Keynote Address

Deafblindness and Neuroscience: educational implications

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Introduction

Words are like birds: Suddenly away.
Words are like birds. Some of the will stay

Kari Bremnes, Norwegian artist

First of all, I would like to thank the National Institute of Special Education for the invitation to give this lecture. It is an honor to be able to share with you some aspects of neuroscience and its implication on educational interventions for the deafblind.

Our daily work as scientist-practitioners represents a blend of research, training and clinical practice. However, an approachable question that each practitioner and researcher can contribute to answering is: "What are the ideas, observations, and data that underlie interventions for the deafblind?" By posing this question, the focus of analysis is on clinically relevant research that bears directly on deafblind practices. And, this may lead to an approach to intervention research in the deafblind field.

An approach to intervention research

In the recent years, various approaches to deafblind interventions have been developed most often focusing on communication. In the area of intervention research, Judd (1999) addresses four general theoretical approaches to intervention: the general stimulation approach, the functional approach, the process-specific approach, and the natural functional approach.

The general stimulation approach is often born from an enthusiasm that some social stimulation is better none than. This is likely usually true, but it is rarely an adequate approach for resolving complex emotional, behavioral and communicational problems and it lacks the individual specificity. In contrast, the functional approach is individually adapted and focuses on concrete goals and improving functions. A limitation of this approach is that skills retrained or compensated for in one context often do not easily generalize to other contexts.

The third approach, the process-specific approach depends on accurate theory-based assessment of functional processes to determine the configuration of deficits. Impairment is approached through the therapeutic strategies of compensation, adaptation, and/or restoration. While compensation involves finding a way around a problem or a solution coming from outside the person to do the jobs he or she cannot do, adaptation involves using preserved abilities to carry out activities usually done using functional processes that are now disturbed. Restoration is the direct regaining of disturbed abilities through practice and relearning.

The natural functional approach, like the functional and process-specific approaches, focuses on functional outcomes, and on identification and analysis of problem areas. But it emphasizes working on those problems in natural contexts as early and as much as possible. The keyword is “natural”, meaning a familiar day-to-day environment. In addition, it emphasizes a social-interaction (co-activity) and communication support approach using the concepts of zone of proximal development (Vygotsky, 1978) and scaffolding (Bruner, 1990). The zone of proximal development is the level of difficulty of an activity just a little harder than the person can manage independently; the kind of learning he or she can accomplish with a little help. It is in this zone, Vygotsky maintained, that the most learning takes place. In the same way, scaffolding enables a person to perform/communicate or learns a skill that could not otherwise be performed as effectively or learned as quickly. Specifically, it is about finding the right activity level and building communication skills or an activity around the person. The focus is on co-activity since it is meant to scaffold the individual’s competencies until they are strong enough for him/her to act independently. The approach to intervention research in the deafblind field may draw on the natural functional approach.

In an approach to intervention research in the deafblind field, the following principles quickly surface: deafblind research principles, deafblind characteristic principles, and deafblind practice principles. These are overlapping principles (figure 1) and they include a variety of methods (table 1).

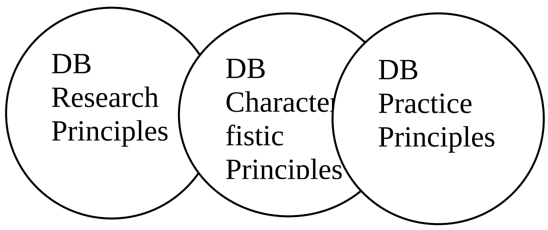

Figure 1. **The different principles in the deafblind field.**

Table 1. **The different principles and a variety of methods.**

- **Deafblind research principles:** etiology/genetics, communication, cognitive neuroscience, developmental psychology, musicology, linguistic, and sociology.
- **Deafblind characteristic principles:** identification/functional assessment*- strengths and weaknesses [sensory (visual acuity/activity, hearing level/activity) behavioral, communicational, emotional, neuropsychological].
- **Deafblind practice principles:** communication interventions, educational practice, behavioral management, quality of life, in-service training and staff development, dissemination of information and interdisciplinary teamwork.

*Functional assessment for the purpose of intervention planning, for example the comprehensive diagnostic measure of congenital deafblindness, developed by Karen Andersen and Inger Rødbroe (2000).

An attempt to integrate research, characteristics, and practical principles in intervention research may be a suitable approach to link clinical research and practice in the deafblind field. Encounters between the research and practice field may lead to new theoretical contributions, new inspiration, and new visions. In this way, we can develop clinical practice that truly reflects theoretical knowledge. It is important to provide teachers with the opportunity of in – service training in the field of the education for the multi-sensory impaired, including deafblindness, so that they can enhance their knowledge in this field and develop links with other fields in order to accumulate and enhance their experience, knowledge and skills (Sugai & Tsuchiya, 2000). Such an approach makes use of the knowledge of the needs in the deafblind field and supports the belief that the researcher and practitioner, provided with detailed and relevant knowledge is more likely to hit on original and useful solutions. Louis Pasteur told us more than a century ago, “In the fields of observation, chance favors the prepared mind.”

Contributions from cognitive neuroscience research

My focus will be on the deafblind research principles, specifically on cognitive neuroscience issues. Steven Pinker, a Canadian-born psychologist and author of “How the Mind Works” (1997), suggests that understanding the mind is engineering in reverse. In forward engineering, one designs a machine to do something; while in reverse engineering, one figures out what a machine was designed to do. We’ve got the product (the brain), and we want to know how it functions.

Cognitive neuroscience helps us to understand the communication in the nervous system and is the scientific key in understanding how the brain processes information. The brain is a highly modular organ, with each module organized around a particular computational task. According to this view, the processing of information is not confined to a single region of the brain. Instead, different neural modules process (sensory) inputs in different ways.

Cognitive neuroscience research may shine some light on how the brain organizes itself as a result of sensory deprivation, as in the expansion and reorganization of brain cortical maps due to auditory and/or visual deprivations. If this may happen, what are the mechanisms that govern it? To answer this question one must consider the concept of neuroplasticity.

A simple definition of neuroplasticity is the capacity of the nervous system to modify its organization. However, such changes may occur as a consequence of many different events, including normal development, the acquisition of new skills such as learning (in both mature and immature organisms), following damage to the nervous system and as a result of sensory deprivation.

The issue of neuroplasticity is important to the field deafblind since sensory deprivation (with/without organic impairments) is commonly seen within the deafblind population. The evidence for documenting neuroplasticity across sensory modalities has led investigators to focus on the expansion of cortical maps in one modality as a result of deprivation in another. The long-held belief that multi-sensory integration is a required step to achieve full-fledged development has led research to initially focus on the disabilities caused by early vision loss or deafness. Can cortical areas change their functional specificity depending on the inputs they receive? There are scores of studies of the effects of auditory and visual deprivation on the organization of remaining modalities. Cognitive neuroscience research evidence supporting this view is reviewed below.

With the advent of modern imaging techniques it became possible to map the distribution of neural activity during auditory or tactile stimulation in the blind subjects and during visual/motion stimulation in the deaf subjects. These sophisticated tools include noninvasive imaging techniques such as functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET), and electrical brain activity recordings such as Event-Related Potentials (ERP).

A study using PET in congenitally blind subjects and sighted subjects during an auditory localization task revealed significantly greater activation in the occipital areas of the blind subjects compared to the sighted subjects (Weeks, et.al., 2000). This suggests that the visual cortex in the blind subjects is recruited for auditory processing. Interest in the question of whether blind individuals develop enhanced capacities in their fingertips has been great since at least the days of Louis Braille. Recent PET studies have begun to shine some light on this problem in neurocognitive terms. Activation of occipital areas by tactile Braille reading was demonstrated, and transcranial magnetic stimulation of the occipital cortex disrupts the ability to recognize Braille characters (Cohen et. al., 1997). This finding demonstrates that somatosensory regions normally participating in this task have expanded into formerly visual territory, and the expanded cortex actually participates in the processing of tactile information.

Processes analogous to the auditory and tactile compensation in the blind have been demonstrated in congenitally deaf subjects. It has been shown with ERP as well as neuroimaging techniques that the brain of deaf subjects is reorganized profoundly. Auditory areas in the superior temporal cortex are activated by sign language (Nishimura et. al., 1999), but are not activated by the presentation of English words, as they normally are in hearing subjects (Neville et. al., 1998). A fMRI study which compared deaf and hearing individuals, on the effects of visual attention on motion processing, found greater recruitment of the motion-selective area MT (visual cortex area 5) in deaf than in the hearing participants, whereas the two groups were comparable when attending to the central visual field (Bavelier et. al., 2000).

The results of these studies taken as a whole, point to the adaptability of the brain following sensory deprivation. Thus, in the absence of competition from visual inputs, the visual cortex may become recruited for auditory or tactile processing and in the absence of competition from auditory input; the auditory cortex may become recruited for visual/motion processing. Perhaps, then, we can ask the question, “Could it be that in the absence of competition from both visual and auditory inputs, the visual and auditory cortex become recruited for tactile and motion processing?”

Neurobiologically speaking, the mechanisms responsible for neuroplasticity across sensory modalities during visual or auditory deprivation must be similar for both auditory and visual deprivations. Furthermore, this assumption may provide support for the importance of tactile aspects in communication interventions (tactual communication) and educational programs for the deafblind.

Neuroplasticity: How does it occur?

In principle, there are three ways that the brain could show plastic changes. First, there could be changes in the organization of the remaining, intact circuits in the brain. The brain could reorganize in some way to do “more with less”. Neuroplasticity is more likely to occur from change in the intrinsic organization of local circuits in regions directly or indirectly disrupted – reorganization of cortical connectivity. This is as likely to be associated with maladaptive plasticity and abnormal functioning, such as in the case of phantom pain following amputation. Second, there could be a generation of new circuitry. Interventions and treatment (pharmacological) could influence reparative processes in the brain or could enhance the production of new circuitry. Third, there could be a generation of neurons and glia (support cells) to replace at least some lost neurons. New neurons could be stimulated after injury or disease, as we can see it in neural stem cells research, where specific stem cells are being located, identified and manipulated for the purpose of developing new cells in the brain. Contrary to dogma, the human brain does produce new nerve cells in adulthood. The mature brain does spawn neurons routinely in the hippocampus: an area important to memory and learning (Eriksson, 1998).

The brain’s role in emotion: theoretical contributions

Neuroscientists have, in modern times, been especially concerned with the neural basis of cognitive processes, and have most part ignored the brain’s role in emotion. There are very few neuroscience studies on noncortical structures, and for this reason we neuroscientists have been referred as cortical chauvinists.

The human cerebral cortex does not ride piggyback on an ancient emotional system (limbic system). The systems work in tandem, integrated by many two-way connections. The amygdala, an almond-shaped organ buried in each temporal lobe, houses the main circuits that color our experience with emotions (Pinker, 1997). This structure has been given emphasis by imaging studies of the emotion of fear (LeDoux, 2002). In views of the relationship between emotions and the limbic system, this system would seem an appropriate place to look for developmental changes with the rise of social behaviors (Anders & Zeanah, 1984)

The debate within psychology on cognition versus emotion over which comes first has existed for more than a century. Yet in recent years, due to the understanding of the neural basis of cognition and emotion, investigators have begun to tackle this problem. What is the relation between cognition and emotion? As Joseph LeDoux (1996) posed the question, “Are emotion and cognition two sides of the same coin or are they different currency?” The journey into the emotional brain has taken different neural paths and different views. Walter Freeman (2000) gives one such view.

According to Freeman (2000), emotion is essential to all intentional behaviors, and he attempts to give an alternative view on the processing of emotions. He refers to the common view of how the brain processes emotional information, as the passivist-materialist-cognitivist view. In this view, the starting point of analysis is assigned to the sensory receptors, at which, information from the world is transduced from energy to action potentials.

Bundles of axons serve as channels to carry the information to the brain stem, where it is processed through nuclear relays and converged into the thalamus, which is a central sensory clearinghouse at the top of the brain stem. The information is already subdivided by the receptors in respect to its features –color, motion, tonal modulation, and so on. The thalamus sorts the information for transmission to small areas within each of the primary sensory cortices, which are specialized to deal with their designated kind of information. Information is then selected for transmission to the frontal cortex in the process of selective attention. The frontal lobes are the site of selection and organization of motor activity in accordance with the objective perception of sensory input. It is there that the rational information processing selects the appropriate motor commands that are issued through the motor cortex. Emotion is added to color the output commands by side channels that include the amygdala. This serial pathway constitutes a linear causal chain (figure 2). In this view, the brain is seen as an input-dependent processor of information and representations. Freeman suggests that, in this view, the role of the limbic system is underemphasized and misrepresented. Furthermore, the neural mechanisms by which the limbic system performs functions are bundled into "higher functions" that are to be analyzed after the problems of cognition have been solved. Additionally, he argues that olfaction does not fit within these architectures and is widely ignored. Olfaction is given little clinical importance from this point of view.

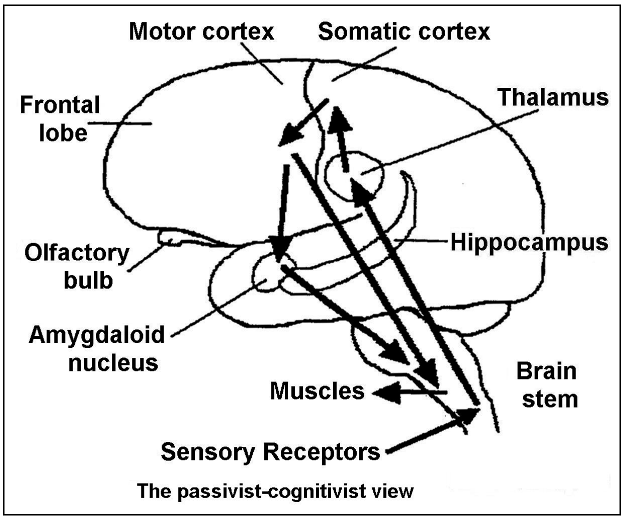

Figure 2. Passivist-materialist-cognitivist view of the brain as an input-dependent processor of information and representations.

Freeman's alternative view, the activist-existentialist-pragmatist view, approaches the brain as a semiautonomous generator of goal-directed behavior. In this view, the starting point of analysis is assigned to the limbic system, and not the sensory receptors. This is because perception is defined as a form of intentional action, not as a late stage of sensation. Thus, perception begins with the emergence of a goal through self-organizing dynamics in the limbic system. Commands from the limbic system are sent to the brain stem causing change in sensory inflow. At the same time, corollary discharges are sent to the primary sensory cortices to prepare them for anticipated sensory barrage. The loop starting and ending in the limbic system illustrates circular causality (figure 3). The consequences of this change in perspective include reassigning the pivotal roles of the thalamus and the frontal lobes to the limbic system. According to Freeman the organization of brain dynamics is seen as a set of loops of interaction in which the limbic system is embedded. This space-time loop indicates the interaction between the components of the limbic system by which experience is organized for intentional action through time and space.

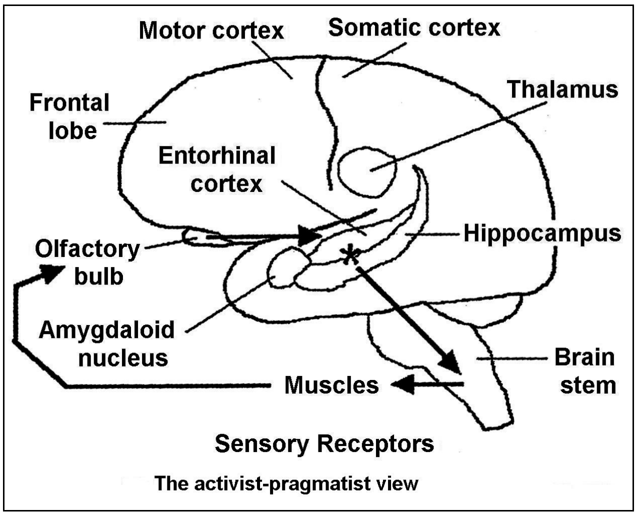

Figure 3. Activist-existentialist-pragmatist view of the brain as a semiautonomous generator of goal directed behavior.

Although these are two opposite views, it is most likely that both processes occur. However, the activist-pragmatist perspective favors a dynamic view of brain organization, suggesting that emotional systems have certain intrinsic dynamics that help establish coherent, emotion-specific forms of action and cognitive readiness. In other words, emotions are the mechanisms that set the brain's highest-level goals. Perhaps, then, in the field of deafblind education, communicative exchanges in interpersonal processes should pay more attention to the emotional aspects of the communication process. The essential thing in communication is communicating which means sharing affects and experiences (Rødbroe, 1997).

In the case of emotion, the body is crucial to emotional experience. It is difficult to imagine emotions in the absence of their bodily expressions. Different emotions are induced in the brain and played out in the theater of the body (Damasio, 1999). The varieties of the emotional responses are responsible for profound changes in both body landscape and the brain landscape. The opportunities for bodily feedback during emotional reactions to influence information processing by the brain and the way we consciously feel are enormous. The neural circuit responsible for the body image or schema is not only limited to somatosensory cortex, but also includes the limbic system (Melzack, 1990). The response of the body is an integral part of the overall emotion process, which can be modified by experience.

On the basis of the cognitive neuroscience research outlined, an approachable question that can be posed is, "Could it be that by providing the deafblind person with bodily and emotional expressions that emphasize tactile and motion perceptual interventions, we enhance the deafblind person's ability to recognize expressions?"

Again, neurobiologically speaking, the answer probably has to do with the type of communication. For the deafblind person, communication processes that emphasize bodily and emotional aspects, including touch and movement, eventually supported by residual vision and/or hearing, are the key.

Educational intervention on the basis of neuroscience research: From bodily and emotional expressions to the development of co-constructed communication

The development of co-constructed communication occurs through conversations between deafblind individuals and their communicative partners. So, how do we develop these conversations? Some suggestions are outlined here. (For a detailed description see: Amaral, 2004, Nafstad & Rødbroe, 1999)

By developing social interactions, including proximity and exploration - such interactions are usually based in movement, rhythm, repetition and emotional involvement. These interactions are referred as resonance, meaning that the teacher mostly provides resonance for children's behaviors (van Dijk, 1986).

By developing social interactive turn-taking - This requires the teacher and child to coordinate attention skills that enable them to jointly attend to objects, and to shift attention between the information provide by those objects, and information provided by partners in conversation

By focusing more on the deaf blind individual bodily and tactile attention during interact-ional events.

By interpreting appropriately the emotional and gestural expressions of the deafblind individual - Sometimes we could get to which gestural or bodily expression the deafblind individual would be most likely to use to repeat emotionally loaded experiences from the event.

By working in real life situations - as mentioned earlier, the natural functional approach emphasizes the use of real life experiences and familiar day-to-day environment in educational intervention. Educational interventions should happen in normal environments in order to provide for context and meaning.

By developing the use of appropriate communicative forms - This can be achieved by selecting the forms to serve the individual learner, and introducing more than one form whenever possible to enlarge communicative opportunities. Using selected forms consistently when communicating with the learner, and providing for new communicative forms whenever learners show that they can be given more abstract levels of communication.

By developing co-constructed communication -Developing expectations about the deafblind individuals` ability to take turns in conversation, pacing interactions and providing time for the deafblind individual to respond are basic issues that teachers and personals need to incorporate into their practice as effective communicative partners.

Conclusion

In recent years, various approaches to deafblind interventions have been developed, most often focusing on communication. From a theoretical point of view, the approach to intervention research in the deafblind field may draw on the “natural functional approach”. This approach emphasizes social interaction, co-activity and the use of real life experiences in educational intervention with children and students who are deafblind. However, understanding on how the brain processes information from an educational perspective may encourage staff to understand and develop strategies to increase communication and learning opportunities. Neuroscience research such as the brain’s role in cognition, emotion and bodily expressions may shine some light on how the brain organizes itself as a result of sensory deprivation. These contributions, in turn, may lead to the development of deafblind interventions that reflect theoretical knowledge. More important effective communication is needed between professionals within the deafblind field, as it may lead to cooperation, collaboration and mutual benefits.

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