ROTHER STROOP'S ENDURING EFFECT

A mental task devised nearly 60 years ago still intrigues psychologists

By: Bruce Bower

As part of its centennial celebration this year, the American Psychological Association will inaugurate an exhibit that provides a close-up of key findings of psychological research over the last 100 years. The exhibit which opens May 18 at the Smithsonian Institution in Washington, D.C., and will travel to nine other museums throughout the United States by 1995 - includes a booth that offers visitors a chance to experience the Stroop effect. The "gold standard" of attention measures, the Stroop effect was devised 57 years ago by one of the most unusual figures in the history of experimental psychology

J. Ridley Stroop achieved instant scientific prominence when his doctoral dissertation appeared in the December 1935 JOURNAL OF EXPERIMENTAL PSYCHOLOGY. Yet Stroop published only four studies between 1932 and 1938, before he abandoned the psychology laboratory for a life devoted to teaching, preaching and writing about the Bible. Stroop's students and colleagues at a small Christian college in Nashville, where he served as head of the psychology department and a popular instructor of Bible classes, referred to him as both "Doctor Stroop" and "Brother Stroop."

But the more Stroop ignored the experimental effect that quickly became known by his name, the more it inspired new ranks of psychological researchers. "The Stroop effect has never been adequately explained, making it a source of continuing theoretical fascination," asserts psychologist Colin M. MacLeod of the University of Toronto. MacLeod charts the profound impact of this test on psychological research in the March JOURNAL OF EXPERIMENTAL PSYCHOLOGY: GENERAL, which also features a reprint of Stroop's 1935 article.

The Stroop effect, a fixture in nearly every psychology textbook, has proved deceptively straightforward. When asked to name aloud the incompatible ink colors in which a list of color words is printed (for example, to say "blue" in response to the word "yellow" printed in blue ink, "red" in response to the word "green" printed in red ink, and so on), people experience a mental sensation comparable to running in a swimming pool - you just can't do it quickly. As MacLeod points out, the task usually evokes frustrated laughter from those performing it for the first time.

However, when asked simply to read the same list of words (say "yellow" in response to the word "yellow" printed in blue ink, and so on), people dash right through the task.

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Stroop's documentation of this effect followed upon related research conducted 50 years earlier by psychologist James McKeen Cattell, who reported that objects and colors take longer to name aloud than their corresponding words take to read aloud. In 1929, a German psychologist studied volunteers' responses to color words printed in contrasting ink colors, but few psychologists elsewhere heard about or could read his untranslated monograph.

Stroop apparently had no knowledge of the German work, MacLeod notes. The U.S. scientist's fascination with the mental "interference" that occurs when someone tries to think about two dimensions of a task at the same time led him to combine colors and words, MacLeod maintains.

Since then, more than 700 studies have addressed some aspect of the Stroop effect, by MacLeod's count. And in the last 20 years, the pace of research has really picked up. Between 1935 and 1964, 16 articles examined the phenomenon directly This relatively dry period coincided with the height of behaviorism, a scientific movement that deemed observable behavior the only appropriate subject for psychological study "Cognitive" psychology and its emphasis on inner mental processes then gained prominence, paving the way for a new generation of Stroop studies. Since 1969, about 20 research articles per year have directly tackled the Stroop effect.

A number of consistent findings emerge from the extensive Stroop-effect literature, contends MacLeod in a review article published in the March 1991 PSYCHOLOGICAL BULLETIN, namely:

- The Stroop effect occurs with exposure to lists of words or other stimuli that are presented one at a time and that require many variations in response. For instance, incompatible words embedded in line drawings--such as the word "horse" placed within a rendering of a bear interfere with the person's ability to name the pictures.
- Words closely associated with Stroop-test colors interfere more with color naming. A case in point: The word "green" printed in red slows down the ability to say "red" more than the word "take" printed in red.
- People name colors faster when color words correspond to ink color, rather than when color words are printed in black ink. However, this effect proves weaker than the disturbance in color naming caused by mismatches of words and ink colors.
- If experimenters present colors and color words in different locations (say, a red bar above the word "green" in black ink), people still experience difficulty in naming colors, but to a lesser extent than in the standard Stroop task.
- Speed in color naming takes a nose dive when a color word on one trial corresponds to the ink color on the following trial, as when "green" in red ink precedes "blue" in green ink. Conscious suppression of the reading response "green" on the first trial seems to make it harder to say "green" in response to ink color on the next trial, MacLeod says.

- People allowed to practice naming the incompatible ink colors of various color words gradually improve their color-naming ability, but they also experience greater difficulty in reading color words printed in nonmatching colors (an effect noted by Stroop in his 1935 article).
- The Stroop effect appears early in the school years and peaks around grades 2 to 3, as reading skill blossoms. The amount of time needed for color naming declines through adulthood until about age 60, when it begins to increase again. Men and women display comparable response times to the Stroop task.

Theoretical explanations of the Stroop effect currently fall into two general categories. One theory holds that people read words faster than they identify colors. Thus, when different words and colors collide in the same test, the faster reading response interferes with the slower color-naming response, especially when the faster response must be ignored. When words and colors match, the faster response gives the slower response a helpful nudge.

However, recent research challenges this notion, MacLeod asserts. Several teams have found that presenting various colors just before incompatible color words, which theoretically allows the slower mental activity to take place before the faster one, does not interfere with the speed of reading the mismatched words. Moreover, presenting matching colors just before color words - the color red before the word "red" - does not speed up word reading.

The second theory states that certain mental activities, such as reading words, proceed automatically, regardless of conscious intent, whereas others, such as naming colors, require considerably more voluntary effort and control. When an automatic stimulus clashes with a controlled stimulus, responses to the latter slow down, according to this view; when they match, the automatic stiumuls lightens the mental work necessary to handle the controlled stimulus.

Unfortunately for this scenario, experiments suggest that mental tasks generally do not fit into inflexible categories of automatic or controlled, MacLeod asserts. Any mental activity becomes more nearly automatic with enough practice and can interfere with a less well learned activity, he contends.

MacLeod and psychologist Kevin Dunbar of McGill University in Montreal demonstrated this tendency in a study described in the January 1988 JOURNAL OF EXPERIMENTAL PSYCHOLOGY: LEARNING, MEMORY, AND COGNITION. Volunteers learned to call each of four arbitrary shapes by a different color name (green, pink, orange or blue). At three points in this process, the researchers presented each shape in a neutral color (white), a color that matched its name and a color that clashed with its name; they then asked participants to name the shape or its ink color.

With a small amount of practice with arbitrary shape names, clashing ink colors interfered with shape naming, but shape names did not slow down the naming of different ink colors. With moderate practice, performance decreased proportionately in both

conditions. And with extensive practice, clashing shape names slowed color naming, but not the reverse. Nevertheless, ink-color naming always occurred more quickly than shape naming.

Simply put, differing amounts of practice result in one task appearing more automatic than another, the researchers concluded. Word reading seems automatic compared with color naming in the classic Stroop test, but color naming appears automatic compared with shape naming, which also approaches an automatic fluency with extensive practice. Mental interference effects, such as those in the Stroop test, probably derive from the contrast between a well-learned and a less-practiced mental activity, MacLeod maintains.

This view builds on Stroop's original explanation of his findings. He argued that people receive far more training in reading color words than they do in naming colors. The fluid association between a word and a reading response interferes with the relatively more labored association between a color and a color-naming response, Stroop contended.

Further evidence that the Stroop effect depends on the strength of mental associations - or, in current lingo, "connections" - comes from a computer simulation conducted by psychologist Jonathan D. Cohen of Carnegie Mellon University in Pittsburgh and his colleagues. Cohen's group recreated many Stroop-test findings in a connectionist computer, also known as a neural network. The computer contained a layer of input units, a layer of output units and a layer of intermediate units where training occurs. On successive training trials, the system gradually developed pathways that recognized information representing ink colors and color words in one experiment, ink colors and shapes in a second experiment and animal pictures and animal words in a third trial.

During training, preprogrammed signals traveled back through the network and adjusted the mathematical strength of connections between units. In this way, the system eventually "learned" to respond correctly. The researchers gave the computer substantially more practice with word reading than with the other tasks, a tactic meant to approximate the typical human experience.

Additional processing units attached to the system's intermediate layer served as "attention modulators," increasing the intermediate units' processing sensitivity with practice.

Cohen's group then presented the system with various Stroop tasks, such as a direction to name the color in the stimulus "word GREEN in red ink." Color naming slowed with clashing color words; it speeded up with matching color words. The same pattern held for animal words and pictures. Other Stroop effects noted in human volunteers also appeared, such as the influence of practice on ink color and shape naming observed by MacLeod and Dunbar.

The computer simulations suggest that responses to all sorts of mental activities become more automatic with practice, with Stroop tasks pitting "more automatic" against "less automatic" responses, Cohen's team asserts in the July 1990 PSYCHOLOGICAL

REVIEW. Enough practice in a particular task, such as naming shapes with specific color words, allows stimuli (shapes) to activate correct responses (corresponding names) directly without recourse to conscious memory strategies or other "indirect pathways," they propose. But the connectionist model has yet to characterize how indirect pathways operate and evolve into direct pathways.

Ironically, Stroop--who died in 1973 at the age of 76--expressed little interest in the task he created and the research boom it spawned. "The Bible, not psychology, was Stroop's life work," MacLeod says. In contrast to his meager output of psychology research, Stroop wrote seven books based on his biblical teachings that achieved widespread use as textbooks in Christian schools.

While preparing an influential 1966 review of then-burgeoning research on the Stroop task, psychologist Arthur R. Jensen of the University of California, Berkeley, spent months trying to locate Stroop, to no avail. By chance, he ran into a colleague at a conference in Nashville who recalled that Stroop taught at nearby David Lipscomb College. Jensen traveled out to the small campus where Stroop's office door declared: "J.R. Stroop, Professor of Bible."

"He didn't know anyone who even knew about his test," Jensen recalls. "He seemed slightly embarrassed that he was no longer really interested in psychology."

In fact, Stroop quickly lost contact with cutting-edge psychology and its practitioners following his 1935 publication. Upon consulting his files, Stroop told Jensen that someone named L.L. Thurstone had written to him in the early 1940s about the Stroop effect, but the Nashville educator had not recognized the name and did not respond. The letter, Jensen explains somewhat incredulously, came from psychologist Louis L. Thurstone, the preeminent investigator of mental tests in the 1940s and early 1950s.

Jensen studied various aspects of the Stroop effect around 30 years ago but has since become known for his view that genes influence IQ differences between blacks and whites. His research now focuses on the relationship between IQ and response times to various mental tasks, a clear legacy of the Stroop effect's reliance on response times.

Other psychologists take a more direct interest in unraveling the meaning of the Stroop effect. "Stroop was a scientific pioneer, and research on the Stroop effect may ultimately help us understand how attention works," MacLeod comments. "I suspect this field of research will continue to grow."

PHOTOS: Rapidly naming the ink colors of the words shown above requires concentration. (American Psychological Association)

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