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"The Hands and Feet of Genius"

Automaticity

Photograph of Mario Bernardi, courtesy of the Washington Performing Arts Society

The mastery of any skill—whether a routine daily task or a highly refined talent—depends on the ability to perform it unconsciously with speed and accuracy while consciously carrying on other brain functions.

For the better part of five years, my staff and I studied the process of talent development in outstanding individuals in six fields. These individuals included concert pianists, sculptors, tennis stars, Olympic swimmers, research mathematicians, and research neurologists.[1] In each field we attempted to select the top 25 individuals in the U.S. under the age of 35. Each one was, roughly speaking, the most accomplished individual in

early to learn skills and subject matter that later on turned out to be relevant to their chosen field.

The talented individuals we interviewed talked about the great amount of practice and training time they devoted to their work. By adolescence, his or her particular talent field, out of more than a half million others who also began to study in that field.

No individual in this study reached this high level of attainment in less than a dozen years, and it took the average person about 16 years. In most fields, the typical individual began learning at a very early age. This was especially true in music and sports. In the cognitive fields and in sculpture the individuals began very

Photograph of Mary Lou Retton, courtesy of the United States Gymnastics Federation

Photograph of Marcel Marceau, courtesy of the Washington Performing Arts Society

most were spending about 25 hours a week on practice and learning in the talent field. And there were many years thereafter when they practiced as much as 50 hours each week. They also described how they "overlearned" particular aspects of their repertoire of skills. In preparation for a public event, for example, pianists might practice a particular set of pieces of music for six months or more before they and their teachers were satisfied. The tennis players practiced particular subskills and parts of the game endlessly. Even when they reached the peak of their game, they still practiced those skills almost daily.

Why does talent development require so much learning time? And why is an early start in particular fields so necessary?

We believe much of this time and overlearning is necessary to develop *automaticity* in the many subskills required to reach top-level performance in a talent field. Even when individuals reach this high level, they frequently must practice a great deal to maintain a high level of automaticity. Our talent development studies support the 1899 research of Bryan and Harter who were concerned with the development of automaticity in expert Morse Code telegraphers. They most eloquently described the benefits of automaticity as an outcome of the learning process.

Photograph of Peter Serkin by Dorothea V. Haeften, courtesy of Washington Performing Arts Society

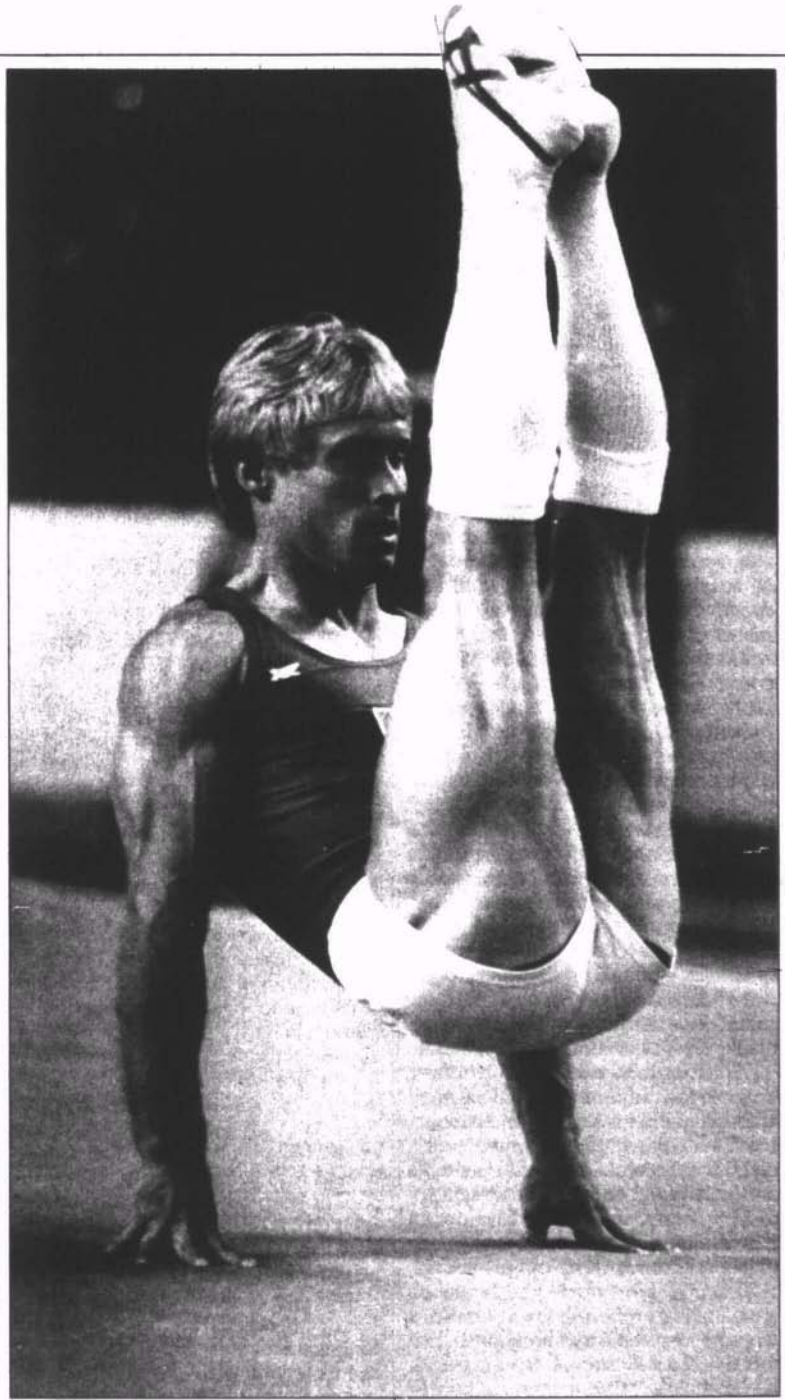
The learner must come to do with one stroke of attention what now requires half a dozen, and presently in one still more inclusive stroke, what now requires thirty-six. He must systematize the work to be done and must acquire a system of automatic habits corresponding to the system of tasks. When he has done this he is master of the situation in his [occupational or professional] field. . . .Finally, his whole array of habits is swiftly obedient to serve in the solution of new problems. Automatism is not genius, but it is the hands and feet of genius.[2]

Some Illustrations of Automaticity

Perhaps the simplest illustration of automaticity is the *walking* of an adult. Unless they are having some special difficulty, most adults give almost no conscious thought to the process of walking other than some notion of a destination and occasional monitoring—to check the traffic before crossing the street, to note some change in the surface of the road or path, or to realize they are becoming overly tired. While walking, adults may think of many things, but only rarely will they consciously think of the process of walking. Walking has become an automatic process. We can more fully appreciate this process by contrasting the automaticity of an adult's walking with the efforts of a young child just learning to walk, or by contrasting our normal walking with that of someone learning to walk again after recovering from leg injuries.

There are two points to this illustration of automaticity. The first is that over time we have developed our walking (or running, jumping, stair climbing, etc.) to a point where it works well *without conscious attention*. The second point is that we can walk while consciously thinking about something else; that is, we are able to do *two very different processes* at the same time.[3] And, in fact, if we consciously concentrate on the process of walking, it will not be as regular and as efficient as when it is automatic.[4]

A second illustration of automaticity is *reading*. Suppose, while reading this article, you were to spend a few minutes timing how long it takes to read the first letter on each line of



Photograph of Bart Conner by Dave Black, courtesy of the United States Gymnastics Federation

several pages. You would find that you can read about 80 *letters* a minute. Similarly, if you were to read only the last word of each line of several pages, you would find that you also read about 80 *words* a minute. But if you were to read two or three entire pages of this article, you would discover that you read about 300 words per minute.

How does one go from reading 80 letters a minute to 80 words (400 letters) per minute to 300 words (1,500 letters) per minute?

The great speed of word reading, versus letter reading, is possible because most of the words read are now *sight words* for the adult who can process them without paying attention to the individual letters. The even greater speed of reading connected discourse is because the adult is now reading phrases, sentences, and ideas rather than letters or individual words.[5] While we are in the process of reading connected discourse, we may also be making judgments about the ideas, enjoying the story, getting new ideas and insights, or being involved in other conscious processes. The point is that the reading process has become *automatic* for capable adult readers, and much of our conscious attention is now on the ideas, insights, plot, and characters rather than on the mechanics of the reading process.[6] Again, as adults we may contrast our reading with that of a child in the 1st or 2nd grade of school to see how reading has changed from a slow and difficult process to a rapid and highly automatic one. Or, we may contrast our reading in the mother tongue with reading in a foreign language studied for less than a year.

A third illustration of automaticity is *typewriting*. Suppose you are a capable touch-typist; you probably type about 50 or 60 words per minute (that is, about 250 to 300 individual letters per minute). If you can only type with one or two fingers by the hunt-and-peck method, you probably type only about 10 to 15 words (50 to 75 letters) per minute. However, in this hunt-and-peck method much of your conscious attention is on the letters and how to find them quickly. In contrast, the capable touch-typist doing 50 to 60 words per minute hasn't the faintest notion of what each finger is doing at any time. When you use the typewriter to compose a letter or manuscript, you are thinking about the ideas you want to get on paper, and your speed of typing is controlled more by the speed of your thoughts than by your typing skill. What is more, your fingers are not only automatically hitting the right keys, they are also spelling the words automatically. If you were to try to concentrate on what each finger is doing, the entire typing process would collapse. Conscious attention to what the fingers are doing impedes the automatic typing process.

Photograph of Dance Theatre of Harlem by Macbeth, courtesy of Washington Performing Arts Society

The Functions of Automaticity

Once a skill has been developed to a high level of automaticity, it requires frequent use but very little special practice to maintain at that level. If it has been developed to an automatic level, the process can be used with great *economy of effort*. That is, it is a very efficient process that involves a minimum of wasted motion or effort. For example, my *walking* without conscious thought about the process involves a minimum of effort and for my body build is likely to be very efficient. My touch-typewriting after reaching the automaticity level involves a very economical use of my fingers and hands and requires a minimum of effort. I can type for long periods of time at a relatively high rate of speed without tiring. Similarly, my automatic reading is at a high speed with very little effort and with a minimum of errors. If the book or the article is highly interesting, I can continue at this high rate of reading (300 words per minute) with good comprehension and enjoyment for several hours.

While individuals are likely to vary in the efficiency of their automatic processes, it is likely that each individual uses these processes with a minimum of effort. If one compares the efficiency of a process when it is done with conscious attention versus when it is done automatically, there is little doubt that the economy of effort is far greater when done automatically.

Some processes, especially in sports and cognitive fields, are done so *rapidly* under automatic control that the same individual could not even come close to this rate under conscious control. The Olympic diver doing a series of a dozen or more subtasks automatically in three or four seconds could not possibly do them at this speed under conscious control. The interplay between the different strokes in tennis, handball, and fencing; the speed of different actions in basketball, football, and baseball; the speed of reading and typewriting; and the speed of fingering musical instruments is so great that few individuals could attain such speed if they had to consciously control each action. Especially in races, games, and contests, individuals must develop automaticity to a high level in order to accomplish a particular series of actions rapidly enough to match an opponent.

A third function of automaticity is to increase *accuracy* in carrying out a particular process. Again, automaticity in reading, speech, driving, piano playing, skating, or dancing is far more precise and accurate than the same processes would be if they were done with full conscious control. Furthermore, once automaticity reaches a particular level of accuracy and precision, it can be maintained at that level over long periods of time with only a small amount of practice from time to time. In 1908 William Book demonstrated that once the individual had reached a particular level of speed and accuracy in typewriting, he was able to maintain it with only a slight loss over more than a year in which he did no typing.[7]

Thus, we have noted the functions and qualities inherent in the various types of automaticity.[8] But there is a fourth characteristic of most types of automaticity: *other conscious brain functions may occur simultaneously with the automatic functions*. This is most clear in an activity like walking, during which the individual may be thinking great thoughts, listening attentively to music, giving a lecture, planning some new enterprise, solving a scientific or mathematical problem, observing nature, or countless other things. The walking does not appear to interfere with various conscious thoughts. In some cases, individuals find they are most creative while walking. For "walking" one might substitute running, riding a bicycle, driving a car, typewriting, skiing, swimming, eating, dressing, washing, or almost any other process that has become highly automated. Some researchers believe that the clearest index of automaticity is that other conscious cognitive processes may take place simultaneously with the automatic processes.[9]

While *separate* automatic processes and conscious processes do occur simultaneously, this in and of itself is not of great interest. What is amazing is the evidence that automatic functions can simultaneously *serve* higher functions. The automatic typing functions may serve simultaneously to record the author's story, ideas, or thoughts. For the concert pianist, the automatic playing of the correct notes may occur as the pianist is thinking about the qualities, style, or effect she is trying to create with the music during a concert. The athlete may be involved in various automatic processes in the interaction with an opponent while thinking and executing various strategies to counter the opponent's plays. Similarly, the actress who has already automated her lines until they are letter-perfect may simultaneously assume the role she is playing with a high level of intensity. So, too, the reader of a new book may automatically read it as he critiques it, analyzes it, applies the ideas, relates the parts to each other, *or* relates the reading matter to another set of ideas or works in his mind.

The use of automatic processes to serve individuals as they rise to the highest functions in a talent field seems to this writer to be one of the miracles of our learning and brain functions. These functions enable humans to transcend daily existence and to rise to creative heights in one or more of the talent and occupational fields.

Theories, Speculations, and Evidence on How Automaticity Is Developed

Basically, there does seem to be some

consensus about how automaticity is learned or developed.[10] The *first learning* in a field typically emphasizes very basic isolated details that are learned to a high level. The *second type of learning* (which may overlap with the first learning) emphasizes larger units composed of the isolated details already learned. The *third type of learning* emphasizes series of units and processes built out of the previous units in the second type of learning. The movement from the first to the second type of learning typically requires the individual to have thoroughly mastered the first type of learning. The movement to the third type of learning requires the individual to have already reached a mastery or *threshold level* on the second type of learning.[11] (This threshold may vary greatly from field to field, but the notion is that the individual is comfortable enough with the second level of learning to use these processes *voluntarily* when the occasion arises.)

In the case of *typewriting by the touch method*, the first type of learning is devoted to learning the fingering of the keys until the individual can do this with a minimum of time and thought. The second type of learning is devoted to typing words and phrases separately as well as in context. Here there is an emphasis on the most frequently used words as well as sets of words that require the use of all the keys with some frequency. The third type of learning emphasizes speed and accuracy in copying consecutive verbal material or in some cases typing one's own thoughts and ideas as they come to mind. With further experience, frequent use of the typewriter, and need for accuracy and speed, automaticity develops to a high level.[12] This is especially true for the processes (copying vs. composing) emphasized by the typist.

In the case of *reading*, the basic processes may be very similar to those in typewriting. The first type of learning emphasizes letters and phonemes. The second type of learning emphasizes frequently used words and phrases, while the third type of learning emphasizes greater speed and accuracy in reading connected discourse at the child's appropriate level of difficulty and interest.

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Some methods of teaching reading with automaticity emphasize *sight words* and their use in connected discourse. Other methods emphasize the *experience approach* in which children *dictate* brief stories and incidents based on their own experiences. These are typed out by the teacher and then "read" by the child. The children become very skillful in "reading" their own stories. It is clear that in the early years, the children's use of oral language is very much ahead of their reading—so that any method that makes good use of this disparity is likely to be effective. However, a high level of automaticity in reading requires that children at some critical early point in the process do a great deal of reading *on their own* ideally for their own interest and enjoyment.[13]

The development of automaticity in *motor skills* requires the isolation and practice of particular skills and subskills.[14] In tennis, these would involve serving, forehand, backhand, accurate placement of the ball, and game strategies. In diving, these would include the separate parts of a complex dive learned in the order in which they are to be done. That is, each new part would be added to the previous parts. In juggling, the individual learns to juggle two balls, then three balls, then four balls and more, reaching a high level of mastery on one phase before moving to the next phase.

In addition to the learning of each part of a subskill to a high level of mastery before moving to the next phase, the learner, especially in sports, must also make use of these subskills in competitive situations so that the mastered subskills are used as they are relevant in the complex sport situation. In a sport like tennis, it is important that players make use of their subskills in playing with competitors who are at least their equal or somewhat better.

What Can Be Automated

Table 1 lists some of the skills that can be learned to an automatic level. The particular *bodily control* processes we have listed are done almost daily by each individual. Most individuals have reached some level of automaticity on most of these processes by the time they enter school. They frequently do them while thinking about something else or at least with a minimum of thought about the process while they are doing it.

Household skills are also done frequently, and the family members who accept responsibility for them learn to do them with economy of effort. Frequently, these skills and chores become highly routinized, and they can be done while the worker is consciously thinking about other things.

Communication skills, once learned, are used frequently until they are done with great automaticity. In conversations, we rarely think of each word as we say it; we apparently have a set of intentions or responses, and the words "come to us" as we say them. This appears to be much the same when we write a letter or the first draft of a paper. When watching people who are skilled in sign language, we are likely to be fascinated by the great speed of the process and the animation of the individuals in the sign language conversation.

Man-instrument skills also become highly automated when used frequently. After they are overlearned, they are used with a minimum of attention to the process involved. (We have listed singing and dancing under this category even though the voice and body do not quite fit the notion of physical instruments).

Man-machine skills are much the same as the man-instrument skills in that humans adapt to the different types of equipment, and when they use them frequently enough they develop a high level of automaticity. A possible danger in automaticity with

machines is the chance of serious accidents unless the operator maintains sufficient vigilence.

Our list of *sports* includes those that primarily involve the use of the body with little or no equipment as well as those that involve equipment. Virtually all sports require a great deal of training and conditioning to reach high levels of performance. Automaticity is essential because of the great speed and accuracy needed in virtually all competitive sports.

Not listed are the many cognitive skills used in mathematics, science, engineering, and various technical and professional fields. Although many of these skills are highly automated by frequent users of them, these areas have not been as well explored as the more obvious ones listed in Table 1. Most of the processes and skills listed here can be observed readily; few of the cognitive skills can be observed while they take place.

Neurology

We can find no clear picture of what takes place in the central nervous system when a process changes from a highly conscious process to an automatic one. Some neurologists view automaticity as being similar to conditioned responses although somewhat more complex and continuing for greater time periods.[15] Some writers (especially sports coaches) sometimes refer to automaticity as *muscle memory*, as though the memory traces had moved from the central nervous system to the particular muscles involved.[16] Still other researchers have found evidence that the location of the memory is still in the central nervous system.[17]

We are inclined to agree with this last view. It is hard to imagine all the possible locations for the different automated processes if they become separated from the sites of the relevant conscious processes that preceded them during the learning. Perhaps as more is learned about the development and maintenance of automaticity, we will also learn more about the neurological processes involved. In any case, it is likely that we will learn much more about the development and uses of automaticity long before we understand the way in which the brain operates with these processes.

The Role of the School in the Development of Automaticity

The school, especially at the elementary level, has some responsibility for developing automaticity in the basic skills and processes that students need for more complex learning at later levels. It is clear that the home, especially from age two to about five, has the major responsibility for teaching the child *to speak and understand the mother tongue* (typically, the child has developed a vocabulary of about 5,000 words before entering 1st grade). Where the home is woefully delinquent in this, the *school* or the *school and the home* have some responsibility to do something about this deficiency in order to ensure that the rest of the child's required schooling will not be disastrous. Because oral language is used so frequently, most children develop some automaticity in language use (correct or not) by the age of school entrance. The development of early childhood programs, including Head Start, was primarily intended to help children in special need during the years of three to five. Some of these programs have been very effective in meeting these language needs—especially when both the child and the parents were involved.[18]

Given the schools as they are now with group instruction, textbooks, and most instructing through the use of oral and written language, reading must be the central responsibility of schools during the elementary years. However reading is taught in the schools, there should be a great emphasis on "voluntary" reading for pleasure and for the students' own purposes. Reading to mastery and automaticity cannot be developed if children read only for classroom purposes. The *habit of reading* for several years is necessary for automaticity to develop.

Writing for personal use is also one of the skills children should develop in the elementary school years. Children should be able to communicate with others through writing, and the basic writing skills should become highly automated during these years. While handwriting may be improved,

Table 1. Some Possible Automated Processes

Bodily control	Household skills	Communication skills	Man-instrument	Man-machine	Sports
eating	sewing	speaking	musical-instruments	driving	swimming
walking	knitting	reading	singing (trained)	flying	diving
running	ironing	writing	dancing (trained)	motor-boating	running
jumping	mopping	Braille	drawing	motor-cycling	jumping
catching	sweeping	deaf sign-language	painting		gymnastics
throwing	use of	computer-languages	sculpturing		
stair	spoon	shorthand	juggling		tennis
climbing	fork				handball
descending	knife		typing		
dressing	hammering		adding-machine		skating
washing	sawing		Morse code-telegraphy		cycling
	raking				skateboard
					wind-surfing
					skiing
					sailboating

it is even more important for children to learn how to put their thoughts and ideas into written form. Ideally, the initial writing should be little more than the equivalent of a one-way oral conversation with someone who lives some distance away and doesn't have a telephone.

The basic arithmetic processes should also be developed to a high level during the early years of school. These processes and skills will only become automated if they are frequently used outside of the classroom. It is the type of thinking emphasized in arithmetic that needs to be stressed rather than the so-called facts in this subject.

Other skills such as safety rules and skills; some of the basic motor skills of movement, use of hand and eye coordination; and some game skills may also be emphasized in these early years. If these skills are used frequently outside of school they will become highly automated.

Ideally, an introduction to poetry, music, art, sports, science, and a second languge should begin at the elementary school level. (Some of these may begin in the schools while other ones may be provided by other agencies.) It is the basic idiom of these fields and some of the basic skills that should be emphasized, learned in an enjoyable way, and at least partly automatized.

In the past, schools were delighted when they could bring a third or more of their students to the level of mastery. In the future, it is likely that the schools will give more attention to the development of automaticity in particular processes and skills that are prerequisites for later learning. It is likely that some of these processes and skills are learned well in the school and that the individual students use them frequently enough that the skills become automatized. It is also likely that when some of these processes and skills are not learned well enough for the student to use them voluntarily, they do not become automatized. Schools should make an inventory of the skills and processes that do become automatized for the majority of students. The school personnel should also give thought to other processes and skills that need to become automatized—if further learning is to be effective.□

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