Automaticity

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Skilled performers, whether they are performing physical or cognitive acts, universally describe their performances as necessarily involving an automatic component. This automatic quality of performance, which results from much practice, is known as automaticity. Benjamin Bloom (1986) delineates several types of performances that can involve automaticity: bodily control (walking, running, eating, dressing), household skills (sewing, ironing, knitting, mopping, raking), communication skills (speaking, reading, signing, shorthand), man-instrument skills (musical instruments, singing, dancing), man-machine skills (driving, flying, etc.), and sports (swimming, diving, gymnastics, etc.)

A skill consists of automatic processes specific to the involved procedures, knowledge about how and when to use the procedures, as well as verbal knowledge about the procedures (Logan, 1985). Automaticity refers to the performance part of a skill. "Tasks that can be performed quickly, effortlessly, and relatively autonomously are thought to be automatic. Tasks that cannot be are thought not to be automatic" (Logan, 1985, p.368). Another very important characteristic of automatic tasks is that they can be performed simultaneously with other non-automatic tasks, and they can be made to serve higher functions (Bloom, 1986). Because of this characteristic, for example, a typist can compose on a typewriter or computer without thinking about the individual, automatic keystrokes and can focus thought on the meaning of the words being typed. Superior performance is made possible because the simpler components of the task are done automatically, freeing the performer to focus on the much slower, but much "smarter," higher-levels of non-automatic thought (Bloom, 1986; Logan, 1985, 1988, 1990; Rossman, 1987; Stanovich, 1990).

Automaticity is developed, very simply, by practice. When there is a consistent mapping (CM) of stimuli onto responses (that is, when a stimulus always demands the same response), automaticity develops. When there is a varied mapping (VM) of stimulus onto response (that is, when a single stimulus demands different responses on different occasions), automaticity does not develop (Logan, 1990). This necessity of consistent mapping is why much repetitive practice is necessary, for example, for the highly-skilled delivery of performances as different as the fluent reading of a page of text, the demonstration of a martial arts routine, and the playing of a piece of music on the piano.

Theories of Automaticity

The most recent theories of automaticity fall into two categories: the limited-resource or modal theories and the memory-based theories. The limited-resource theories delineate two modes of information processing: controlled and automatic. Controlled processing is used in novel (VM) situations, is controlled by the subject, requires attention, and is capacity limited in the way that the working memory in a computer is limited (Cheng, 1985; Gagne, 1982; Strayer & Kramer, 1990). Automatic processing is used in repetitive (CM) situations. It is fast, not constrained by capacity limits, and thought not to be under the direct control of the subject once initiated (Cheng, 1985; Strayer & Kramer, 1990). In the limited-resource theories,

> . . . automatic processing does not demand (much) attention. It is fast because it is not subject to limitations on attentional capacity. It is effortless because it demands little (or no) attention, and effort increases with demand for attention (Logan, 1990, p.1-2). [Parentheses in quote are author's]

In this model automaticity is simply the result of faster processing of information. The calculation of 2 X 10, for example, is made automatic by the muchspeeded-up adding of ten two's, rather than by any qualitative change in information processing (Cheng, 1985). In the limited resource theories automatic performance is seen as possible because of the gradual withdrawal of attention (Cheng, 1985; Logan, 1985).

There is also a variation on this theory, which proposes that automatic performance is the result of using <u>different</u> resources rather than the reduction of demands on the single resource of attention. Problems with this multiple-resource theory arise because no one has described the different resources automatic performance would use. The multiple-resource theory would seemingly also necessitate the existence of an executive function, which has not been identified (Logan, 1985).

In both the limited-resource and multiple-resource theories, a lack of control of automatic functions is predicted. Studies have shown, however, that this lack of control does not result (Cheng, 1985). This and other problems with the limited-resource theories have led to the recent development of memory-based theories of automaticity.

The memory-based theories of automaticity distinguish between algorithmic processing of information and memory retrieval. Algorithmic processing is what is commonly known as conscious thinking. It is used in VM situations. Memory retrieval is used in CM situations. Whereas the limited-resource theories assume that the same algorithm is used with less attention, in the memory-based theories the speed up in performance is thought to be because the memory retrieval is faster than the algorithmic processing (Cheng, 1985; Logan, 1990; MacLeod, 1991; Stanovich, 1990; Strayer & Kramer, 1990). Memory-based theories maintain, for example, that the speed and effortlessness of automatically multiplying 2 X 10 results from the qualitatively different act of recalling the fact from memory rather than from adding ten two's very quickly and without attention (Cheng, 1985).

Memory-based theories of automaticity rest on three main assumptions. The first is called obligatory encoding: anything we attend to is necessarily encoded into memory. The second is obligatory retrieval: anything we attend to necessarily recalls memory associations from similar past experiences. The third is instance representation: each instance of a similar stimulus is stored separately (Logan, 1988, 1990). It should be noted here that the memory used in automatic performance is implicit memory rather than explicit memory. Explicit memory is what we usually think of as memory, and it is used for recall and recognition tasks. Implicit memory is formed automatically, as mentioned above, and the memory search during automatic performance is not represented on the level of working memory or conscious thought (Logan, 1990; Stanovich, 1990).

> Memory-based theories of automaticity predict that performance in a memory search task that is automatic will not require a representation of the memory set in working memory (Strayer & Kramer, 1990, p. 291).

A skilled typist, for example, does not consciously think at all about where the various letters are located on the keyboard, but finds them by means of an implicit memory search.

This encoding of information into implicit memory is also called information encapsulation, and it is very important in that it allows for the quick and accurate access to the internal representation of the world, and that it facilitates automatic and consistent responses to frequently occurring situations (Stanovich, 1990). These encoding and retrieval processes may be similar to Piaget's notions of accommodation (building internal representations of the world) and assimilation (classifying an experience as being a member of an already-internalized category ["schematum"]). Indeed, the enormous amount of interaction of the senses and environment during the sensorimotor stage of cognitive development may be for the main purpose of automatizing basic perceptual and motor skills. This automatizing would occur as a result of the establishment of internal representations of the world and their corresponding implicit memory retrieval mechanisms.

According to memory-based theory, each time a stimulus is presented, a kind of race occurs between the retrieval of the memory trace and the algorithmic processing. The novice uses algorithms because there are no memory traces for the stimulus or because the memory retrieval is at first slower, but as experience with a stimulus increases, the memory retrieval becomes much faster. Eventually the algorithmic processing is abandoned altogether, and automatic functioning results (Logan, 1988, 1990; Strayer & Kramer 1990).

> Performance becomes more automatic as the direct memory access plays a greater role. At the lower bound of the continuum, performance is completely dependent on the algorithm. The upper bound of the continuum is determined by the fastest direct memory access (Strayer & Kramer, 1990, p. 303).

Memory-based theory has shown that the speed-up in performance can be predicted with the equation $RT = A + B(X)^{-c}$ where "A" represents asymptotic performance, "B" is amount to be learned, "c" is the rate of learning, and "X" is the amount of practice (Logan, 1988, 1990; Strayer & Kramer, 1990).

The Practical Use of Automaticity Concepts

Theorists often disagree on appropriate instructional sequences for the development of skilled performance in the areas of reading and mathematics. In the area of reading, there is conflict between those who believe that instruction should first focus on the development of automatic word decoding skills (phonics) and those who advocate first focus on the primary use of non-automatic thinking about the meaning of the reading (whole language).

> The idea the background knowledge should saturate central processes of text inferencing, comprehension monitoring, and global interpretation is now widely accepted, while at the same time the advantage of modularly organized input processes is acknowledged (Stanovich, 1990, p. 87).

I found no information on the impact of phonics instruction on automatic reading, but I did find two researchers who maintained that the best predictor for automatic reading and reading achievement was the average number of minutes of reading done per day. At least 85% of students in grades two to eight who read more than 3.5 hours per week achieved automatic reading, nearly all who read less than 3.5 hours per week did not (Bloom, 1986; Rossman, 1987).

In the area of mathematics instruction, there is a similar disagreement about whether instruction should first focus on automatic calculation skills or on the non-automatic concepts of mathematics. Gagne (1982) asserts that math skills should be taught before math concepts because automaticity of skills frees the mind to think on the higher, conceptual levels. He also advocates the use of computer drills to achieve automatic calculation skills. Wachsmuth (1983) writes that concepts should be taught first, and then the skills taught during the solving of problems. Automatic performance, she believes, results from practice at solving problems that demand both conceptual knowledge and calculation.

I believe there is no single "correct" method for teaching or learning the skilled performance of reading or mathematics — or anything else, for that matter. As explained in Howard Gardner's Theory of Multiple Intelligences (1983) and Robert Sternberg's Theory of the Triarchic Mind (1988), different people learn very differently from one another. Some learners learn best when approaching a subject first from the non-automatic, conceptual angle. Others may learn best when approaching a subject using a skills-first strategy, or using a kind of oscillation between a skills approach and a conceptual approach. Still others may learn best by employing their strongest kind of intelligence, whether it is musical, spatial, or kinesthetic — even if the skill being learned happens to be mathematical or language-based.

In terms of Piaget's stages of cognitive development, different approaches also may be more useful for teaching specific learner age groups. It may prove to be effective for some students, for example, to focus on the automatizing of word recognition and math facts during the preoperational stage, begin some conceptual work during the concrete operational stage, and move to purely conceptual work only after they are firmly established in the formal operational stage. This approach, however, may prove to be entirely ineffective for global learners who do best whenever they can conceptualize a subject or task before focusing on the details of fact and process involved.

Because individual learners differ so widely in their styles of learning, I believe that advocating a single strategy for the teaching or learning of any particular skill is inappropriate. Skilled performance, however, is clearly the result of the coordinated functioning of non-automatic thinking and supporting automatic processes. Knowledge of the above-mentioned components of skilled performance and of the general trends of human cognitive development can be extremely useful when one is devising a teaching or learning strategy appropriate for a given individual learner.

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