Effects of Color and Word Length on Verbal Working Memory

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Abstract

In fields such as the academia and the work force, the recall of words is especially important. Research has shown that the ability to recall words could be affected if presented in abstracting colors. It was also indicated that it gets more difficult for the working memory to establish longer words. Sixty-one business professionals viewed six slides of either two-syllable words in blue and grey, or five-syllable words in blue and grey. Participants recalled as many words as they could and resulted in no significant differences in the interaction of the factors. What was significant was the five-syllable words were more difficult to recall, with the difference more pronounce between Whites and Non-whites. This study implies that it would not have much effect whether a pencil or blue pen is being used, and that short length words could help Non-whites better recognize and memorize words.
Introduction

Working memory is short-term maintenance of information processed through the phonological loop. This process is responsible for verbal information, visual information, and the selection of reasoning and storage capabilities (Baddeley, 1986). The subsystems of verbal and visual working memory have significant limited storage capacity. Being able to select what is important information to recall can lead to efficient use of memory (Castel, 2009). When screening of over 3000 school-aged students in public school system, 1 in 10 of school-aged students have been found to perform below age-expected levels in reading and mathematics. This corresponds with evidence that low working memory skills constitute a high risk factor for underachievement of students (Bastin, 2004). This evidence suggests that working memory impacts all areas of learning from kindergarten to college. Students with working memory difficulties are typically judged by teachers as highly inattentive, have short poor attention spans, and high levels of distractibility. Students often forget what they are currently doing, failing to remember instructions and complete tasks, makes careless mistakes, and have difficulties solving problems. Findings such as these illustrate that student with poor working memories have a high risk of poor academic progress. Without early intervention, the deficits cannot be recouped over time and will continue to compromise a student’s possible success (Alloway, 2009).

General Background

Working memory is another name to what is also called short-term memory, where small amounts of information are stored for a short period of time to be retrieved when needed in completing a task. The cerebral cortex receives nerve messages from eyes, ears, and touch sensors. These sensory stimuli are stored for a fraction of a second in the sensory memory. Then, three things can happen. It can be repeated, providing auditory cues or the information is
then stored in long-term memory, or the information will be lost (Bridger, 2009). The storage capacity of working memory is different for every individual, distinctively different among age groups, gender, educational level, environmental upbringings, and especially hereditary. Working memory is used for studying, solving problems at work, and focusing on daily responsibilities (Cowan, 2008). One level of measuring the capability of working memory is the capacity of memorization.

Memorization using working memory can last as little as a few seconds, and its capacity is very limited, playing a central role in individual differences in cognitive abilities (Myers, 2004). On average, a person’s mind can hold up between five to nine items at one moment; any effort to try to hold more than that more than likely will result in forgetting the “middle” items (Cowan, 2008). Memorization skills vary in techniques and what aspects the individual chooses to use it for. A student may use a certain method to aid in memorizing vocabularies, whereas an employee may have a completely different method to try to memorize procedural steps in completing a task. The differences emerge both behaviorally and in method patterns (Buckner, 2006). Rehearsal and practice can increase the strength of responses, regardless of age, if it is done enough (Baddeley, 2003).

Specific Background

Word length. Word length has been shown to effect one’s working memory pertaining to the memorization of words in recall tests. As the number of long words to memorize in a list increase, the proportion of correct responses decreases, if there is no suppression of the phonologic loop. If other components of working memory are suppressed, correct responses for long and short words also decrease (Cowan, Baddeley, Elliot, & Norris, 2003).
Within word length, the number of sounds when a word is spoken in a language (phonemes) and the number of syllables have also been shown to effect the memorization of words during recall tasks. Based on Finnish phonotactics, three-syllable items were recalled less than short pseudowords structured as consonant-vowel-consonant-vowel and two-syllable items. Researchers contrasted the difference between the numbers of syllables with the number of phonemes. Two-syllable items with six different phonemes were as difficult to recall as three-syllable items (Service, 1998).

Syllable length and spoken duration of a word have been studied in determining word length effects. Trace decay plus rehearsal models have been challenged in recent years with the number of experiments. Researchers in Australia conducted an experiment to test the trace decay plus rehearsal model of word length effects. Results showed in serial recall that participants free to rehearse one and two syllable words performed better than when suppression was used, with one-syllable words recalled more than two-syllable words. During this portion of the experiment, duration effects were only present during suppression conditions of two-syllable words. During the second portion of the experiment, no significant duration effect for one-syllable words, and for two-syllable words, the long duration words were better recalled than the short duration words. Researchers’ results support non-decay models of word length effects and that duration effects are not important for trace decay plus rehearsal models. This absence of duration effects in serial recall is not surprising, due to previous research (Tolan&Tehan, 2005).

Recent research has brought into question the validity of item and list-based theories explaining the word length effect. Research tested the word-length effect for distinctiveness comparing serial recall both visually and auditory of immediate serial recall. Word length effects were present when comparing pure short word (one-syllable) lists to pure long word
(five-syllables) lists and when comparing background short and long words during isolation word tests. These results were similar to previous research. However, when one short word was isolated in a list of long words and when one long word was isolated in a list of short words, the isolated word was recall significantly more than the pure short word list. Most significant was the result that the long isolated word was recalled more frequently than the isolated short word, which was a reversal of the word length effect. The same researchers conducted a second experiment in hope of replicating this data, with the exception of having the words visually displayed and using a pool of more words, with the long words ranging from three to five syllables in length. Results were similar to those of the first experiment with respect to pure word lists and background word lists during recall. These results also indicated a significant higher recall rate for isolated words and a reversal of the word length effect, with long isolated words recalled more frequently that pure short word lists. Although the SIMPLE model (Brown et al., 2002) explained some of the results, it could not explain the reversal of the word length effect. The Researchers suggest a modified SIMPLE model could be used to help explain these results and that item distinctiveness is a main component of recall (Hulme, Neath, Stuart, Shostak, Surprenant, & Brown, 2006).

**Color.** Experiments on environmental context effects have shown a relationship to recall of items. The environmental context of background color for to-be-remembered items, in free recall, has shown mixed results. Background color always exists behind any item although it may not always be noticed. When background color is the same or repeatedly changed for each to-be-remembered item, no significant context effects are found and recall is not significantly affected. However, to-be-remembered items were recalled more frequently when against the same background color during study and test times (Isarida, Takeo and Isarida, Toshiko, 2007).
Researchers have studied the use of a highlighting marker as a tool to emphasize text material to determine if retention scores increase. Participants were divided into four groups, *actively highlighting, passive highlighting, experimenter highlighting, and no highlighting*. Although there were no significances in total scores for all four groups, the experimenter highlighting group scores were significantly better than the no highlighting group scores on 18 test questions pre-highlighted for the experimenter group. Overall, this test qualified highlighting as a means to increase retention for long-term memory. Whether it was the use of a highlighting pen or that the participant chooses to emphasize a specific part of the article to remember, has yet to be studied (Fowler & Barker 1974).

An experiment involving colored letters and color names in a modified memory recall test have also been conducted. Color names and Xs printing in colored ink were recalled equally, whereas color names printed in incongruent colored ink were recalled significantly less. Participants choose the actual printed word rather than the color printed on the word in this experiment (Sagi, 1980).

The Stroop effect was originally published by John R Stroop in 1935. Since then it has been widely cited in numerous research (wikipedia.org, August 31, 2009). The Stroop effect indicates that women complete the Stroop Color-Word test quicker than men. Researchers wanting to improve the validity with previous studies of the Stroop effect, although this population had a slower time for of this test used a modified version of the test on African American population. The results were consistent naming words, the results were not significant (Strickland, Elia, James, & Stein, 1997).

**Word length and color.** The literature review search yielded no published research on the interaction of both word length and color on working memory for memorizing words or word
recall. As suggested in prior research, continuous different color backgrounds or the same color background for memorizing long words with multiple syllables, will be more difficult to recall than two separate colored backgrounds for the same list of words. The interaction of both factors of word length and color, and how they affect word memorization, would be affected by the different variations of long words selected and in which way color was used in conjunction with those words.

Methods

Participants

Sixty one business professionals (20 female and 36 male) who work in public service in the City of Daly City and the City of Santa Clara. Participants were not given any incentives for the time they took during this study. Participants came from a variety of ethnic backgrounds and for a few, English was their second language. Participants varied in age, ranging from 21-years-old to 65-years-old. Participants’ data was excluded from this study if their writing was illegible (n=3) or data was lost (n=2).

Materials

Lists of long (five syllable) words (see Appendix A) and short (two syllable) words (see Appendix B). Of the lists of short words, three were printed in grey and three in blue, with each list containing eight words each. Of the lists of long words, three were printed in grey and three in blue, with each list containing eight words each. The words were retrieved from the MRC Psycholinguistic Database, deriving from The University of Western Australia, School of Psychology. It is a program designed to be of use to psycholinguists in selecting stimulus materials for testing. The program contains 150,837 words and provides information about 26
different linguistic properties. The words that were selected were narrowed down based on the number of syllables and the average familiarity rating.

Response sheets contained eight lines with a label for each trail at the top of the sheet. The lines were horizontal across the page, with lines under each other. All response sheets were identical, except for the label for the trial number at the top.

Background questionnaire (see Appendix C) included fill in and circling questions asking for the participant’s age, gender, education level, ethnic background, whether the participant has been diagnosis with a learning disability, the participant’s primary language, if the participant is color blind, if the participant currently use corrective lens (glasses or contacts), or if the participant has participated in a similar study before and a description of that study.

**Procedure**

The study occurred in a conference room setting containing a long table and several chairs positioned at the table. Testing times varied per session, with City of Daly City employee sessions at 8:00am, 3:00pm, and 8:00pm, and City of Santa Clara employee sessions at 9:00am on separate days. While testing occurred, the conference room was mostly free of distractions. Prior to testing, participants were informed that this study involved memory, that participation was completely voluntary, and that they were free to leave at any time. Consent forms were handed out to each participant and time was allowed for questions. If participants agreed to participate in the study, they were asked to sign the consent form, upon which it was collected. City of Daly City employees were given two sets of conditions, three lists of five syllable words printed in the color grey and three lists in the color blue. City of Santa Clara employees were given two sets of conditions, three lists of two syllable words printed in the color grey and three
lists in the color blue. All participants had one second for each syllable to view the lists of words to memorize and two seconds for each syllable to recall and write down the words in each list.

Each group heard the same set of instructions and the same instructions were displayed on a screen, which was viewable via PowerPoint presentation. Participants were instructed to view the list of words displayed, to memorize the list, and then to recall the words and write them down on the appropriate response sheet. Prior to beginning the study, all participants were allowed time to ask any questions. After all questions had been answered, the first list of words was displayed on the screen. The lists of two-syllable words were displayed for 12 seconds and lists for five-syllable words were displayed for 30 seconds ($\frac{3}{4}$ of a second per syllable). After this time had elapsed, participants were allowed 24 seconds for two-syllable word lists and 60 seconds for five-syllable word lists to recall as many words on the list and write them on the response sheet (1 ½ seconds per syllable). The time allowed was to help reduce tactics such as rehearsal or chunking before recall and a constant formula for time for both sets of lists. This process was used for all lists of words, printed in either grey or blue.

After all lists had been displayed and recall was complete, the background questionnaire was given to each participant to complete. Once all questionnaires were completed, they were collected with each participant’s response sheets and keep together. After each session of the study was finished, all participants were advised not to inform anyone of this study as it may affect the participant’s scores in the next session. The participants were also advised they could receive feedback and outcomes of the study by sending an email to either of the experimenters and results would be emailed back after completion of all sessions and once analysis was done.

_Design & Analyses_
There were four experimental conditions in this study. Color of print (blue and grey) was a within-participant factor and Word Length (two-syllable and five-syllable words) was a between-participant factor. Researchers scored each word correct as one point. Words were counted as correct if the word to be recalled was 80% correct. Each missing letter, wrong letter, or wrong order of a letter in a word counted was counted as incorrect. The amount of correct letters in order was divided by the total number or letters in the complete correct word listed to determine if a correct word was recalled. Additionally, factors for Age (less than 34 and greater than 42), Gender (male and female), Ethnic background (white or non-white), and Education levels were also grouped into categories, taken from the completed background questionnaires and analyzed.

Results

The effects of Color printed words had on the Word Length effect in the recall of words during working memory tasks was the primary focus of this study.

Effects of Color printed words

Participants who viewed lists of grey printed words recalled more than participants who viewed the lists of blue printed words. The mean number of correctly recalled words for two-syllable blue printed words were \( (M = 10.67, SD = 2.51) \) and two-syllable grey printed words were \( (M = 10.70, SD = 2.48) \). The mean number of correct recalled words for five-syllable blue printed words \( (M = 7, SD = 4.02) \) and five-syllable grey printed words \( (M = 7.70, SD = 3.31) \). Although grey printed words were recalled more frequently, this effect was not statistically significant, \( F(1, 54) = 1.221, p < .274 \).

Analysis of Color printed words and Gender (male or female) was reviewed. Males recalled on average more grey printed words \( (M = 10.00, SD = 3.46) \) than blue printed words (M
than females [grey words (M = 8.50, SD = 2.44), blue words (M = 8.55, SD = 3.83)]. However, this difference between males and females was not significant \(F(1, 52) = .966, p < .330\).

Age and Color printed words was also analyzed. Age was separated into two groups (Younger and Older), participants 34 years old or younger and participants 42 years old or older. The Younger group recalled fewer blue colored words (M = 8.63, SD = 3.16) than the Older group (M = 9.80, SD = 3.96). The Younger group also recalled fewer grey words (M = 9.31, SD = 3.48) than the Older group (M = 9.70, SD = 2.98). This effect was not statistically significant \(F(2, 50) = .428, p < .654\).

After separating Ethnic background into two races, White and non-White, an analysis was conducted with it as a factor along with Color printed words. Whites recalled more blue colored words (M = 9.56, SD = 4.34) than non-Whites (M = 9.10, SD = 2.98). Whites also recalled more grey colored words (M = 9.72, SD = 3.54) than non-Whites (M = 9.45, SD = 2.90).

**Effects of Word Length**

As in previous research conducted, shorter words in blue (M = 10.67, SD = 2.51) and grey (M = 10.70, SD = 2.48) were recalled more frequently than longer words in blue (M = 7.00, SD = 4.02) and grey (M = 7.70, SD = 3.31). In this study, shorter words where characterized as 2-syllable words and longer words as 5-syllable words. In this study, the Word Length effect was statistically significant \(F(1, 54), p < .0001\).

Additionally, a between-subject analysis was conducted with Gender and Word Length as factors. This effect was not significant \(F(1, 52) = .134, p < .716\). The same between-subject analysis was conducted using Age and Word Length as factors. This effect was also not
significant $F(2, 50) = .732, p < .486$. Ethnicity was the last factor analyzed with Word length in a between-subject analysis. This effect was also not significant $F(1, 51) = .680, p < .413$.

Interaction of Word Length and Color

Although words printed in grey were recalled more often than words printed in blue, the interaction between Word Length and Color printed words was not significant, $F(1, 54) = 1.026, p < .316$. However, as noted in previous studies (Word Length Effect), number of syllables in a word had a significant effect $F(1, 54) = 19.433, p < .0001$.

A separate analysis with Gender, Word Length, and Color as factors was also conducted. The result of this analysis was not significant $F(1, 52) = 1.146, p < .289$. Using Age along with Word Length and Color as factors, another analysis was conducted. The results for this analysis was also not significant $F(2, 50) = .293, p < .747$.

Analysis of Ethnic background, described as Race (White and non-White) with Word Length and Color was done. The result for these three factors together was not significant $F(1, 51) = .109, p < .742$. However, Ethnic background as a lone factor was significant $F(2, 51) = 3.89, p < .028$.

Discussion

This study investigated the effects of color on two-syllable and five-syllable words on the ability to recall the words using short-term memory. Previous studies have documented that short words were recalled more often than longer words (Service, 1998). In regards to colorWords, there were more studies done on highlighted words than the color of the words. Words highlighted in colors have increase retention for even long-term memory (Fowler & Barker, 1974). The goal of this study was to explore the effects of the color of the word instead,
as well as the results of its interaction with the length of the word, by examining the number of words recalled from a series of lists.

Effects of Word Length

The number of syllables had a strong effect on number of recalled words overall, reflecting the fact that two-syllable words were easier to recall than five-syllable words. This mirrors the results of prior studies (Cowan, Baddeley, Elliot, & Norris, 2003; Tolan & Tehan, 2005). A database intended to produce materials utilized by psycholinguistics for research testing (MRC Psycholinguistic Database) was used to generate words based on an average of familiarity. There were more word lists in this study than were used in previous studies (Baddeley, 1986). About half of the words on Baddeley’s lists were used for this present study. By using similar lists, the results were similar, verifying that short words were easier to recall. Two-syllable words leave more storage capacity to store more words, resulting in more words being recalled. Longer words take up more capacity, resulting in less room to store more words that is to be retrieved.

The interactions of Word Length with Age, Gender, and Ethnic Background were not significant in this study. This confirmed that the effect of Word Length occurs independently from these other factors.

Effect of Color-printed Words

Although the colors blue and grey were not dramatically different in contrast and hue, the results of this study showed that there were minor differences in recall. Brighter hue colors are expected to enhance peoples’ visual experience and that can aid short-term memorization (Spence, et al., 2006). The results of this study did not show such expectation. The participants in the present study viewed the lists of words via Power Point program displayed onto a
projection screen. The color exhibited can vary from device to device. This can involve the different machine models being used. Also, the level of lighting in the different settings where the study was being conducted could have contributed to the hue of the colors displayed on screen. Previous research implied that contrast perception is associated with luminance (Lindbloom, 1989). This suggested that a brighter-lit room could have lightened the contrast color of blue on the projection screen, and a poorly-lit room could have accentuated the grey color.

Interactions

There was no statistically significant interaction of the two main factors. This suggests that Word Length and Color-printed Words act independently from one another. Since Word Length had significant results separately, the factor that could be tested differently is the color being used.

When analyzing the interactions of Color-printed words and Word length with either Age, Ethnic, or Gender, there were no strong significance. This could imply that the test did not have a high level of difficulty to have an impact on the participants. However, when looking at the response sheets closely, there was a trend of slight significance with color. The color grey in both two- and five-syllable words was recalled slightly more than the blue. Although the significance was not noted statistically, it should be mentioned that the grey had a small positive effect on the participants. This trend occurred for all the participants. What may have happened was that since the hue of the grey was lighter than the brighter blue, it may have forced the participants to strain their visual attention to review the words. With this increase in effort, it was probably why more words were recalled in grey. It should be mentioned again that statistically, this was still not significant.
Closing

As the number of long words to remember increases in a list, correct responses decreases. Also, the amount of time allowed from study to recall of long words and how long words are constructed (number of vowels and phonemes) also affect the memorization of words, tested by recall tasks. Although little research has been done on color and recall of items, researchers suggest the background color influences the memorization of items, and color can impact word recognition if the color and word names are incongruent.

Little research was conducted specifically on the interaction of color and word length on verbal working memory, there are few answers for students and researchers alike. Future research needs to determine what hue of colors printed words should be that would produce significant recall of words. With more people attending colleges every year, answers are needed to explain if specific background colors demonstrate the context effect more than others in memorization and whether words mispronounced incorrectly, and using fewer syllables, affect how words are memorized. The questions researchers have answered and will answer in the future could have a profound impact on how teachers create lesson plans, how information is presented, and how students study. Methods that increase our memory of items and words are a necessity in continue education and everyday life.
References


