A Neuroscientific Perspective of Language Processing in Transforming Input into Intake

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Abstract: Language research has endeavoured to provide evidence to support the notions that language proficiency is a function of either the *quantity* or the *quality* of input, or a combination of both. Most research into second language acquisition has focused on the auditory-dependent, verbal characteristics of input and seems to have neglected to address the role of the visually-dependent, non-verbal language in enhancing the facilitative characteristic of input and its consequential role in intake. This paper postulates that this improvement in learning under multi-channel exposure (i.e. the simultaneous exposure to verbal and non-verbal stimuli) may be the result of the learner being able to attend selectively to the stimuli in a way that would enhance the transforming of input into intake, and it advances a neuroscientific perspective which argues that the brain structures and neural networks responsible for these processes are seen as being critical to explaining why the exposure to multi-sensory input can enhance intake, and ultimately comprehension and language production.

Keywords: language acquisition, input, intake, language production

A Focus on Verbal Processing in Transforming Input into Intake

Researchers have become more and more aware of the need to examine the input with which learners have to work in learning a second or foreign language. As a consequence, research has endeavoured to provide evidence to support the notions that language proficiency is a function of either the *quantity* or the *quality* of input, or a combination of both. Within the context of second language learning and teaching, it is widely acknowledged that, since the inception of L2 acquisition some 50 years ago, researchers have searched for a link between the type or quality of *input* and aspects of the learners' *output*. From this research, a recurring finding has been the correlation between the frequency of certain forms of input and their manifestation in the learners' *interlanguages*. It can therefore be adduced that learners' approximations of L2 (i.e. their interlanguages), and ultimately their ability to

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understand and communicate in L2, is directly influenced by the nature of the input to which they are exposed.

All aspects of input involve a transformation of input into "intake": a change from unintelligible noise into a meaningful subset that is internalised by the learner for immediate or future use (Larsen-Freeman and Long, 1991; Scarcella and Oxford, 1992). The distinction between input and intake is an important one, and it has been long recognised that not all input becomes intake. This is due to the fact that learners are not able to process all the input to which they are exposed and therefore have to attend selectively to that information which is eventually "internalised" as intake. This concept of "selective attention" is discussed in more detail later in this paper.

Most research into L2 acquisition has focused on the auditory-dependent, verbal characteristics of input and seems to have neglected to address the role of the visually-dependent, non-verbal behaviour in enhancing the facilitative characteristic of input and its consequential role in intake, and ultimately communicative competence. The reason for this bias may be attributable to the difficulties in dealing with the intangibility of the non-verbal component of verbal communication. Edward Sapir, one of the early exponents of non-verbal theory, perhaps provides an underlying reason for this phenomenon, when he refers to non-verbal language as "... an elaborate and secret code that is written nowhere, known by none, and understood by all" (Sapir, 1949, cited in Allan, 1986:51).

There are three possible arguments as to why investigations into language have been focussed on verbal rather than non-verbal communication. First, it is perceived that non-verbal behaviour is a primitive or inadequate form of what can be expressed verbally. Second, it is thought that non-verbal communication forms are unnecessary, since verbal communication can occur in the absence of non-verbal communication. Third, non-verbal behaviour in growing children seemingly becomes less important with increasing age and increasing verbal fluency. Given these arguments, it is not surprising that verbal communication has dominated language research and investigation.

Words alone lack the capacity to carry the whole weight of a conversation, because they co-occur with non-verbal constructs, the exceptions being telephone conversations and radio broadcasts where the visual element is completely lacking. In commenting on the advantages of the use of vision through video-tape over the use of sound only through audio-tape in the L2 classroom, Kellerman (1990) emphasises this point:

> There are few occasions in our normal lives when we find ourselves in such a position: the telephone, the radio and loudspeaker announcements are the only examples most of us have to contend with (and these listening activities are generally considered to be the most difficult in a foreign language. (272)

It must be said that in these "invisible dyad" interactions, the aural element is more explicit to make up for the lack of the visual component. However, it is interesting to note that even when speaking on the telephone, people do use gestures even though they cannot be seen. This illustrates just how automatic and spontaneous non-verbal behaviour is.

In any model of language development, there exists a constant interplay of different channels of communication, verbal expression being only one facet of the multi-modal process. Non-verbal elements are a pervasive part of communication and also carry very real meaning. The worth of non-verbal behaviour in communicating meaning is perhaps best summed up by Galloway (1979:198): “There is no truth like the whole truth. And nonverbal expressions provide a fuller measure of what we mean to communicate.”

A Neurological Representation of the Transformation of Input into Intake

This unified nature of verbal communication reveals the importance of L2 non-verbal behaviour as being an essential and integral part of face-to-face discourse, and as such, should be considered as a formal level of realisation of discourse on a par with the various grammatical dimensions of language. Fitch (1985:17) affirms the significance of non-verbal behaviour in relation to semantics and the teaching of grammar: “. . . definite norms of non-verbal behaviour exist, and may be discussed as concretely as are grammatical rules and connotative differences between synonyms.”

In the context of L2 learning, the combination of verbal and non-verbal stimuli then is seen as being pivotal to providing the learner with the necessary communicative elements that will engender better learning.

It is postulated that this improvement in learning under multi-channel exposure (i.e. the simultaneous exposure to verbal and non-verbal stimuli) may be the result of the learner being able to attend selectively to the stimuli in a way that would enhance the transforming of input into intake. Intake is a complex process which involves the perception and encoding of input, followed by the integration of linguistic forms into the developing grammar. Abstract psycholinguistic characterisations of learner behaviour, such as Krashen's (1982; 1985) construct of "comprehensible input" and Corder's (1967) theory of "intake" have attempted to describe this transforming process, but have revealed little on the mechanisms involved. This has given rise to the need to explore more tangible representations of learner behaviour that might describe the underlying neural mechanisms responsible for processing input and intake.

In response to this need, the field of language education has taken on a broader perspective in attempts to explore further the cognitive processes underlying language learning. Some language researchers have turned to the neurosciences to gain a more comprehensive understanding of the language acquisition process (e.g. Jacobs, 1988; Greenfield, 1991). This redefining of perspective has seen the emergence of the field of "applied neurolinguistics" which seeks to provide frameworks and notions for investigating patterns of L2 learning. In promoting a more integrative perspective to studying language learner behaviour, Jacobs and Schumann (1992:282) suggest that language practitioners and researchers in “. . . language acquisition must begin to incorporate a degree of neurobiological reality into their perception of the language acquisition process. Such a neurally inspired paradigm helps to provide a common ground for integrating various language acquisition perspectives.”

Just as Krashen's (1985) "affective filter" has found neural correlates in the work of Schumann (1990; 1991), the neurobiological process of "selective attention" (Sato and Jacobs, 1992) and Danesi's (1988b; 1991) pedagogical constructs of "neurological bimodality" and "neurological information flow" appear to have revealed some of the underlying neural mechanisms that may be involved in the processing of sensory stimuli and the subsequent transforming of input to intake. It is postulated that the brain structures and neural networks responsible for these processes are seen as being critical to explaining why the exposure to multi-sensory input can enhance intake, and ultimately comprehension and production.

Selective Attention

Recent investigations in the field of applied neurolinguistics affirm that language acquisition is dependent on the auditory and visual senses for conveying both linguistic and contextual information to the brain, where meaning is derived by comparing incoming sensory information with extant neural structures formed by experience This selective attention of input is a phenomenon whereby a learner directs attention towards and maintains attention on the stimuli of relevance (Sato and Jacobs, 1992). It is hypothesised here that selective attention plays a significant role in transforming input to intake, and as such, is a representation of learner behaviour that might account for the facilitative role of multi-channel sensory stimuli in language learning.

By identifying the brain structures and networks that may be responsible for selective attention, a more tangible explanation for a multi-channel sensory enhancement system can be provided.

Sato and Jacobs (1992) suggest that the selective attention process can be conceptualised from two different perspectives: neurobiological and psychological. From a neurobiological perspective, meaning is derived from the interaction of *external* sensory information with prior knowledge as it is organised in the *internal* organisation of the brain, and "... it is the internal context that influences an individual's selective attention and subsequent understanding of input" (Sato and Jacobs, 1992:269).

From a psychological perspective, Rogoff (1990) refers to two Vygotskian-based theories for how sensory information is given meaning: "bottom-up" processing and "top-down" processing. Bottom-up processing suggests that novel (new) information is analysed into basic, discrete features or elements before being organised into meaningful patterns. Top-down processing examines a stimulus by pattern or spatial organisation, making use of the situational context. Both neurologically and psychologically, the process of learning is activated with a perception of and focused attention to a stimulus. This attention is enhanced in a novel learning environment, such as the L2 classroom, when meaning is attached to sensory signals, including those of a linguistic nature (Jacobs, 1988).

Most theories on language learning account mainly for the linguistic information a learner receives, but it is important to recognise that the brain not only processes (encodes) specific sensory information, but also the context in which it occurs. Any theory that relates brain function to the encoding of language is fundamentally flawed if it does not consider the importance of situational variables, such as contextual factors, which contribute to the meaning of the input. Nord (1986), in observing Helen Keller's first encounter with language, comments that ". . . language is an interactive process between signal and meaning within the brain: an *internal* interactive process . . . until code is placed in context, it is devoid of meaning" (Nord, 1986, cited in Paramskas and Mydlarski, 1991:234).

Guberina (1985), one of the key researchers to provide a neurally inspired theory on the processing of auditory and visual senses, hypothesised that these senses are anatomically and functionally interconnected, and are thus processed simultaneously by the brain. From this hypothesis has emerged a communication channels theory which maintains that information which reaches the brain via several channels simultaneously facilitates selective attention, and thus better and fuller learning.

Neuroscientific studies have identified a number of neural networks that are involved in the selective attention of verbal and visual input (e.g. Desimone and Ungerleider, 1989; Mangun and Hillyard, 1990; Posner and Peterson, 1990). However, as noted by Sato and Jacobs (1992), it is not clear how these networks as a system combine in the selection and enhancement of sensory input. Sato and Jacobs provide a possible explanation to this conundrum by identifying the *nucleus reticularis thalami* (NRT) as:

> . . . the neural structure through which all sensory information, with the exception of olfaction (the sense of smell), appears to pass and be synthesised before proceeding to the region of the brain responsible for processing and responding to sensory information: the cerebral cortex. (271)

This theory is based on the works of Skinner and Yingling (1977) and Scheibel (1980; 1984; 1987) which suggest that the NRT acts as a "gating mechanism" continuously monitoring and filtering sensory information from the external milieu and discriminating between relevant and irrelevant stimuli in a given context. Information flow to the cerebral cortex is therefore dependent on whether the NRT gates are open or closed. The sequence of opened and closed gates appears to be responsible for the selective processing of sensory information by the cerebral cortex (Scheibel, 1980). The gate is controlled by the *brainstem reticular formation* (BRF), a collection of neurons which exerts influence over the NRT in a two-way feedback system that can suppress or excite information flow to the cerebral cortex (Scheibel, 1984). Thus, as argued by Sato and Jacobs (1992), the NRT under the influence of the BRF can preferentially direct attention to those linguistic and non-linguistic aspects of the environment important for language acquisition.

Information flow through the NRT is not only regulated by the *ascending* control exerted from "below" by the BRF, but is also regulated from "above" by the *prefontal cortex* (a part of the cerebral cortex) in a *descending* control. As such, the cerebral cortex helps to select the information it receives from the environment. According to Scheibel (1980), the result of this continual communication between the NRT and BRF and the NRT and cortex is the transformation of selected input into intake. The cortex exerts influence over the NRT in much the same way as the BRF. However, as pointed out by Jacobs (1988), the NRT and BRF influences are directed at selective attention of different sensory input:

> Whereas the BRF influences NRT control of more general reflexive attention, the cortex plays more specifically on the NRT by influencing NRT control of discriminative, voluntary forms of attention. As such, cortical influences are particularly important for the selective attention necessary to attach meaning to sensory signals, including those of a linguistic nature. (285)

Sato and Jacobs (1992) conclude that the cerebral cortex gradually assumes greater influence over the NRT as the brain matures. This theory would seem to support the notion that cortical descending control over the NRT assumes greater responsibility in L2 learning than in L1 learning.

In the context of L2 learning, it is thus plausible to assume that input which can stimulate or excite this influence of the cortex over the NRT to monitor and filter incoming sensory information and direct attention to relevant stimuli will enhance comprehension and learning. It is hypothesised here that it is the exposure to integrated audio- and visually-mediated input that has this potential to bring about this arousal of the cortex.

This increased brain activity through the additive capacity of visual and auditory stimuli in learning is supported by positron emission tomography (PET) scanning, an imaging technique generating anatomical-functional correlations. PET technology has made it possible to exhibit graphically the mapping of brain activity during exposure to auditory, visual and combined auditory and visual stimuli. PET scans documented in Pillar (1998) confirm the increased activity of parts of the brain when exposed to the latter, and affirm that both hemispheres of the brain are active during the processing of language. It would therefore seem feasible to assume that this increased activity, and thus greater processing demand, would translate to greater cognition.

With respect to learning, cognition is defined by Jacobs and Schuman (1992:294) as ". . . the perception of a stimulus, attention to that stimulus, the movement of the information in the stimulus into memory, and finally, the expression or the use of that information." However, Jacobs and Schuman (1992) emphasise that learning can only occur with prior focussing of attention and appropriate *motivation*. Thus, the factors of novelty and pleasantness, and the degree to which the external stimuli is compatible with the individual's goals, needs, emotions and coping mechanisms are important factors for effective learning to occur.

One of the major goals of educators in any learning environment, particularly in L2 pedagogy, has been to provide input that will capture learners' attention and thus engender better learning. It is contended here that in L2 learning, integrated auditory and dynamic visual, multi-sensory input has the potential to achieve this prerequisite and is thus essential for cognition to be realised. Researchers and practitioners have aspired to exploit this phenomenon, but with varied success.

Neurological Bimodality and Information Flow

In the quest to find ways to aid cognition, there have been many attempts to correlate hemispheres of the brain with learner modality preference. The term "hemispherology" (Grinder, 1989) has been coined in an endeavour to classify learners in terms of their *cerebral dominance* (sometimes referred to as *hemispheric specialisation*, i.e. right hemisphere or left hemisphere) and modality preference (visual, audio or kinaesthetic - VAK). This approach to learner classification has spawned such terms as "right brain learner, " "left brain learner," "visual learner," "auditory learner" and "kinaesthetic learner," all of which, for better or for worse, are now common place in the learning/teaching environment.

The *cerebral dominance* theory alleges that one half of the brain - the left hemisphere-controls and directs behaviour. This theory evolved from discoveries in the 19th century by Pierre-Paul Broca and Carl Wernicke, both of whom ascribed language functions to the left hemisphere. Since these revelations, neurological scholarship and research have acknowledged *Wernicke's area* as the part of the left side of the brain responsible for the processing of language comprehension and *Broca's area* to be the part responsible for speech production. However, the notion that only the left hemisphere is involved in the processing of language has since been vigorously challenged on the grounds that language is a complex cognitive process requiring functions which engage both hemispheres.

In addition to PET scan studies, empirical clinical research using electroencephalograph (EEG) techniques has established convincingly that regions of both the right and left cerebral hemispheres of the brain are participants in language processing and that multi-sensory interaction of auditory and visual stimuli engages more brain activity (e.g. Joannette, Goulet and Hannequis, 1990, Damasio and Damasio, 1992; Robbins, 1992; Bellugi, 1994). According to Di Carlo (1994), this cortical parallel interaction reveals complex multi-sensory potentials which have major implications for language teaching and learning.

Such an ideal is embraced in the work of Danesi (1987; 1988a; 1988b; 1989; 1991; 1994), who promotes the view that ". . . the two hemispheres are complementary not antagonistic components of one cerebral system. Nowhere is this ‘whole brain’ model more evident than in the area of language learning" (Danesi, 1987:379). Initial experimentation on language processing carried out by Albert and

Obler (1978) gives an empirical foundation to Danesi's (1987) work on brain functions and psycholinguistic research, which essentially suggests a new generation of neurologically-based ideas on the pedagogical rationale for using integrated auditory and visual media in the L2 classroom. This perspective may explain why L2 learners learn better when all of their senses and emotions are engaged through the global emotional activity of "seeing and hearing."

The pedagogical construct of "neurological bimodality" and the notion of "neurological information flow" advanced by Danesi (1987; 1988a; 1988b; 1991; 1994) and Danesi and Mollica (1988) suggest that both learning modalities associated with left and right hemispheric functions of the brain operate in *tandem* when processing novel or unknown information, as is generally the case in L2 learning. Empirical evidence from research carried out between 1988 (Danesi and Mollica) and 1991 (Danesi) supports the claim made initially by Goldberg and Costa (1981) that in initial learning tasks, the right hemisphere of the brain, which is tuned more to processing global and contextual features of communication (i.e. synthetic, visual), dominates novel learning experiences in language learners. Goldberg and Costa (1981) suggest that because of its physical design, the right hemisphere is more able to process novel material for which there is no existing programmes or routines. On the other hand, the left hemisphere is anatomically designed to process previously learned information. Consequently, according to Danesi (1987), after having been processed in the right hemisphere, the novel information then flows via the main inter-hemispheric channel, *the corpus callosum,* to the left hemisphere, which is attuned to deal with linguistic elements, where it is encoded in a schematic or formal way. In other words, after the right hemisphere provides the meaning and context by discovering the underlying system inherent in the input, the left hemisphere takes over.

While this process seems to imply that each hemisphere is employed separately in language processing, it must be stressed that both hemispheres function in a complementary fashion and are used for total communication (Zaidel, 1977; 1983). One may be dominant, depending on the type of input (i.e. audio or visual or a combination of both), but *both* hemispheres are active in all kinds of information processing with the brain reconciling two clearly differentiated modes of knowing (Danesi, 1988b). Recent neurobiological research on language learning linking three areas of the brain (cingulate gyrus, prefrontal cortex and the fusiform gyrus) to language processing supports this whole-brain view of language rather than the concept of a language-specific brain system (Lem, 1992; Robbins, 1992). Sato and Jacobs (1992) suggest that the NRT (discussed earlier) works "in concert" with the cingulate gyrus, a part of the *limbic system* which contributes to memory and response selection.

Danesi's (1988b) pedagogical framework would seem to promote the notion that the introduction of new material requires a teaching approach that follows a "right-to-left" flow, i.e. moving from visual, intuitive functions to verbal, formal functions. From the Vygotskian-based psychological perspective previously mentioned, this suggests that the processing of new information is processed in a top-down sequence. In broadening the scope of language pedagogy, one consequence of this is to posit that the teacher needs to be aware of these phenomena and strike an appropriate balance among linguistic, non-linguistic, semantic and contextual units to be imparted and that the nature of the learning task, i.e. whether it is dominated by the left hemisphere or right hemisphere, should be taken into account. As previously stated, both are essential for understanding and communication to occur, but the degree to which one or the other hemisphere is active in some language task will depend on the nature of the input and the task in hand.

Danesi (1987:383) declares that ". . . the research shows, above all else, that language learning in any environment is neurologically bimodal, and that this will require a pedagogical approach that will activate both L-Mode and R-Mode learning strategies." Danesi (1987) uses the acronymic terms "L-Mode" and "R-Mode" to refer to the perceptual modalities of the left and right hemisphere respectively. To avoid any ambiguity in terms, it must be pointed out that the term "mode" in this context is not to be equated with the mode referred to earlier in relation to visual, auditory or kinaesthetic learning preferences.

The bimodality and information flow concepts, therefore, would seem to provide a neural framework to give expression to practical issues that confront language teachers in their quest to impart information in a way that will maximise the transformation of this input into intake, and ultimately L2 learning. The instructional methodology which characterises a more integrated teaching approach (i.e. right to left information flow) would seem to run counter to most conventional practice, which places the predominance of analytical processing and language-specific elements over global, non-verbal functions in learning new material.

Danesi and Mollica (1988) articulate the implications for L2 teaching and learning practice in the form of five underlying instructional principles which underpin and characterise any bimodal (i.e. integrated) teaching approach: 1) *modal directionality, 2) modal focusing, 3) contextualisation, 4) creativity* and *5) personalisation.*

1. Modal Directionality: This principal applies to the initial orientation tasks. Teaching practices should follow a R-Mode to L-Mode configuration; i.e. from context -to-text. In other words, strategies to contextualise input rather than language-specific signals should be used.

2. Modal Focussing: his allows the learner to shift to L-Mode learning and process linguistic input presented at the initial stage. Pattern practice is appropriate at this stage.

3. Contextualisation: This is aimed at providing meaningful contexts in the instructional routines to relate form with content, i.e. orientating teaching practices through the use of appropriate contextual support so that the synthetic discourse abilities of the R-Mode can complement and strengthen the verbal processing procedures of the L-Mode. The use of realia and supportive, visually-mediated information, both static (e.g. graphic devices, pictures, cartoons - with and without captions) and dynamic (e.g. video, television, film,) integrates L-

Mode activity with R-Mode activity, and provides stimuli to enhance global comprehension. Contextualisation can also allow grammar to be taught in a way that treats it as a "process" rather than as meaningless "form." Teaching grammar in context through verbal instruction and accompanying visual devices activates L-Mode and R-Mode functions concomitantly.

4. Creativity: This refers to the use of creative and expressive language, suggesting that R-Mode tasks continually be used to complement L-Mode routines. Creativity can be enhanced by initiating teaching practices which provide the learners with the opportunities to generate their own language and discourse material, within the set parameters. Neuropsychological research (e.g. Winner and Gardner 1977; Danesi, 1989) has shown that metaphorical language processing involves the interaction of L-Mode and R-Mode functions. As such, it is a bimodal strategy that should be addressed in the L2 classroom.

5. Personalisation: This focuses on the affective dimension of language learning and entails involving the learner in interactional activities which take into account the learner's interests and aspirations. Since affect is a R-Mode function, activities which consider this aspect will provide the context for the speech event. Affectively-coded techniques offset the more impersonal L-Mode-focused practices. Role-play and simulation activities through scenarios are typical strategies which engender personalisation.

Danesi (1991) cautions against defining bimodality as a language acquisition theory or teaching method. Danesi insists that the motivation behind the bimodality construct is an attempt to extract some basic principles from the relevant research in neuroscience, with the aim of providing a framework for discussing problems and issues in L2 teaching: "In many ways it simply gives expression to things that teachers already knew about in an intuitive way" (Danesi, 1991:23).

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