# **Color Coding the Computer Keyboard**

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Research revealed that the use of the computer keyboard was dysfunctional across the general user public. All users relied upon visual search of the keyboard despite that practice being opposed to industry standards and recommended modes of use. The author proposed that the keyboard was an essential stimulus to users, and that the incorporation of perceptual aids would advantage users. A user-centered innovation, a color-coding device known as the KeyRight System, was devised to enhance the keyboard in order to make it a more effective stimulus. The criteria forming the theoretical basis of that innovation and its suggested advantages are introduced and elaborated. It is indicated that the device should be adopted as an industry standard.

#### Introduction

Research by the author (Whitcroft, 1995a) confirmed that computers are not used properly or to full potential, supporting the findings of Galitz, (1980); Tullis, (1983); Fisher & Tan, (1989) and Gordon, Casabona & Soechting (1994).

Computers are widely accepted as effective means of problem solving. However, the vast majority of users lack confidence in new applications and tend to become proficient only in repeated and familiar tasks, indicating functional fixedness - the inability to perceive better ways of performing tasks and realizing that objects have functions other than familiar ones (Weisberg & Alba, 1982; Fisher & Tan, 1989; Kaplan & Simon, 1990; Payne, 1991; Langer, 1992; Franzke, 1995).

The author found that computer systems, which include keyboards, are not used properly because of deficient user awareness and instruction. For example, there was widespread ignorance of the ergonomic organization of a computer keyboard's layout; more than ninety-five percent of users surveyed were unaware of the order, or the purpose, of the modern keyboard's *finger-key zoned* configuration.

The author attributes that ignorance, in part, to the reluctance of the computer industry to acknowledge that visual search is imperative to the modern user. The author suggests that the industry convention: 'A typist should not look at the keyboard', is now an outdated convention affected through the need to train high-speed typists. Because of the change in the nature and the culture of the modern computer user, that convention is no longer appropriate as it conditions user psychology and user practices on global and individual levels.

The research confirmed that very few users are aware of the ergonomic finger-key zones necessary for effective use of computers. Without that pre-knowledge, progress is slow

and error-prone for the vast majority of users. In light of that finding, and those of Payne, (1991), it was suggested that user-machine synergy at the keyboard interface is underdeveloped. Continued misuse also contributes to dysfunctional development. For the computer user, that means slow-paced skill acquisition which retards proficiency, speed and accuracy, and user confidence and creativity.

The author devised a means for providing a user-centered aid to encourage correct usage of the keyboard interface - the KeyRight System. This article elaborates the theoretical basis of that innovation.

A study by Crowe, Finn, Grindlay & Whitcroft (1997) supports the effectiveness of the innovation. It examined the effect of one application of a color-coded keyboard: The acquisition of typing skills.

#### **Discussion**

## The Keyboard as a Human-computer Interface

The layout of keys on a modern computer keyboard is based on the "basic" typewriter keyboard configuration. That configuration has been accepted as a standard over many decades and defines the positions of the keys on the keyboard. Generally, the "basic" typewriter keyboard has about fifty keys and does not include numeric, control, option, mode, start-up, cursor arrow and function keys found on the modern "extended" or "101-plus" keyboard. The most common legends applied to the keys for identification purposes are the "QWERTY" and "Dvorak" legends, however there are many optional legends which may be utilized depending upon a user's specific requirements (e.g. Japanese, Arabic, Swedish, Mandarin etc).

The widely accepted method for efficient data input is the "touch-type" technique. Extensive research has shown this technique to be the superior means of using data-entry devices (Cooper, 1983, contains an extensive review of the literature). To "touch-type" is to use the appropriate keying fingers with as minimal visual consultation of the keyboard as possible.

This long-standing convention has enjoyed wide acceptance in the computer industry and is the primary basis for developing the means for teaching the "touch-type" method of use. However, the author's research (Whitcroft, 1995b) has established that in excess of 99.95% of keyboard users do, and must, look at the modern "extended" or "101-plus" keyboard visual consultation has became essential to keyboard users, regardless of an individual's proficiency level. That is because the modern keyboard has a far greater number and variety of keys and a larger, denser display area. Whilst the "basic" keyboard has almost fifty keys and can affect about eighty functions, the modern "extended" keyboard has in excess of onehundred keys and can affect, potentially, thousands of distinct functions.

Traditional methods of teaching the "touchtype" technique limit the proficiency of use of the modern extended keyboard and its potentials because these methods only teach how to "touch-type" within the "basic" keyboard configuration (McClurg & Kercher, 1989) where visual consultation is at a minimum. With the development of modern keyboards and dataentry devices visual search has become essential to proficient use. Visual consultation of both keyboard and display screen also plays a vital role in the formative stages of learning to type (Cooper, 1983; Barrett & Krueger, 1994). The KeyRight System acknowledges that the modern keyboard is a stimulus to users and that visual consultation is essential for developing effective usage.

In the "touch-type" technique the user places

the fingers in the so-called "home" position in which each finger, from left to right, is placed on the home keys reading "ASDFJKL;" on a "QWERTY" legend keyboard or "AOEUHTNS" on a "Dvorak" legend keyboard. Home keys are often identified through tactile guides, such as ridges, being attached to the keys. The thumbs are held over the space bar. Each finger operates only those keys within the column defined by the home position, or in the case of the index fingers, also the adjacent columns containing keys on the home row reading G for the left hand and H for the right hand ("QWERTY" legend). "Finger-key zones" are thereby established, corresponding to the "home" position on the keyboard. The respective hands should use the left and right "halves" of the keyboard.

The benefits of the "touch-type" technique are that it develops proficiency, speed and accuracy through utilizing the most efficient finger-key associations and the most economical kinaesthetic-motor responses. The alternative "hunt and peck" method of typing produces difficult-to-reverse keying habits that delimit speed and proficiency. It is therefore crucial to encourage the right motor responses (muscle memory) in the user at the earliest possible stage.

Various systems have accordingly been developed to attempt to teach users to type correctly (examples: Olson, 1970; Ladner & Williams, 1990; Troudet, 1992, Software Toolworks, 1991). However, those systems require the user to wear finger-guides in the form of upstanding labels worn on the back of the hands; or rings worn on each finger; or gloves; or involve time-consuming, repetitive keying drills which in practice are arbitrarily used. Finger guides and accessories indicate the relevant keys to be operated by each finger but have the disadvantage that they restrict movement of the typist's fingers or hands, they block visual search and impair tactile feedback

necessary for establishing the correct motor skills (Cooper, 1983; McClurg & Kercher, 1989; Barrett & Krueger, 1994).

Some of these systems employ colored decals or discs applied to the keys of the keyboard such that the keyboard is divided into a plurality of zones, corresponding to the "home" positions on a basic keyboard as described above. The keys within a particular zone are given a common color, while the color of each zone is different. Each finger is thereby associated with keys on the keyboard having a particular color. Those systems and methods are also restricted to the basic keyboard and do not accommodate extended keyboards used with computers.

The benefits of color-coded keyboards accordingly appear to be known and accepted but there has been no appreciation or understanding of the significance that color selection and patterning can play in the cognitive processes involved in learning and developing proper keying practices. The author on the other hand has recognized that color and patterning can play a significant role in enhancing the learning processes and use habits.

#### The KeyRight System

The KeyRight System utilizes a spectrum-ordered color pattern of finger-key coding. Throughout this report the phrase, "spectrum colors" is intended to denote all hues in the visible range of the electromagnetic spectrum, which may be perceived by a human observer having normal color vision. That phrase is intended to include all the hues within the visible spectrum and is not limited to a number of defined colors or color categories. The phrase, "spectrum-ordered color pattern" denotes the pattern produced

by the spectrum colors when arranged according to their natural order in the electromagnetic spectrum.

The KeyRight System provides a data-entry device, having manually operable input means arranged in a plurality of zones for actuation by the respective fingers of a user, with color-coded keys so that the keys within each finger-key zone share a common color and successive zones display colors ordered according to their relative position within a spectrum-ordered color pattern.

#### Psychological Issues

The theoretical basis of this color coding application is consistent with psychological principles and research findings. The Gestalt laws of organization predict and govern perception of the elements that make up contour, color, structure, and form in the perceptual (visual) field. Those elements are arranged, through psychological processes, into patterns with maximum organization (Koffka, 1935). Perception requires that a stimulus must contain some measure of heterogeneity (Wertheimer, 1923 in Koffka, 1935). The better the organization of the stimulus, the better its perception (Koffka, 1935; Wolfe, 1996). Object segregation within the visual field is necessary for perception; it is not possible to discriminate an object without segregation. A visual field must contain a certain amount of redundant information, ensuring discrimination and contrast of objects and their structures (Attneave, 1954). Redundancy reduces uncertainty and error and contributes to organization. improved Organization emphasizes the context and significance of the functionality of the stimulus. Greater organization allows better perception of the

stimulus. Effective and intelligent responses will always be as good as the prevailing conditions in the perceptual field permit (Koffka, 1935). Gestalt principles determine that a subject's perceptual field is segregated into psychologically ordered parts that are most stable and simple or which create a minimum level of psychological and physiological stress (Forgus, 1966). Perceptual fields tend to be organized into a limited number of minor units. Grouping into smaller units encourages a chunking effect (Miller, 1956). Chunking allows information. like letters, syllables and words, to be grouped into familiar and manageable units which assist encoding, storage and recall (Lefton, 1994). Discrimination will be impaired if objects and their backgrounds have the same color (Javadnia & Ruddock, 1988).

Psycho-physiological factors are important considerations also. Various theories propose the concept of neuro-physiological memory traces. The input of information remains in a passive form as a trace. Recall and response involve a reactivation of a trace which, in effect, renews the same perceptual process and initiates responses consistent with the corresponding original input (Anderson & Bower, 1973; MacLeod, 1991). There is a transformation of unordered or poorly organized memory traces into betterorganized traces through repetition. indicating that memory and recall is also aided by good organization in the perceptual field (Anderson & Bower, 1973). Good organization in the perceptual field also streamlines the neural processes associated with input, storage and retrieval of information (Restak, 1988; Vecera & Farah, 1994). Kinesthesia, or motor memory, is the awareness of movement and position arising from repetition of motor activities. Finding kevs on a keyboard is easier when a fingercolor-key location is familiar (Tsal, 1983). That learned familiarity of movement and its repetition assists efficient and consistent motor coordination. Learning to use the keyboard proficiently can only occur through repetition. Repetition may lead to bad habits as well as good ones. One may easily start to learn wrongly and then acquire bad habits that will retard learning the activity correctly later, and in such cases repetition does not lead to optimum use (Koffka, 1935).

The development of skilled typing is characterized by a decreasing dependence on visual feedback of the keyboard accompanied by an increased dependence on kinesthetic tactile feedback. Kinesthetic tactile feedback is the basis for making and confirming responses once learning has occurred utilizing sensory stimuli, mainly vision (Barrett & Krueger, 1994; Gordon, et al. 1994; Crowe et al, 1997).

The spectrum-ordered pattern of color coding discloses the finger-key zones, which enhance learning performance and encourage the correct keying practices. Research indicates that at least ninety-five percent of "expert" touch-type-method typists do not use the extended keyboard properly. In acquiring the motor skills to key properly, it is crucial to learn them correctly. Better use and, in particular, proper hand positioning minimizes the incidence of repetitive stress injuries like carpal tunnel syndrome, akinesia, and tenosynovitis (Cooper, 1983).

The use of color is an important consideration for effective perception. The physiological and psychological benefits of color application are well appreciated. Color is as an extremely effective way of organizing stimuli (Wickens & Andre, 1990) and an ideal means of segregating, defining and connecting units of stimuli (Davidoff, 1991). Segmentation through color coding quickens visual search responses (Green & Anderson,

1956; Christ, 1975; Carter, 1982; Bundesen & Pedersen, 1983). Color aids the processing and recall of information, and of stimulus organization (Christ, 1975; Fisher & Tan, 1989; Cave & Wolfe, 1990). Color coding also enhances memory performance (Siple & Springer, 1983).

Of the color-coded keyboards known to the author there appears to be no importance placed on the particular colors used. Olsen (1970) suggests the following colors: "red, blue, orange, green, yellow, pink, black, purple". Ladner & Williams (1990) discloses the colors: "dark pink, yellow, violet, green, orange, blue, grey, light pink". Troudet (1994) discloses the colors: "pink, red, green, yellow and orange, yellow and orange, green, red, pink". The "kidBoard" (kidBoard Inc., 1996) uses yellow, red and blue. It can be seen from the examples that colors were selected arbitrarily, with no emphasis on color relationship or effective ordering and patterning.

Patterning plays a crucial role in the effectiveness of the KeyRight System. Organization through patterning is an efficient way of receiving, processing and recalling information. The organization of a pattern is the basis on which discriminating and efficient responses may be made (Murch, 1973: Kotovsky & Simon, 1973). The pattern, which presents the best possible cues, will have the best organization (Koffka, 1935; van der Helm, 1994). Patterns have mnemonic advantages because they are more readily organized into conceptual units (Anderson, 1973). Patterns tend to compel one to perceive in certain ways; subjects tend to endow an object with the maximum regularity, symmetry, simplicity, continuity, inclusiveness and unification towards the best organization (Forgus, 1966). When there are several ways in which a pattern may be organized the simplest arrangement will be perceived most readily (McBurney & Collings, 1977; Kotovsky & Simon, 1973). Good spatial arrangement of patterns facilitates organization levels (Davidoff, 1991; Cave, Bost & Cobb, 1996). Colors are an effective way of creating patterns. Discrimination between stimuli is easier if color categories lie within information boundaries (Mullen & Kulikowski, 1990). Coloring and patterning when used together are compatible and do not lead to dysfunctional responses because they are processed separately (Javadnia & Ruddock, 1988; Cave & Wolfe, 1990). Brown & Monk (1975) and Carter, (1982) found that patterns quicken search response times because participants develop effective search strategies. Perceptual processes are improved when segregation of the units create conjunctions that act as means for separating the units and also as attentional cues for units that receive separate attention and are required for specific functions (Treisman, 1982; Cave & Wolfe, 1990: Kroemer, 1992; Crowe, et al, 1997) as in the case of the color-coded, finger-key zones of the KeyRight System.

The color-coded keyboard of the KeyRight System reveals, first, that the basic keyboard and the extended keyboard have organized configurations. The "within-stimulus" organization is perceived through the arrangement of the colored units and the pattern formed through the color transition of those units. In the case of a computer keyboard, that color transition is emphasized by the sloping columns, a natural complement to ergonomic design standards for keyboard configurations (see Buesen, 1984). The KeyRight System's color-coded keyboard is segregated into zones by a spectrum-ordered pattern of colors. This spectrum-ordered pattern corresponds to the range of so-called "visible light" within the

electromagnetic radiation spectrum (EMS). "Visible light" is "radiation" conceptualised, at variant wavelengths of the EMS between the ultra-violet and infrared extremes of about 380 nanometres and 780 nanometres respectively (Judd, 1966; Wurtman, 1975; Marczenko, 1986). Contemporary theories contend that color is the psychological effect of electromagnetic radiation of different wavelengths, suggesting that objects appear colored, via psychological processes, when they transmit radiation in the "visible" range. That range may be subdivided into seven parametric bands of colors (Newton, 1730; Boring, 1942) corresponding to "focal regions" of the spectrum (Mervis, Catlin & Rosch. 1975: Heider. 1972). The focal regions are the purest examples of a color and the most prominent (salient) parts of the spectrum (Heider, 1971; Neumann & D'Agostino, 1981) as opposed to the vague, low-contrasting boundaries between color categories which are either more difficult to distinguish or to name (Heider, 1971; Bornstein, 1976; Mullen & Kulikowski, 1990). Focal regions incorporate Basic and Nonbasic colors (Berlin & Kay, 1969; Bovnton & Olson, 1990; Sivik & Taft, 1994; Whitcroft, 1998), which may be categorized semantically as the spectrum colors: red, orange, yellow, green, blue, indigo and violet (Munfort, 1924; MacIvor & LaForest, 1979; Marshall 1991: Walker, 1991: Gunstone & Osanz, 1994; Checile, Anderson, Krafczek & Coley, 1996) being arranged in wavelength order corresponding to their natural positions in the electromagnetic spectrum (Boring, 1942; Ditchburn, 1961). That subdivision provides the maximum contrast and separation of the stimulus (in line with Tsal, 1983; Boynton & Olson, 1987; Smallman & Boynton, 1990; Sturges & Whitfield, 1995; Whitcroft, 1997) whilst maintaining the integrity of the pattern.

Stimulus perception can occur at various levels of scale (Duncan and Humphreys, 1989; Robertson, 1996). In line with those findings, the spectrum-ordered color pattern enhances organization of the units at both the within-stimulus level (as referred to above) and at the "whole-stimulus" level, where responses are based on the perceived properties of the entire stimulus. The findings of Duncan and Humphreys, (1989) showed that "homogeneity coding" occurs when a "target," in this case the spectrum-ordered color pattern, as a unit at the whole-stimulus scale level, is applied to the stimulus which imparts a uniquely perceived integration of the sub-units.

The spectrum-ordered pattern of colors, as a whole, is perceived as an ordered pattern because its colored sub-units, at the columnar focal regions, provide information at intervals of a spatial gradient. A spatial gradient is a function of the relationship between the units of a sequence (Koffka, 1935; (Schellenburg & Trehub, 1994). The strength of that relationship is a measure of a sequence's organization and hence a factor determining how readily a pattern may be perceived. An example of this is the sequence of integers: "1, 2, 3, 4, 5, 6, 7, 8" which is a more readily perceivable pattern than: "1, 3, 2, 4, 5, 7, 6, 8". (Kotovsky & Simon, 1973; Kaplan & Simon, 1990).

Color pattern discrimination relies on the detectability of gradients of color that make up the units of a visual pattern (Fitts, 1966). Each unit's color within the subject color pattern corresponds to each color category's characteristic range of radiation (Marczenko, 1986). Those ranges may be represented as parameters of frequencies (λ) in Hertz (Wright, 1964), wavelength specifications in nanometres (Giancoli, 1980), or color-hue specifications as determined through the Munsell, Pantone, L\*a\*b\*, C.I.E., R-G-B or

other color determining system (Judd & Wyszecki, 1975).

When the units of the preferred pattern are assigned rank-order values corresponding to their natural positions within the EMS, a relationship is determinable. The color coding of the KeyRight System uses the spectrum colors in the, "R-O-Y-G-B-I-V" ranked order:

Rank	Color	Order
λΑ	(red)	1,
λΒ	(orange)	2,
λС	(yellow)	3,
λD	(green)	4,
λΕ	(blue)	5,
λF	(indigo)	6,
λG	(violet)	7

 $\lambda$  denoting rank corresponding to that color's position in the spectrum and the numeral denoting the order of colors of a pattern which may be made from these colors). Relationship strength is established through the statistical measure: "Spearman's rank-order correlation coefficient". The strength of the relationship between the colors of the spectrum-ordered pattern, expressed as a correlation coefficient, is the maximum:  $r_{\rm S} = +1.00$ .

No other pattern containing these color units could be perceived as readily because it would have a relationship indicating weaker stimulus organization. For example, the pattern, "Y-O-G-V-I-B-R":

Rank	Color	Order
λΑ	(yellow)	3,
λΒ	(orange)	2,
λС	(green)	4,
λD	(violet)	7,
λΕ	(indigo)	6,

λF	(blue)	5,
λG	(red)	1

has a significantly weaker correlation:  $r_s = +0.07$ .

#### **Design Issues**

The color coding of the KeyRight System is compatible with all keyboards and tactile dataentry devices regardless of key legends and key configurations.

The color coding application of the KeyRight System has the following finger-key-zone colors:

Finger H	ome Key Legend	Color
QWERTY/ Dvorak		
left-hand pinky	, A A	red
left-hand ring	S O	orange
left-hand midd		yellow
left-hand index	c F,(G)U,(I)	green
right-hand inde	ex (H),J(D),H	blue
right-hand mid	dle K T	indigo
right-hand ring	LN	violet
right-hand pink	ov : S	pink

The space bar, operated by the thumbs, may be given a pale neutral color such as cream, light grey, or similar.

The color pink, used for the right-hand pinky finger-key zone, has been introduced to meet the need for eight key-zones corresponding to the eight keying fingers and also to identify and further segregate the keys used by the right hand which requires frequent lateral movement from and to the home keys. Preferably, the pink is a "constant hue" (Burns, Elsner, Pokorny & Smith, 1984) being the same hue as the "red" used for

the left-hand pinky but increased in lightness (desaturated). That color scheme produces a relation between the pinky fingers whereby the terminal hues of the pattern are the same; they lie on the same radial hue-angle of a color wheel but have unequal lightness. The color pink also has a mnemonic advantage as it is naturally related to the "pinky" finger of the right hand.

Color coding of the keys, or their columns, may be achieved in a variety of ways. In one embodiment the sides of the keys may be painted or printed with the appropriate color for each key-zone. Alternatively, the keys may be made of a suitable colored material such as colored plastic. The keys may advantageously be made of a translucent colored material and backlit to emit light of the appropriate color.

Alternatively, the color coding may be in the form of an overlay. The overlay may be a flexible membrane covering the keys. The overlay may be in the form of a rigid or semi-rigid sheet surrounding the keys such that finger-key zones are indicated by a background-surrounding color.

Preferably, all of the keys of the extended computer keyboard are color coded using the same coding as applied to the "basic" section of the keyboard. The colors displayed may be chosen to indicate the relevant fingers to be used to operate the additional keys, such as the numerical keypad, control, mode, option, startup, cursor arrow and function keys.

Advantageously, the finger-key zone indicators may be applied to the keyboard to indicate which finger is to be used for each finger-key zone. Such indicators may be in the form of a hand symbol having the relevant finger colored the appropriate color. Preferably, the indicators are placed at the top of each column comprising a finger-key zone. The indicators may be applied to the surface material of the keyboard by any suitable process such as embossing, screen-printing, decal or transfer.

In the drawings contained in the appendix, Figure 1 shows a plan view of a computer

keyboard incorporating the preferred color coding application of the KeyRight System.

The home keys on a "QWERTY" keyboard correspond to the keys reading "ASDFJKL;". However, these keys may have different labels, symbols or legends depending on the purpose and language of the keyboard or input device.

As shown in Figure 1, key-zones 11 to 18 are color coded using the spectrum-ordered colors. The keying finger corresponding to each colored key-zone is as follows:

Key-zone Finger Color			
11	left-hand pinky	red	
12	left-hand ring	orange	
13	left-hand middle	yellow	
14	left-hand index	green	
15	right-hand index	blue	
16	right-hand middle	indigo	
17	right-hand ring	violet	
18	right-hand pinky	pink	

Each keying finger is thus associated with a particular color and with keys 2 in a particular key-zone of the alphabetical keyboard 3 having that color. The space bar 19, operated by either thumb, is given a pale neutral color such as cream, light grey, or similar.

The numerical keypad 4 includes key-zones 21 to 24 arranged generally in four columns for operation by four keying fingers of the right hand of a user. The key-zones are color coded as follows:

Key-zone	e Finger	Color
21	right-hand index	blue
22	right-hand middle	indigo
23	right-hand ring	violet
24	right-hand pinky	pink

It should be noted that this color coding is the same as that used for the right-hand keying fingers on the alphabetical keyboard 3. The control keys are similarly arranged in keyzones 31 to 33 for operation by three keying fingers as follows:

Key-zone	Finger	Color
31	right-hand index	blue
32	right-hand middle	indigo
33	right-hand ring	violet

The row of function keys 6 above the alphabetical keyboard 3 is color coded as shown in Figure 1 to indicate to the user that the leftmost group of four keys is to be operated by the left hand and the middle and right-most groups of four keys are to be operated by the right hand. For computer keyboards the spectrum-ordered pattern of colored zones, with the additional mnemonic pink for the "pinky" finger's zone, conforms to the essential need to segregate eight finger-key zones to correspond with the eight keying fingers (space-thumb bar excluded).

#### Conclusion

The fundamental problem with keyboards having poorly defined organization (i.e. without color, motor-, memory- or search-aiding enhancements) is that they are perceived as homologous visual fields. Their low-level organization does not confirm an order or break down the whole into its integral parts, which is necessary for optimum information processing. Accordingly, as a stimulus their effectiveness is limited. Their low level of organization overwhelms a user, retarding search efficiency and proper motor development. Breaking down the whole into its integral parts aids awareness of the purpose and functionality behind the keyboard's design configuration. Distribution of the segregated parts of the keyboard by color coding facilitates better awareness of the

integrated whole.

This color coding application has unique advantages that are directly attributed to the high level of organization realised through the spectrum-ordered color patterning. The application of the preferred spectrum-ordered color pattern has the following improvements:

- 1) It is the most expediently perceived pattern of colors. That is because the preferred spectrum-ordered pattern of color coding is the most highly organized pattern. The spectrum-ordered color pattern has the strongest possible relationship because it provides the highest level of within-stimulus pattern contrast, indicating its optimal organizational properties.
- 2) The preferred spectrum-ordered pattern corresponds to the "rainbow" pattern, which is commonplace and instantly recognizable, providing more information at both the withinstimulus and whole-stimulus levels than unfamiliar patterns and thereby further increasing organization of the keyboard.
- 3) It is the simplest pattern. The preferred spectrum-ordered pattern is the simplest pattern that can fulfill maximum organization of the units of the keyboard. It is the only familiar pattern with rank-ordered colors.
- A color-coded keyboard incorporating the KeyRight System has the following practical advantages:
- \* It introduces the order and the finger-key zones of the keyboard.
- \* Novice, casual and expert users become aware of its function immediately.
- \* It acts as a heuristic guide, encouraging users to pursue correct usage of the keyboard.
- \* It introduces the home keys and maps-out their corresponding key zones.
- \* It acts as a constant and permanent reminder of the correct means of use.
- \* Users will automatically learn finger-key associations, which are necessary for learning to "touch-type". That stops the establishment of difficult-to-reverse keying habits.

- \* It encourages correct muscle memory.
- \* It reduces the incidence of repetitive strain injuries by stabilizing the keying hand at its correct location, thereby isolating finger movement to within the appropriate key-zone and minimizing hand and arm movement.
  - \* No accessories are needed.
- \*It is universally suited to all keyboards and tactile-encoding devices.

Incorporating visual-search, motor-aiding and memory-aiding devices by color coding, introduces meaningful relations between the tobe-remembered information and the responses to be realised. The quality of response, in this case one's keying skills including speed, accuracy, and overall proficiency, is directly related to the quality and strength of the organization in the perceptual field - the keyboard - and the processes in learning and developing its usage. The higher the level of organization of the stimulus, the greater the streamlining of the neural processes which assists in more efficient input, storage and recall responses.

It is suggested that the high-level organization of the rank-ordered spectrum colors provides the strongest-possible cues and yields the best-possible responses by adapting the neural mechanisms to process information with maximum economy and efficiency, thereby leading to greater user-machine synergy, confidence and creativity.

It is concluded that the adoption of the KeyRight System as a universal standard for the color coding of keyboards and all data-input devices will make computer use more interesting, attractive and interactive by providing the means to improve motor-, visual-, audile-, feedback-, and memory-aids for the user.

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