RESEARCH

DIFFERENCES IN STUDENT PERFORMANCE

PREDICTING APTITUDE

ENHANCING LEARNING CW
WITH RHYTHM

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INTRODUCTION:

The instructor supplement is the repository of our ongoing research into differences in student performance, predicting aptitude, and the connection between rhythm and memory. We are deeply interested in how incorporating musical rhythm with code may facilitate the perception of characters as a rhythmic sound and positively influence learning code. As with many complex subjects, there are differing views and conflicting data. This is a work in progress.

DIFFERENCES IN STUDENT PERFORMANCE:

<u>The determinant factors responsible for the differences in student performance are aptitude, the distribution and quality of practice, and the degree of motivation.</u>

Learning CW is often described as a journey. For some students, the journey is relatively quick and pleasant. For others, the journey can be long and arduous. A great deal of study has gone into understanding and predicting the differences. The determinant factors responsible for the differences in student performance are aptitude, the distribution and quality of practice, and the degree of motivation.

The same could be said of other pursuits from academics to athletics, but rarely does aptitude play such a dominant role. According to Taylor,[1] individuals vary greatly in their ability to learn the code. Many do not possess the necessary aptitude. Of the men entering schools of radiotelegraphy from 3Ø to 6Ø percent fail to become proficient operators.

In 1968, the US Army[2] reported a broad range in student performance. On average, it took 55 hours of study to achieve proficiency at 12 WPM. Fast learners achieved proficiency in 18 hours and slow learners took up to 11Ø hours.

[1] Taylor, D. W. (1943). Learning Telegraphic Code. Psychological Bulletin, 4Ø(7), 461-487.
[2] Department of the Army (1968). Technical Manual No. 11-459.

PREDICTING APTITUDE:

<u>The most accurate predictor of aptitude and student performance is the speed with which a student learns their initial 4 to 5 characters.</u>

The 1919 Thurstone[3] report is the first known study of the diagnostic value of mental tests for predicting ability to learn telegraphy. The 165 men tested had been drafted into the Army from varied backgrounds including mechanical and electrical trades, building and steel trades, engineers, chemists, salesmen, and bookkeepers. The range in age was 21 to 31. Thurstone concluded there was no occupational differentiation in the ability to learn telegraphy and age has no diagnostic value in predicting ability in telegraphy within the age limits of 21 and 31.

The level of education was equally varied ranging from high school dropouts to college graduates. Thurstone concluded ability in telegraphy cannot be predicted on the basis of general schooling: "*The fact that years of schooling does not agree with ability to learn telegraphy indicates that this is a special ability."*

Mental tests were given in rhythm, opposites, analogies, Gordon directions, Trabue completion, spelling, arithmetic, and sentence. The rhythm and opposites tests had the highest correlation to ability in telegraphy, but based on the scores, Thurstone concluded: *"The general intelligence tests are not as valuable for diagnosing ability to learn telegraphy as for measuring general intelligence. Ability in telegraphy is probably a special ability."*

In his 1928 article, Lipmann[4] suggested the progress of students over a period of months could be predicted on the basis of the speed with which they initially learned a particular number of characters. To 71 subjects he gave a certain amount of practice in learning five characters. According to Lipmann, the exam consisted of giving the examinee a changing and obscure sequence under experimental circumstances.

[3] Thurstone, L. L. (1919). The learning curve equation. Psychological Monographs, 26(3), i–51.
[4] Lipmann, *op. cit.*

In his 1932 report, Koch[5] provided similar findings: "*We were able to determine that those persons who did not learn the recording of 4 characters at a speed of 12 WPM in the first 2 half hours, despite all efforts they were even grouped in a small special course to meet all their difficulties, could never be brought to a mastery of the auditory recording. So we came to the conclusion that we can consider the first 2 half hours of the learning (learning of 4-5 characters) at a speed of 12 WPM as a proficiency test.*"

In 1942, the U.S. Armed Forces[6] implemented the Signal Corps Code Aptitude tests. It was comprised of 78 pairs of patterns of dots and dashes sent at 2Ø WPM. The task of the student was simply to record whether each pair were different or the same.

In his 1943 thesis, Taylor[7] administered the Signal Corps Code Aptitude tests to 59 men and the results indicated the test was unreliable and inadequate for use in personnel selection.

Taylor devised an Initial Learning Test to validate Lipmann and Koch's hypothesis that a valid estimate of a man's ability to learn to receive may be made on the basis of the speed with which he learns the first few characters of the code. The test was designed to provide one measure of the speed with which students learn under controlled conditions eight characters: F, C, 2, 9, period, comma, question mark, and fraction bar. Those particular eight characters were selected only because they are among those usually unknown to beginning students.

Taylor also conducted 11 auditory tests. Those showing the highest correlation with achievement in code were the Seashore tests.

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[5] Koch, *op. cit.*

[6] *U.S. Armed Forces Institute Basic Radio Code*. (n.d.). INTERNET ARCHIVE. Retrieved July 5, 2Ø22, from https://archive.org/details/U.S._Armed_Forces_Institute_Basic_Radio_Code_ca1942

[7] Taylor, D. W. (1943). Learning Telegraphic Code. Psychological Bulletin, 4Ø(7), 461-487.

The Seashore Measurements of Musical Talents[8] initially published in 1919, was comprised of six measurements:

(1) Sense of pitch; Pairs of notes differing in frequency; is the second is higher or lower than the first?
(2) Sense of Loudness of Strength; Pairs of notes differing in intensity; is the second stronger or weaker than the first?
(3) Sense of Rhythm; Pairs of rhythmic patterns; are they the same or different?
(4) Sense of Time: Pairs of notes differing in duration; is the second longer or shorter than the first?
(5) Timbre: Pairs of notes. each of which is made up of the fundamental and first five harmonics, the intensities of the third and fourth harmonics being varied; are the two notes the same or different?
(6) Tonal Memory: Pairs of note sequences. Ten item search of three, four, and five notes; which note is different?

The subjects were 21 professional musicians (11 men and 1Ø women) all members of an acclaimed symphony orchestra. Their scores were compared to a normal population derived from high school and college students whose ages ranged from 11 to 24 years.

The results show the professional musicians were better than the estimate of the normal population in only three tests: pitch discrimination, rhythm, and tonal memory. Those attributes may have the highest correlation to performance in learning code.

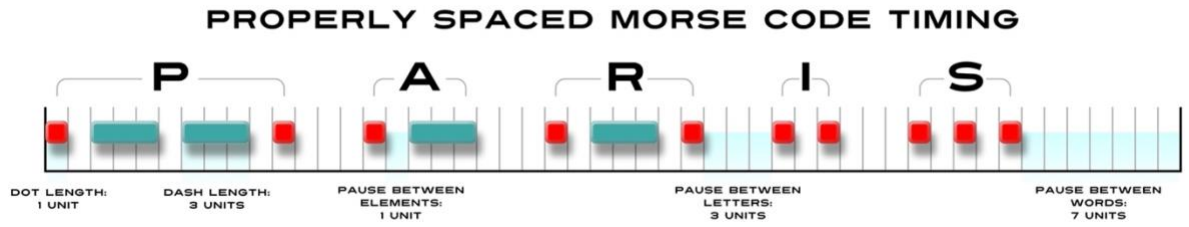
Among all the tests given by Taylor, the Initial Learning Test was found to yield the best prediction of eventual achievement in code: "*It is high both in reliability and in validity and is the best test yet developed for use in the selection of men for training in code. Its use in personnel selection may be expected to reduce greatly the proportion of failures among men in training*."

[8] C. E, Seashore, Manual for Measures of Musical Talent. 1919.

THE SYMMETRY AND HARMONICS OF MORSE CODE:

The ARRL has adopted the following standard for all training material, code tests, and W1AW Morse transmissions:

- A single dot is one unit.
- A dash is a period of three units.
- One unit separates each element (dot or dash) within a character.
- Three units separates each character within a word.
- Seven units separates each word.



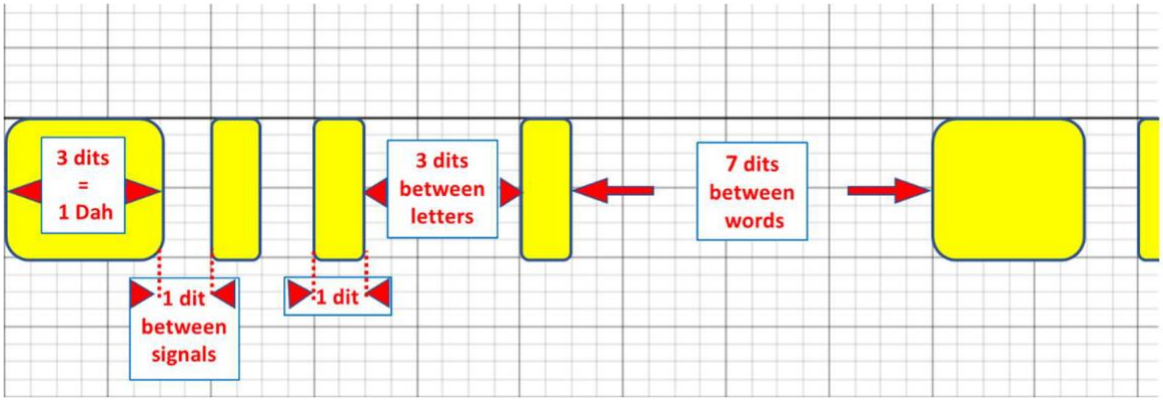
This graphic designed by Michael Maynard[9] K4ICY depicts properly spaced Morse code timing.

A STANDARD FOR MORSE CODE SPEED:
For purposes of determining code speed, the “PARIS” 5Ø-unit standards is used. The word PARIS contains 5Ø units comprised of dots, dashes, intra character, inter character, and word spaces. Code speed in Words Per Minute (WPM) is derived by counting the number of times “PARIS” is sent in one minute. At 12 WPM, the target speed of this curriculum, PARIS would be sent twelve times in one minute.

THE HARMONIC ORIGINS OF MORSE CODE:
In his book, The CW Way of Life, Chris Rutkowski[10] NW6V explores the harmonic origins of Morse code. According to Chris, the original American Morse invented by Samuel Morse and Alfred Vail did not have a 3:1 ratio. It wasn’t until Friedrich Gerke, a linguist and musician, modified American Morse in 1848 to meet the needs of the German language for the German Post Office that a 3:1 ratio was established.

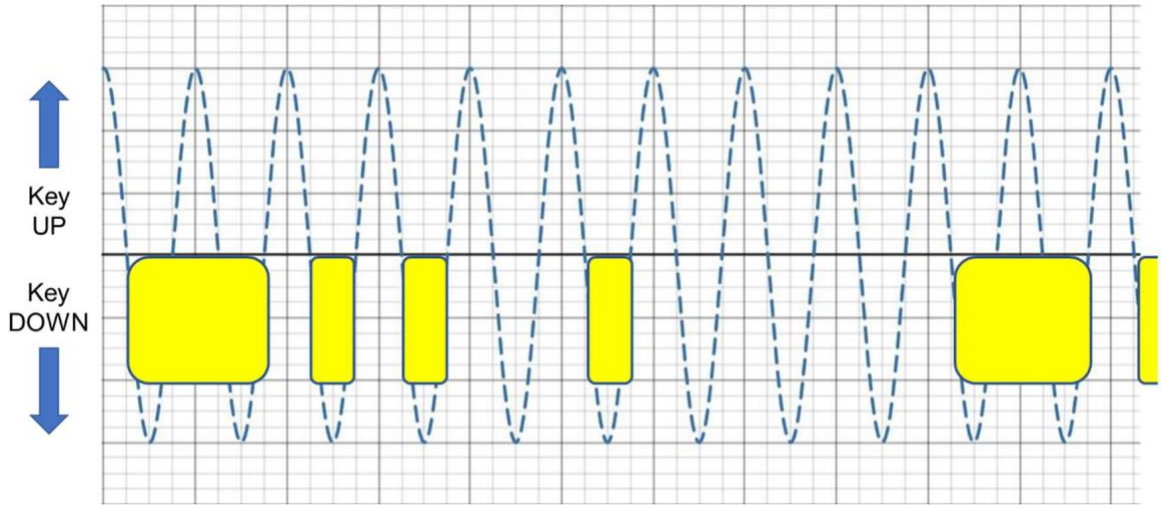
[9] Maynard, M. A., 2Ø22. *Home – K4ICY* - properly spaced Morse code timing. [online] Available at: < http://www.k4icy.com/cw.html > [Accessed 4 August 2Ø22].
[10] Rutkowski, C (2022). The CW Way of Life. Chapter 4, Part 1, Theory

Below we see the 3:1 ratio. A dit is one unit and a dah three units. Also, one unit separates each element within a character, and three units separates each character within a word. It is less obvious why seven units separates each word.



Below, Chris illustrates the logic of seven-unit separation between words. By sliding the origin of the graph a half-dit to the left, so it starts with the hand and key 90 degrees prior to contact one may visualize the nominal motion of the hand maps perfectly to the ON and OFF states of the signal. They always align because they are in-phase. The blue line reflects the inherent rhythm of Morse code.

The region above the centerline signifies KEY CONTACTS OPEN and below centerline signifies KEY CONTACTS CLOSED. This correlates to the motion and state of hand up and hand down.



Chris[11] was the Gold Medalist in straight key sending at the RadioSport competition. We turned to him for an explanation of several important questions:

WHY A STRAIGHT KEY?
The straight key is our key of choice for initial learning of code because of its inherent ON/OFF nature. It perfectly mirrors the ON/OFF pulses of the Morse signals. There is a 1:1 correlation. All other forms of keying require the addition of another skill, another layer of translation, and thus complicate the process.

WHAT IS PERFECT CODE?
Perfect code is perfectly legible. The dividing line between well sent code and poorly sent code is legibility.

WHAT IS A GOOD FIST?
A fist is the Morse equivalent of handwriting. And just as with ABC handwriting, individual variations render the message more-or-less legible.

To have a good fist (i.e., to have good Morse "handwriting") you must:

- Make your dits and dahs sufficiently different to tell them apart.
- Leave enough space between letters to know where they start and stop.
- Leave even more space between the words to know where they start and stop.
- Make them consistently.

ENHANCING LEARNING WITH RHYTHM:

<u>Rhythm plays the key role in learning Morse code as pitch and timbre (as in music and language) are not varied.</u>

Koch[12] reported on the Bucher 1924 report, Work and Rhythm, which found the rhythm which is created by the sequence of the signals in a certain

[11] Rutkowski, C (2022). The CW Way of Life. Chapter 4, Part 1, Theory
[12] Koch, *op. cit.*

tempo can also have a favorable influence on the performance, if the learning conditions make these effects favorable.

In her 2Ø15 thesis, Mohapp[13] explored the transferable attributes of rhythm perception in music as a teaching and learning mechanism for Morse code. Mohapp's review of wartime techniques used by the Women's Royal Australian Naval Service to expedite and enhance learning code with the aid of music strongly suggests musical rhythm positively influenced the skill acquisition of Morse code.

For help in better understanding the rhythm of Morse code we turned to acclaimed orchestra conductor Johannes Stosch KI6M. Johannes believes the ear is the best teacher. Like learning a language or learning to play an instrument, repetition, and listing to good code make the difference.

Johannes acknowledges the symmetry and harmonics of Morse code but rejects their importance since pitch remains constant. The dits are not at a higher frequency than the dahs. Rather than pitch, he believes rhythm is key. Not so much the rhythm of individual letters, since they are all different in length and don't line up with a steady beat (metronome). However, words have distinct rhythms - similarly to language - and pop out to him. For example, abbreviations like RST, FER, BK, AS, SK, and callsigns were the first to jump out at him. Rather than music that relies much on pitch, acoustics, and timbre, the rhythmic element, especially for words, are what is most applicable. When learning a new language, we don't get stuck on letters but words and phrases. We model the sound we hear, may retain an accent, but try to replicate as best as we can. Memorization plays a role. In the end, it is practice. In music, we talk about 1Ø,ØØØ hours required to achieve mastery. It is probably the same with confident, high-speed, reliable CW sending and receiving.

Rhythm undoubtedly plays the key role as pitch and timbre (as in music and language) are not varied.

THE DIFFERENCE BETWEEN RHYTHM AND BEAT:
Beat is the unchanging tempo of a piece (like a metronome). It's the beat you would naturally tap your foot to. Rhythm is the pattern in which the

[13] Mohapp, C. (2Ø15). The rhythm of life: the perfect rhythm of morse code.

notes of the piece move. Rhythm is the variable length and accent given to a series of notes in a piece. The length of Morse characters and words is always varied. They do not align with a steady beat. Code is like rhythm, not beat.