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THE RATE OF INNER SPEECH [1]

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Summary.—Self-reports of elliptical inner speech were measured to assess the speed of verbal problem solving. Rates of inner speech were correlated with physiological measurements of subvocal activity during verbal problem solving to evaluate the association between self-reports of verbal cognition and covert oral behavior. Subvocalization was electromyographically recorded during the silent solution of verbal tasks. Subjects reported the elliptical inner speech used to solve each problem (elliptical word count) and expanded that volume of words into a full statement of their internal problem-solving strategies (extended word count). The speed of processing and task simplicity were important in obtaining a high correlation between elliptical and extended word counts. The extended word count represented an equivalent rate of speech in excess of 4,000 words per minute. The volume of subvocal activity was correlated with the elliptical word count to assess whether subvocalization could be linked to introspection. This correlation was stronger during the rapid solution of simple problems.

Our cognitive experiences, such as "talking to one's self," "listening," or "imagining an interaction," represent covert language processes with which thought is internally formulated. Our overt language processes convey thoughts to others. Although covert language does, at times, include the silent rehearsal of external speech, the private construction of elliptic thought (inner speech) occurs in a linguistic form independent of the semantic, syntactic, and pragmatic rules of external speech.

Researchers have attempted to establish the rate of inner speech by measuring the speed at which memorized material was internally "rehearsed" (Landauer, 1962; Foulke, 1971). They reported that covert recitation of predicated speech was not appreciably faster than speaking the same material out loud. Clearly, the speed at which we speak, if measured by overt recitation, bears little resemblance to and is a poor predictor of the speed at which elliptical inner speech processes occur.

However, if a subject's self-report of elliptical inner speech, that occurs during a verbal problem solving task, is correlated with a physiological measurement of the simultaneously subvocal activity (McGuigan, 1978), an accurate estimation of the rate of inner speech may be produced.

INNER SPEECH

Inner speech, which is employed for self use, differs in structure and function from external speech, which is designed for public consumption.

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Composed of selected words and elliptic phrases, inner speech functions as an indispensible tool of comprehension: an idiosyncratic shorthand that fires memory, and evokes macroconcepts represented by words.

Characterized by four interdependent attributes, inner speech promotes the rapid mediation of complex cognitive stimuli (Vygotsky, 1962). Foremost, inner speech is a silent, intermittent activity (McGuigan, 1978). Sokolov (1972) aptly reflected on the inaudible nature of verbal thought when he wrote:

> . . . the usual characterization of inner speech as "soundless" is justified only from the point of view of an outsider; for the thinker himself, however, inner speech remains linked to auditory speech stimuli . . . (p. 55).

Second, inner speech is syntactically crushed (Johnson, 1984). Vygotsky (1962) called this condensed, syntactic arrangement "predication," remarking that the subject of a thought is almost always known to the thinker and so is seldom stated. Public speech must fully represent the thought to be intelligible. Third, despite its elliptic, incomplete form, inner speech is semantically elaborate (Vygotsky, 1962). Individual words expand their symbolic function and may be loaded with multiple, complex associations and rich emotional content. The elliptical word represents the mere skin of a thought. Finally, because inner speech is private, it is a highly egocentric language. Without an external function, our inner speech serves internal purposes: it is self-centered.

Inner speech is a dynamic and adaptive process that functions to link the "self" to the environment with which it symbolically interacts. This linkage occurs as internal or external word meanings are compared and contrasted through socialization. Inner speech also functions to regulate behavior through the processes of self; instruction, persuasion, criticism, identification, analysis, and consciousness.

Last among the functions of inner speech is the natural development of mentation or the ability to think conceptually through the use of language. Inner speech is the prime agent or tool of mentation and enables the purely human forms of abstract and practical intelligence.

Measurement of Inner Speech

Unfortunately, cognitive behavior as complex as verbal conceptualization is not easily accessible to observation and does not reveal its formation for analysis. While many external language behaviors can be accurately measured, covert language behaviors are often abrupt, fleeting and heavily concealed. Despite these barriers, covert language behaviors can be studied through two research methodologies, metacognitive self-report (Borkowski, 1983) and psychophysiological instrumentation (McGuigan, 1979).

Inner speech occurs so automatically and with such astonishing rapidity that we are prone to underestimate the volume of complex verbal cognition that takes place when we listen, write, or speak. The inaccuracy of subjects' recall presents a significant threat to the validity of cognitive studies that rely exclusively on this research strategy. Yet subjects' self-report still remains the quickest and most complete method for obtaining information about how we think.

Physiological instrumentation is far more accurate and reliable than self-report techniques, yet these methodologies can only detect the neurological and skeletal muscle responses of the cognitive and somatic systems. Elliptical inner speech may be detected through electrochemical impulses and neuromuscular depolarization, but it can only be expressed through subjects' self-report.

Subvocalization

A rich legacy of psychophysiological theory and empirical research originated with investigation of the reflex character of mental activities initiated by I. M. Sechenov in 1863. With his claim that, ". . . all the external manifestations of brain activity can be attributed to muscular movement" (cited by Herrnstein & Boring, 1965, p. 309).

While it would be erroneous to claim that we think with our muscles, it would be as imprecise to say that we think without them. Sechenov's (1965) model of neurological arcs or "loops," which connect the cortical speech areas to the speech musculature by efferent neural impulses, describes the subvocal response. These efferent impulses return along afferent, speech-motor pathways, and generate covert, soundless articulation or subvocalization. Later, Watson (1914), in his famous *Behavior: an Introduction to Comparative Psychology*, defended the process of thinking as implicit movement of the speech musculature and supported the conclusion that speech muscle activity occurs in all subjects during verbal thought.

McGuigan (1978) compiled an extensive psychophysiological review of covert behavior and evaluated many "electromyographic" (EMG) measurement techniques: ". . . critical events occur in the eyes, the somatic skeletal musculature, the speech musculature, and in the brain during the internal information processing that we call verbal thought" (p. 15). Although inaudible, inner speech produces a kinesthesia within the peripheral effector speech organs that can be measured electromyographically.

A comparison between the rate of elliptical inner speech and the rate of expressive external speech should permit an estimation (in equivalent, external words per minute) of how rapidly we think. Hypothetically, the physiological measurement of subvocalization (EMG) should be related to the self-reported, psychological rate of verbal cognitive thought and provide information concerning the accuracy of self-report measurement techniques. This task clearly warrants scholarly investigation.

METHOD

Subjects

Seventeen male and 21 female students (mean age 19.2 yr.) were randomly selected from an introductory lab course at a midwestern university. One female subject was eliminated from the electromyographic portion of the study due to equipment failure.

Apparatus

Approximately 6 mm of insulated coating was stripped from 128 gauge copper wires shaped into circular patterns 2 mm in diameter. Microcircuits CSC-20 silver electrode paste secured these electrodes to the orbicularis oris superior and inferior muscles, half-way between the midpoint and corner of the lip, along the vermilion border. A separate electrode located 4 mm below the nasion acted as a ground.

A second set of 128 gauge copper electrode wires were shaped and secured as above, and located on the ocularis oris superior and ocularis oris inferior muscles, 1 cm above the upper eyelid by 1.5 cm from the external canthi, and .5 cm below the lower eyelid by 1.5 cm from the external canthi, following the placement described by McGuigan (1979). A ground for these electrodes was placed above the prominent bone structure on the cheek.

The electrode wires led into J. J. Enterprise Model IP-5 isolator preamplifiers which were integrated and rectified by a J. J. Enterprise Model M-50 electromyometer. Signals were filtered through a DKI high band pass filter set for frequencies above 1 hz and below 100 hz and amplified by a factor of 105. A gain of 2 mv was used to monitor the subvocal EMG channel, and 20 mv for the ocular EMG channel. All signals were scanned continuously on an oscilloscope. The EMG signal was fed into a 4-channel Honeywell Visicorder (Model 1858), then recorded on Honeywell photographic paper (16774562-810), and exposed by a Honeywell 1884 interface module. The paper speed was 1 ips.

All EMG recording took place in a shielded facility with one door and no windows, so the area was kept at constant temperature and humidity. Each subject sat in a comfortable chair in the same room as the EMG Polygraph/Oscillograph system. A cassette recorder, set at a constant level, was used to deliver instructions to all subjects. A ribbon condensor microphone recorded the subject's description of how the task was solved. A second ribbon condensor microphone led to a third channel on the Visicorder that recorded the subject's verbal responses to the experimental task.

All tasks were written in 2-in. letters on 8- × 10-in. cards placed 24 in. from the subject. Both the researcher and an assistant were in the room during the experimental phase.

Procedure

Each subject was seated and electrode locations were prepared with a thin layer of silver electrode paste. Each subject was provided a clipboard, pen, and trial work sheet. A ¼-in. audiocassette recording provided an overview of the experiment and furnished practice exercises that were designed to familiarize each subject with the task of recalling verbal thought processes, restructuring the problem-solving strategies, and rapidly recovering these thoughts in written form. When the tape ended, the electrode wires were attached to the prepared sites. With the subject relaxed, a baseline EMG was established for later analysis.

Each experimental trial followed identical procedures: a subject rested with eyes closed until an audioprompt (ocular cue) signalled visual examination of the problem. The subject silently solved the verbal task, and if the solution could be deduced, spoke the answer out loud (speech onset). The cognitive window for inner speech (subvocal duration time) was defined as "occular cue to speech onset." Immediately after providing a verbal response, the subject silently attempted to record all inner speech on a form. For this study inner speech included verbal thoughts such as: self-instructions or criticisms, letters, letter combinations, syllable combinations, or visual images verbally referenced as part of the problem-solving strategy. When a subject was satisfied that all thought processes had been recorded, the subject explained the meaning of the logged inner speech, in fully predicated ostensive speech. These sentences were recorded on a ¼-in. audiocassette, and the entire procedure repeated with each new trial. The verbal responses, the ocular EMG data, and the subvocal EMG data were monitored on parallel Visicorder channels.

Each of the research trials consisted of word-completion tests such as "__UIT __ASE." Following the perceptual salience techniques of Davis (1983), the tasks were brief and contained either 2, 3, or 4 missing letters. If a subject did not solve a problem in 12 sec., he was asked to stop and immediately to reflect on the inner speech that he could recall until that moment.

To standardize the data, all subvocal measurements were set to a sensitivity gain of 2 mv. All ocular muscle movements were set to a sensitivity of 20 mv. Given the instrumentation used, these levels reflected the maximum sensitivity to the target muscle behaviors, without recording tonic interference.

Occasionally large bursts of tonic muscle activity (biting or pursing the lips) would inundate and overload the subvocal channel with major electrical depolarizations. These trials, whether correct or incorrect, were treated as overloaded trials, and no data were calculated when compiling subvocal responses.

Results

Self-report

Table 1 indicates the correct number of responses for all four trials given to the subjects. A comparison of data in Table 1 with those in Table 2 indicates that Trial 1 was not only simple to perform but was solved quite rapidly ($M = 3.10$ sec.).

TABLE 1
TASK COMPLETION RATE FOR EACH OF FOUR WORD PROBLEMS

Trial	Correct	Wrong	Overload	No Answer	Failure	Totals
1	30	1	5	1	1	38
2	8	20	5	4	1	38
3	20	7	4	6	1	38
4	3	29	4	1	1	38

Table 2 indicates the mean problem-solving time, based upon the length of time between the initial audioprompt and the onset of speech which ended the trial. Subject totals have been adjusted to reflect the completion rate in Table 1.

TABLE 2
MEAN PROBLEM-SOLVING TIMES (SECONDS), AS REPRESENTED BY CUE TO SPEECH ONSET, FOR EACH OF FOUR WORD PROBLEMS (*n* VARIES 37)

Trial	Subjects	Time/Seconds		Range
		M	*SD*	
1	31	3.10	1.93	9.19
2	28	3.48*	2.46	9.68
3	27	4.26	3.02	11.33
4	32	2.57*	3.35	10.81

*This mean score indicates that subjects responded rapidly but with wrong answers; see Table 1.

Pearson product-moment correlations were calculated between the number of elliptical words used during covert problem solving and the number of extended words necessary to expand those words to expressive speech. Of most importance, Trial 1 ($r = .387$, $p = .01$) and Trial 3 ($r = .434$, $p = .01$) showed a strong relationship between the elliptical and extended word counts. Trials 1 and 3 also reflected the largest number of correct responses to the research problems. Based upon 1-sec. increments, problem-solving (subvocal duration) times of the fastest subjects were divided into two problem-solving speeds; see Table 3. Twenty-one subjects or 55% of the total group tested, solved Trial 1 in less than 1 sec. The mean subvocal duration time for this group of problem solvers was .619 sec. per trial. Those 21 subjects averaged 3.9 elliptical words and 43 extended words for Trial 1. Dividing extended words by elliptical words for Trial 1 produces an approximate ratio of 1:11.

TABLE 3
MEAN SCORES FOR ELLIPTICAL WORD COUNT, EXTENDED WORD COUNT, AND SUBVOCAL DURATION TIME (SECONDS) FOR TWO HIGHEST PROCESSING SPEEDS ON TRIAL 1

Speed	n	Word Count				Subvocal Duration	
		Elliptic		Extended		M	SD
		M	SD	M	SD		
Fastest	21	3.90	1.18	43.04	15.21	.62	.23
Fast	10	4.60	1.84	43.00	20.45	1.04	.19

By dividing the elliptical words in Trial 1 by .62 sec. and also the extended words in Trial 1 by .62, an adjusted per second figure of 6.3 elliptical words and 69.4 extended words per second (wps) is established. This figure represents a rate of inner speech, when multiplied by 60 sec. of 4,164 words per minute (wpm).

Given that Trial 1 was an easy problem to solve rapidly and given the process of verbal problem solving in compressed, elliptical speech, the figure of 4,000 + equivalent words per minute does not appear unreasonable as an upward range for the rate of inner speech.

Subvocalization Results

Pearson product-moment correlations were computed between the incidents of subvocalization with the elliptical word count, and incidents of subvocalization with extended word count for all four problems. Neither the elliptical word count (Trial 1, $r = .294$, $p = .07$; Trial 2, $r = .036$, $p = .83$; Trial 3, $r = -.049$, $p = .77$; Trial 4, $r = -.191$, $p = .25$) nor the extended word count (Trial 1, $r = .091$, $p = .58$; Trial 2, $r = -.047$, $p = .78$; Trial 3, $r = .129$, $p = .44$; Trial 4, $r = -.058$, $p = .73$) correlated very well with incidents of subvocalization during any of the trials.

DISCUSSION

While definitive answers seldom result from preliminary investigations, a number of important relationships have been examined, and an estimated rate of elliptical inner speech has been established. The unsuccessful attempts to demonstrate a positive correlation between the electromyographic measurements of subvocalization and the self-report measurements of elliptical inner speech, raise a number of conventional criticisms of these approaches and prompt some observations about covert oral behavior.

The difficulty in correlating elliptical inner speech with subvocalization is not surprising. The interfunctional relationship between verbal thought processes, speech specific neural pathways and structures, and the proprioceptive speech apparatus, clearly has no simple structure to measure or analyze. (1) Many subjects expressed frustration with their inability to regenerate their cognitive thought processes or annoyance with their failure to recall/identify accurately which morphemes or specific words had been used in verbal problem solving. (2) Physiologically, to state that five peak subvocal incidents were equivalent to five self-reported elliptical words, was far too simplistic a statement to reflect accurately these complex neuromuscular processes.

Yet, given these methodological problems, an intervening variable was observed that accounted for a few inadequacies in both physiological and psychological approaches. When the silent, verbal problem-solving tasks were answered correctly, a strong correlation would be expected between task difficulty and the speed of problem solving (or time of subvocal duration). This relationship was confirmed for all trials.

Table 3 indicated that the speed of problem solving was a positive factor in establishing the correlation between elliptical and extended word counts. Rapid solutions appear to foster more reliable recovery of thought processes, which also led to higher correlations between elliptical and external words. When comparing subvocal incidents with elliptical word count, the fastest speed of problem solving (Trial 1) also had the strongest correlation ($p = .07$). Problem-solving time appeared to be directly affected by the complexity of the task or trial.

Task difficulty was related to the structure of the word problems (Brown & McNeill, 1966). Trial 1 was a two-syllable, compound word with the first letter missing from each syllable (__UIT__ASE = "suitcase"). This trial proved to be the easiest problem to solve ($M = 2.77$ sec.). Trial 2 ("__OLLE__E = "college") had letters missing from each syllable. Trial 3 (__LE__ __ANT = "pleasant" or "elephant") was a multisyllabic word with a pair of letters missing. Trial 4 (__AR__A__E, = "yardage" or "garbage") had one missing letter in the first syllable, and two in the second. Brown and McNeill (1966) reported this type of problem was difficult. The evidence reported in Table 1 supports these conclusions.

The extended subvocal duration for task difficulty could reflect a number of cognitive operations that functioned simultaneously. Phonological recording (Kleiman, 1975), lexical access (Baddeley & Hitch, 1974), and dual coding (Paivio, 1971) have been offered in different studies as three separate explanations of an hypothesized multichannel processing system (McGuigan, 1984). The complexity of cognitive processing of a nonverbal nature would clearly affect the outcome of this study.

While simple tasks require less cognitive activity, this brief problem-solving window fosters greater clarity in the metacognitive recall of elliptical problem-solving strategies. The problem solving criteria for simple tasks, conducted in the shortest periods of time, appeared to provide the optimal relationship between the subvocal signal and the self-reported rate of cognitive problem solving.

Conclusion

Elliptical word count did not appear to give a reliable indication of extended word count, except in those instances where problems were simple to solve or where corresponding problem-solving times were short. One subvocalized word may evoke, through internal associations, multiple words in inner speech that are implicitly understood and are not themselves subvocalized. There is greater likelihood that words were lost rather than gained through the self-report processes of this study. The rate of 4,000 + words per minute is offered in this study as an estimate for further evaluation.

Reliability of Self-reports

Many higher cortical functions, such as lexical access, retrieval from working memory, and speech recoding, occur in the formulation of a thought or the construction of a word. The relationship and sequence of these cognitive events often control the relative "ease" at which cognitive processing is conducted. Individuals have embedded perceptual structures for accessing memory in unique ways. The ability to recall accurately, evaluate the meaning of elliptical words, and maintain processing patterns are attributes of individual cognitive processing "styles." Each of these factors conspires to affect the reliability of self-report measures.

Thinking is complex behavior that may never be adequately described or explained through introspection, yet in the study of cognitive processing there remain few alternatives that are as accessible and informative as introspection. Unfortunately, there appear to be equally few activities within our culture that give us practice at reconstructing or identifying thought processes for public scrutiny. Training in metacognitive awareness or the development of introspective strategies and exercises that could strengthen the process of "covert verbal acuity" would be extremely useful in examining information processing capacities.

Self-report and Subvocalization

The lack of correlation between incidents of subvocalization and extended elliptical or extended word count is indicative of the complexity of the internal neuromuscular processes and what these represent as manifestations of covert oral behavior. The subvocal (EMG) signal gives only a profile of phasic muscle firing. As such, muscles may fire for a combination of syllables or potentially for a combination of words themselves. One peak amplitude in an integrated and rectified electromyograph does not equal one subvocalized word. Yet the internal "verbal" code may be represented in neuromuscular depolarizations in some complicated fashion.

As elementary as these procedures appear to be, there currently are few alternative strategies for measuring inner speech. The unraveling of, or at least the appreciation for, the structure and function of the efferent and afferent neural impulses with which the speech musculature is associated with higher cortical functions is at the fundamental basis of much of the physiological research on inner speech.

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