensory redundancy hypothesis proposes that information presented redundantly across two or more sensory modalities selectively recruits infant attention during early development, causing amodal (redundant) stimulus properties to become foreground and other modality-specific properties to become background.

Because most objects and events are multimodal in nature, this selective attention on the part of the infant gives initial advantage to the perceptual processing, learning, and memory of stimulus properties that are bimodal over the processing, learning, or memory of unimodal properties of sensory stimulation. In other words, information that is simultaneously presented across two or more modalities is thought to be highly salient to infants and directs attentional selectivity at the expense of information that is not redundant.

Several aspects of the intersensory redundancy hypothesis have recently been supported, including the relative power of redundancy to guide attentional selectivity and perceptual learning in early infancy (L. E. Bahrick & Lickliter, 2000). Five-month-old infants were habituated in an infant-controlled procedure to films of a hammer tapping out one of two distinct rhythms. The two rhythms were irregular, having elements and intervals of different durations and differed only in terms of the arrangement of elements in the sequence. The rhythms were presented visually or acoustically (unimodal condition) or visually and acoustically (bimodal condition). Infants then received test trials depicting either a change in rhythm or no change in rhythm. Infants receiving bimodal exposure during habituation showed significant visual recovery to a new rhythm and showed greater recovery than the no-change controls (whereas infants receiving no change in rhythm during testing showed no evidence of visual recovery). In contrast, when infants received exposure to the rhythm display unimodally (auditory only or visual only), they were unable to discriminate between the two rhythms during test trials. These results suggest that unimodal exposure was not sufficient to support the discrimination of a complex novel rhythm at 5 months of age. A further experiment indicated that the effectiveness of bimodal presentation of a rhythm was evident only if the soundtracks and films were temporally synchronous. Infants who received asynchronous auditory and visual information did not show evidence of rhythm discrimination, indicating that the attentional salience of intersensory redundancy appears to be dependent, at least in part, on the proper temporal alignment of the auditory and visual stimulation. Taken together, these experiments indicate that redundant and concurrent stimulation to the auditory and visual modalities can selectively guide young infants' attention to the bimodally specified property of rhythm, fostering successful discrimination. This pattern of influence is likely to have consequences not only for early perceptual development but also for early learning, memory, social, and language development.

Previous research examining infants' sensitivity to rhythm information has typically shown discrimination of complex rhythms at older ages (Trehub & Thorpe, 1989). For example, Morrongiello (1984) reported that although 6-month-olds were able to detect absolute timing shifts (where the duration of elements in a rhythm is changed) in a series of white noise bursts, infants did not detect more difficult relative timing shifts (where the order of identical elements is changed, as in the L. E. Bahrick & Lickliter, 2000, study) until 12 months of age. We suggest that prior research has failed to demonstrate complex rhythm discrimination at earlier ages because temporally aligned, multimodal stimulation has not typically been included in most experimental designs (but see Pickens & Bahrick, 1995, 1997). The importance of redundant stimulation for directing attentional selectivity is expected to be most pronounced during early perceptual learning in a given domain, as infants are clearly capable of detecting amodal stimulus properties in unimodal stimulation (e.g., Mendelson, 1986; Morrongiello, 1984, 1986; Rose & Ruff, 1987) within the first months of life.

PERCEPTUAL CONSEQUENCES OF THE SALIENCE OF REDUNDANT INFORMATION

What are the consequences of the attentional salience of redundant information for the developing infant? What does the apparent power of multimodal stimulation suggest regarding infants' typical patterns of early perceptual responsiveness? One possible consequence is that in the everyday perception of multimodal events, the chain of attention and perceptual differentiation in a given event is likely to begin with more global information (i.e., amodal, specified by two or more sense modalities) and then proceed to increasingly more specific information (i.e., modality-specific stimulus properties). Such a processing lag between the detection of amodal and modality-specific relations has been proposed and supported by a series of studies by L. E. Bahrick (1992, 1994, 2001). The results of this body of work provide converging evidence for a pattern of increasing specificity across early development. Infants appear to detect global, amodal synchrony relations earliest, then nested amodal relations, and finally arbitrary, modality-specific relations within a domain. Similarly, Walker-Andrews (1997) concluded from a comprehensive review of the literature on the development of face and voice perception that recognition of emotional expressions develops first in the context of multimodal information with the dynamic face and voice of the speaking person. Subsequently, the emotional properties of the face and voice become progressively differentiated and discriminated from the whole.

The fact that more global audiovisual relations can guide and constrain learning about other more specific stimulus properties is illustrated in a recent study of early speech perception (Gogate & Bahrick, 1998). In this study, 7-month-old infants were taught a relation between verbal labels and distinctive looking objects in one of three conditions: (a) when there was temporal synchrony relating the motions of the objects with the timing of the speech sounds, (b) when the objects moved out of synchrony with the speech sounds, and (c) when the objects were motionless while the speech sounds were presented. Seven-month-old infants proved capable of learning the arbitrary relation between a verbal label and an object, but only when the object was moved in temporal synchrony with the sounds.

When the object was still or moved asynchronously with the speech sounds, infants showed no evidence of linking the speech sound and the object. In this example, learning of arbitrary relations appeared to be, at least initially, guided and facilitated by the detection of amodal relations (temporal synchrony) present in the multimodal stimulation. In other words, synchrony highlighted the relatedness between the sound and the object, promoting further processing of the nature of this relation. Hernandez-Reif and Bahrick (2001) have also shown that 6-month-old infants can detect the arbitrary relation between the tactually perceived shape of an object and a specific color or pattern, but only under conditions when amodal information for object shape unites their visual and tactile exploration. That is, the relation between an object's color or pattern and its shape appears to be learned by young infants only in the presence of amodal shape information made concurrently available to vision and touch and not under unimodal or nonconcurrent conditions. Converging evidence is accumulating suggesting that perceptual differentiation begins with more global, amodal information redundantly available to two or more modalities and then proceeds to more modality-specific levels (see L. E. Bahrick, 2000, for a review).

This developmental trend highlights the insight that the nature of the stimuli presented and the task or responses required of the infant can clearly guide and constrain the nature of the conclusions drawn (see Schmuckler, this issue). Depending on the choice of stimuli, the task employed, and the context provided, investigators can be led to undercharacterize or overcharacterize infants' specific skills or abilities. For example, the studies providing multimodal stimulation reviewed previously have consistently demonstrated perceptual capabilities at an earlier age than similar research in which unimodal presentations were used (L. E. Bahrick & Lickliter, 2000; Gogate & Bahrick, 1998). As a case in point, the majority of studies of infant-directed speech have ignored or downplayed the fact that infant-directed speech is inherently multimodal, including gesture, changing facial expression, and touch in addition to the auditory information available in the speech stream (but see Lewkowicz, 1996; Meltzoff & Kuhl, 1994). In general, conclusions regarding young infants' emerging speech perception skills have typically been based on unimodal research, which may not necessarily generalize well to the multimodal conditions normally encountered in the everyday world (Burnham, 1993; Kuhl & Meltzoff, 1984; Ostroff, 2000).

IMPLICATIONS OF THE INFLUENCE OF MULTIMODAL STIMULATION FOR ECOLOGICAL VALIDITY, GENERALIZATION, AND METHODOLOGY

In regard to the issue of ecological validity, we have highlighted what we consider to be one important variable or boundary condition that can influence the generalizability of research from the study of perceptual development. Convergent findings indicate that concurrent multimodal stimulation is an important dimension in experimental settings, and we argue that this insight can help constrain and specify the nature of our generalizations to ordinary, everyday settings. From this view, unimodal research is most appropriately generalized to conditions of unimodal stimulation that occur in the natural environment (e.g., perception of speech from a nearby room), and multimodal research findings are most appropriately generalized to multimodal situations (e.g. face-to-face encounters) in the infant's typical developmental milieu. An increased appreciation of the differences that make a difference to young infants, such as unimodal versus multimodal stimulation or static versus dynamic stimulation (see Walker-Andrews & Bahrick, this issue), will go a long way toward ensuring more appropriate generalizations from the laboratory to the real world. Of course, natural multimodal events make a variety of intermodal relations available, including amodal information and modality-specific information arbitrarily related across the senses (see Lewkowicz, this issue). More research is needed to better delineate the dynamic nature of salience hierarchies over the course of early development in terms of infant attention to the various stimulus properties of objects and events.

As recently pointed out by Massaro (1998) in his treatment of the perception of talking faces, it is important to know to what extent the processes uncovered in a given experimental situation generalize across (a) sensory modalities, (b) behavioral measures, (c) tasks, and (d) environmental domains. In support of this challenging quest, much more detailed knowledge is needed regarding infant attention, perception, and memory for stimulus properties in the context of everyday events. If we are to improve our understanding of how these processes develop in the dynamic and multimodal physical, biological, and social contexts of early development, we need more information about those stimulus properties that are selectively attended to and under what conditions. The accumulation of this type of information cannot depend simply on one-condition or single-factor assessments but will also require experimentation based on multiple assessments across different tasks, conditions, and domains (see Wachs, 2000, for further discussion).

Such an approach recognizes the value of both reductionistic and contextualistic approaches to experimental design and appreciates that there is no inherent inconsistency in utilizing both approaches in concert (H. P. Bahrick, 1989). Both have the potential to offer useful insights, and they are often most effective in combination (i.e., a focus on internal structure and external constraints). However, most of psychological science has emphasized the use of the reductionistic viewpoint, and contextual considerations have tended to be minimized or neglected, even in developmental studies. The idea of embedding an organism in its surroundings, thereby studying not just what it can do in a given situation but what it does do in its natural circumstances and what it may do under

slightly different circumstances, is central to what we consider ecologically valid developmental analysis.

As pointed out by a number of developmentalists over the last several decades (Gottlieb, 1977, 1997; Johnston, 1985; Miller, 1981, 1997; Oyama, 1985), relatively unobtrusive observations and descriptions of ongoing behavior in a variety of natural, everyday contexts provide a necessary anchor, but a fuller understanding of behavioral development also requires an experimental approach whereby certain variables are held relatively constant while others are systematically varied. This back-and-forth cycle between descriptive or normative assessment and experimental manipulation is particularly important to students of infancy, because as the young organism develops, its relation to the external world changes rapidly and dramatically such that the infant's effective environment—the actual physical, biological, and social factors with which it interacts—also changes (Johnston, 1985; McCall, 1977). What does this dynamic environment provide in terms of opportunities and constraints? What kinds of sensory stimulation are routinely available and how does the infant respond to these patterns of experience? How do research findings generalize to infants' everyday contexts? These types of questions require both naturalistic observation across representative developmental contexts and systematic experimental intervention and manipulation designed to uncover the developmental resources necessary and sufficient to support normal development.

We believe that concerns about ecological validity are best approached from a methodological framework that is grounded in this back-and-forth strategy of research in which investigators obtain descriptive baseline data in the everyday world to guide and evaluate data subsequently obtained via experimentation, and then obtain further normative baseline data for validating the previously obtained experimental findings, and so on. This recursive observational–experimental approach has been promoted by comparative psychologists for many years (Gottlieb, 1971; Miller, 1977, 1981; West & King, 1996) but remains relatively underutilized in developmental psychology. Nonetheless, such an approach can go a long way toward preventing either the overgeneralization or undergeneralization of research findings across stimulus properties, organismic properties, or developmental contexts. This can provide a degree of ecological validity that, although far from absolute, is well within the bounds of responsible empiricism in that it is based on the study of variables that are ecologically important and developmentally meaningful rather than variables that are simply more easily managed or manipulated.

ACKNOWLEDGMENTS

The writing of this article was supported by Grants NIMH RO1 MH62225 and KO2 MH01210 awarded to Robert Lickliter and NICHD RO1 HD25669 awarded to Lorraine E. Bahrick.

We thank Robin Panneton Cooper, David Lewkowicz, and Arlene Walker-Andrews for constructive comments on this article.

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