Searching for the Invisible with Eye Movements: The Beginning of Shift of Attention to Inner Mental Objects

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Abstract

This paper explores the emergence of lateral eye movements (LEMs) preceding memory access in two young children when talking to their mothers in a home situation. LEM was not observed until 15 months after birth, and the first episodes occurred abruptly and were related to words in the mother's utterance. By 24 months, LEMs were frequently observed during conversation concerning topics related to the infant's past experience, and it was often followed by utterances of new topics (names of person, object or event) by the infant, suggesting a causal relationship between the utterance of a new topic and LEMs. Discussion was made in terms of its significance in our understanding of the development of memory and attention control in young children.

Key Words: Eye movements, Memory access, Attention control, Thinking, Emergence, Inner mental state, fNIRS.

Introduction

More than thirty years ago, in predicting the role of psychology in the *very distant* future, Toda forecast, "Psychology will be the most important of all the sciences." The reason Toda gave for this is that so long as we, as people, have to live with our fellowman, "in order to achieve this very difficult task, our attention must inevitably be oriented toward the inner world within ourselves" (p. 312). Psychology has since changed quite a bit; it is doubtful if psychology is still in a state, as Toda seemed to have envisaged it in the height of Cognitive Psychology. However, the quest for ever more inner and deeper world within ourselves does not abate. Today, under the new banner of neuroscience, researchers strive for new knowledge about the inner world, probing such topics as awareness, consciousness, interpersonal experience, etc., which would be almost unthinkable in a more behavior-dominated program of psychological research (Kinsbourne, 1988, Siegel, 1999). In this paper, I will explore one aspect of our inner world, namely, the emergence of attention shift toward the inner world in young children.

A Brief Review

Even during the reign of Behaviorism, researchers tried hard to peep into the inner world of ourselves. One example is the study of what was called 'the psychophysiology of thinking' by measuring eye movements in various cognitive conditions such as imagination, problem-solving, answering question, memory, and hypnotic dreams, using record-

ing instruments such as EOG, EMG and direct observation (McGuigan, 1973, 1978). McGuigan assumed that 'the eyes function in the formation and transmission of verbal codes within neuromuscular circuits which engage the linguistic regions of the brain.' (McGuigan, 1978. P. 118). He also reviewed more than seventy related previous studies and concluded that the majority of studies showed positive relationship between eye movements and cognitive processes such as those mentioned above (McGuigan, 1978. Table 5.1). In this paper, among the various cognitive processes, I will focus on imagery and recall memory, especially on the relationship between these inner processes and eye movements.

Students of developmental psychology would easily be reminded of what Piaget has said about imagery as 'internalized imitation'. Although Piaget mentioned the studies by Aserinsky and Kleitmann, among others, he did not seem to have studied eye movements himself (1963). In reviewing studies that had examined eye movement and imagery, Paivio discussed several relevant studies reporting correlations between eye movements and imagery and concluded that either the "outflow theory of eye movement control" (i.e., the eye movements were presumably initiated by the central activity of the imagery), or the proprioceptive feedback cues theory (i.e., via this feedback, eye movements generate or regenerate imagery) was not supported by positive evidences (Paivio, 1973).

Another line of research that deals with eye movements focuses on lateral eye movements (LEMs), or conjugate lateral eye movements (cLEMs). It has been proposed that 'LEMs may be related to activation of the cerebral hemisphere conralateral to the direction of deviation of conjugate gaze' (Beaumont, 2001). This line of research found its recent beginning in Bakan's hypothesis that LEMs during the period of preparing the response to a question is related to hemispheric asymmetry and that "verbal" questions elicited a rightward deviation in gaze, while "spatial" questions elicited a leftward shift in gaze (Bakan, 1969). According to Beaumont, this hypothesis was further developed through the work of Kinsbourne, who linked the phenomenon of LEMs with his attentional explanation of laterality phenomena, suggesting that the eye movements reflected a shift in the gradient of attention towards the sensory hemispace contralateral to the activated hemisphere (Beaumont, 2001. P. 448).

Beaumont also pointed out that previous researches had discussed two different ways in which the association between LEMs and neuropsychological laterality. One is as an indicator of transient states of hemispheric activation; the other is as a more enduring index of an individual's neuropsychological style and is linked with cognitive style and with hemisphericity. While more recent srtudies have not provided enough conclusive evidence for the latter view, concurrent measurement of electrophysiological variables employing evoked potentials, the ongoing EEG, as well as blood flow studies, have been employed to validate the association between cerebral asymmetries and LEMs, supporting the hypothesis that, under certain condition, LEMs may reflect the relative activation of one of the lateral cerebral hemispheres (Beaumont, 2001. P. 448).

As we have seen in the brief review sketched above, eye movements have attracted the attention of researchers for a long time; many aspects of eye movements have been hypothesized to have association with various cognitive processes. However, questions

such as, When do they first appear in the young infants? How do they change, either in appearance or in function? What are the social contexts of their natural occurrence? etc. do not seem to have been asked, let alone systematically investigated, so far. The author believes that these are important issues and they need to be investigated systematically.

Preliminary Observations of LEMs in A Natural Situation

A younger sister of one of the girls attending the kindergarten was playing by herself in one corner of the room in the Center's experimental kindergarten one morning, when the author was making observation of other children's play nearby in the same room. While the author was making a video recording of the play, he also talked to the children about a particular past event. The younger sister (let us call her M), who was obviously watching the author and other playing children and was listening to our conversation, suddenly began to join the conversation by telling us about her own story. At this point, the author turned the handycam toward M, who the author found out later had just turned three years the previous Saturday, and recorded the following episode (Figure 1).

M: "....Daddy and M all laughed.... How funny!" (She said this with a big smile).

Author: "When was that? How old were you then?" Upon hearing the author's question, M's smile faded, she listened with a serious expression and looked at the author. Then, she gazed away, turning her head toward her upper left corner for a while, turned her eyes to the same direction, as if searching for something in the air. Then, she looked at the author and said "Eh, probably six years old."

Author: "Six years old!? How old are you now?"

M looked at the author again. Then, gazing away, she looked toward her upper left corner again, searching for something in the air, but now with a puzzled expression on her face. Then, she said "Three years old."

Figure 1 A three year old girl was observed to show LEMs when trying to answer the author's question concerning her age in connection with a past event she experienced.

Author: "But you were at that time six years old."
M looked away from the author and toward the same direction as
before. She then she looked back to the author and, with a slight blush, said "I don't know."

LEMs in An Experimental Situation

In order to explore the LEM phenomenon further, three children aged four- and five- years were observed in the laboratory. The subjects' blood flow of the frontal lobe was monitored by using multichanneled fNIRS device, while they answered questions put to them by the experimenter. Questions included personal knowledge such as date of birth, the breakfast menu, colors of mother's dress that day, and some riddles. All children were observed to show LEMs frequently. Some episodes of LEMs lasted for several seconds, with the eyes tracing various trajectories, in various directions. These LEM episodes occurred almost immediately after the exsperimenter had completed presenting the questions. The subjects made several attempts in answering the questions, with multiple LEMs (Figure 2). While further analysis of the fNIRS data collected from this observation will be necessary and will be reported in a later occasion, the present paper will only touch on a tentative finding.

After identifying all the episodes of LEMs in the whole session for all three subjects, the onset and offset of each episode were recorded by noting the frame counter readings. The level of oxygenated hemoglobin (oxy-Hb) after the onset of LEMs was compared with that before the onset of LEMs, with 14 data points each. The additive averages of these levels after the onset of LEMs were in general lower than that before the onset of LEMs. Several channels of each subject showed statistically significantly lower blood flow. This was true of all three subjects.

Although further analysis will have to be carried out in order to rule out various irrelevant factors before a more definite conclusion can be made, the result of this preliminary analysis seems to suggest that the onset of LEMs are related with decrease in blood flow in dorsolateral prefrontal cortex and prefrontal pole.

Indication of the Emergence of A Pointer to the Inner Mental World

As seen above, children as young as three years were observed to show LEMs in

Figure 2 A four year old girl was talking with an expermenter in front of her (left). She was asked to give the names of three nurses she knew. The middle and the right pictures show her attempt to search for the names, with LEMs.

connection with thinking. However, it is uncertain how young an age one can go to see the first application of LEMs in children. Many ingenious researchers have shown us that very young infants 'think'. Indeed, one of the messages of developmental psychology with its impressive findings during last three decades is that even newborn seems to be intelligent. However, if 'thinking' is reserved for function or ability involving symbolic processes, as most psychologists would agree, we do not expect infants several months old to possess this capacity. On the other hand, if LEMs can be considered to indicate the element or one of the preparatory steps toward thinking, the beginning of thinking skills can be ascertained by examining longitudinally when LEMs begin to emerge.

Another developmental significance that can be attributed to the emergence of LEMs is that it indicates the existence of a new capacity for the infant to shift his/her attention from external objects to inner mental objects. When an infant is born, we immediately see that he/she can feel most of the sources of stimulation, as do adults. They hear sounds and voices; they see objects, lights and faces, even if we are not sure if these are 'understood' by them or not. We are quite sure that when infants touch objects, they obviously feel their temperature and textures. As adults, we show them toys and faces; we talk to them, assuming that they sense these stimuli that we offer, through some kind of inner processes. In other words, we assume that an inner mental world exists from the very beginning in the newly born human beings. However, it is difficult to identify these inner processes, and to say exactly when they occur without using complicated instruments, or even with these instruments. LEM, however, is an observable overt behavior that is directly related to the process of thinking. When we are asked questions, the answer of which requires information not readily available, we tend to show LEMs before giving our answer. LEM, in this case, serves the function of searching for the information in our inner mental space. The temporal contiguity between LEMs and the production of words or sentences leading to the answer suggests that this behavior is an external indicator of the beginning of a series of inner processes, which we usually call thinking, or memory accessing. Although the exact functions of LEMs are not yet known, I venture to suggest that their emergence around 15 months in children signals the advent of a new stage in the memory development. LEM can be considered as a behavioral switch for turning on the processes of recalling.

A Preliminary Study of LEMs in Two Children Observed Longitudinally

Two female children, DA and OM, were observed three times a month, starting from when they were 10 months and 15 months, to 25 months and 26 months, respectively. The children's mothers were asked to carry out the data collection by making video recordings of their conversations with their children, focusing the camera on their children. The video recordings were collected and examined to identify the occurrence of LEMs.

Preliminary analysis showed that no LEMs were observed in suject DA in 11 sessions of observations from 10 months to 14 months. The first episode of LEM was observed during month 18 (four sessions lasting 872 seconds in total). During month 19, only one episode was observed (one session lasting 384 seconds). Month 20 saw no episode of LEMs. During month 21, four episodes were observed (6 sessions lasting 190 seconds in total). No data was recorded during month 22. In month 23, again, four

episodes were observed (two sessions lasting 295 seconds in total). In month 24, 4 episodes of LEMs were observed in 3 sessions lating a total of 816 seconds. Finally, in month 25, 9 episodes of LEMs were observed in four sessions lasting 705 seconds in total.

With subject OM, the first episode of LEM was observerd in month 15 (four sessions lasting 429 seconds in total). During month 16, four episodes of LEMs were observed in one session lasting 166 second. Again, during month 17, four episodes of LEMs were observed (two sessions lasting 244 seconds in total). Then, in month 18, two episodes were observed in one session lasting 173 seconds. Unfortunately, no recording was carried out during the next five months (month 19 to month 23). When the video recording resumed in month 24, more than 50 episodes were observed (three sessions lasting 2560 seconds in total).

The above descriptions indicate that the first episodes of LEMs could be observed in children as young as 15 months old. The two subjects showed a difference of three months in the emergence of LEMs. Furthermore, in nine months (if not shorter), LEMs in OM showed a great developmental change, both in terms of the frequency and in their forms. If the ease of observability of LEMs episodes during natural situation is represented by an indicator, *K*, where K= length of observation time (in seconds) / frequency of LEMs observed during a time period (e.g., a month), then it can be observed that with OM, *K* started at 429 and dropped below 200 the next month (month16) and this level was maintained untill the end of the reported observation period, when the *K* was smaller than 51.2, or about once every miniute. However, with DA, the *K* did not go lower than 200 until month 21, and this level was only maintained for three months before it went over 200 again in month 23.

Differences in the Style of LEMs over Time

A more detailed examination of the styles of LEMs over the period of observation of one of our subjects, OM, reveals that LEMs changed from a sporadic and fleeting phenomenon, suddenly popping up from the subject's behaviors, to a more sustained and elaborated component in her communicative behaviors with the partner. For example, one of the first three episodes, observed during month 15, was an independent occurrence unrelated with the partner's conversation or the context. Here, the subject was seen to turn her eyes upward a few times while muttering something to herself (Figure

Figure 3 OM was uttering something (not understandable by her mother) while she was observed to show LEMs for the first time. Aged 15 months.

Figure 4 OM, aged 16 months, was observed to show LEMs while being reminded of the name of a food item (left), and the name of a person she knew (right).

3). The second episode was observed when her mother mentioned the name of a food item (raisins, pronounced *rezen* in Japanese), which the subject was very fond of as a snack. The subject was trying to stand up from her chair when she heard the word *rezen* being spoken. She stopped her movement and maintained still for a very short while, during which time she turned her eyes toward her upper left hand corner, as if she was being reminded of the name and saw the image or its equivalent in her mind's eye (Figure 4, left).The last episode in this early period occurred after OM finished drinking from her plastic cup. Her mother was talking to her, asking if she remembered the name of a person. The subject looked upward slightly to her left hand side and, instead of answering the question, said "Ah, Oishi (yum-yum)." (Figure 4, right). In these episodes, LEMs appeared to serve no particular function in the subject's interaction with the others but exist as elements, waiting to be integrated into the communicative behavior sequences to appear several months later. This aspect of developmental change becomes much clearer when we look at the LEMs after an interruption of five months. When OM reappeared in the observation in 24 months, she not only showed LEMs frequently as mentioned before, her LEMs were so much a part of her conversation with her mother. Very often, OM would turn her eyes toward the upper left or right hand side of herself, and then brought up a new topic in her conversation with her mother. Of course, at this age, her linguistic ability was much higher than five months ago when the observation was interrupted (Figure 5).

Figure 5 At 25 months, OM was observed to show LEMs when talking with her mother. The scene on the right shows her LEM just before she recalled the name of her playmate, in connection with a play episode occurred the previous Sunday her mother had mentioned.

Conclusion

Eye movement has been considered an important element of cognitive processes for several decades now. Various cognitive processes have been hypothesized to have close relationship with different kinds of eye movements. Lateral eye movement is a special category of eye movement that has been proposed to relate to the activation of the hemispheres. However, no definite conclusion has been drawn as yet. In this report, I suggested that the developmental aspect of eye movement be taken into cosideration. I have tried to show that LEMs begin to appear around 15 months of age, when significant changes seem to occur in memory function, especially, recall, or evokative memory. I also suggested that the rapid development of language around this period could also be related to the emergence of LEMs. Obviously, language skills call for higher level of memory functioning. If LEMs are indeed indicator of development of new stage of memory functioning, especially memory function in the form of a new capability in directing one's attention to the memory (inner mental world) hence more efficient searching, further understanding of the development of LEMs and their various functions in communication would be worthy of future study.

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References

Bakan, P. (1969). Hypnotizability, laterality of eye movement and functional brain asymmetry. *Perceptual and Motor Skills*, 28, 927-932. (Quoted in Beaumont (2001), p. 448.)

Beaumont, J. G. (2001). LEMs. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience*. Cambridge, Mass.: MIT Press. Pp. 448-450.

Kinsbourne, M. (1988). Integrated field theory of consciousness. In A. J. Marcel and E. Bisiach (Eds.), *Consciousness in contemporary science*. Oxford: Oxford University Press. Pp. 239-256.

McGuigan, F. J. (1966). *Thinking: Studies of covert language processes*. New York: Appleton-Century-Crofts.

McGuigan, F. J. (1973). Electrical measurement of covert processes as an explication of *higher mental events*. In F. J. McGuigan and R. A. Schoonover (Eds.), The psychophysiology of thinking: Studies of covert processes. New York: Academic Press. Pp. 343-385.

McGuigan, F. J. (1978). *Cognitive psychophysiology: Principles of covert behavior*. Englewood Cliffs, N. J.: Prentice-Hall, Inc.

Oleron, P., Piaget, J., Inhelder, B. and Greco, P. (1963). Mental images. In H. E. Gruber and J. J. Voneche (Eds.), The essential Piaget. New York: Basic Books. Pp. 652-684.

Paivio, A. (1973). Psychophisiological correlates of imagery. In F. J. McGuigan and R. A. Schoonover (Eds.), The psychophysiology of thinking: Studies of covert processes. New York: Academic Press. Pp. 263-295.

Siegel, Daniel J. (1999). *The developing mind: Toward a neurobiology of interpersonal experience*. New York: Guilford Press.

Toda, M. (1972). Possible roles of psychology in the very distant future. In F. J. McGuigan and P. J. Woods (Eds.), *Contemporary studies in psychology*. New York: Meredith Corporation.