Is Digit Superiority Indispensable with regard to Short Term Memory Span?

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Keywords
Digit superiority, short term memory, memory span

Abstract
It is known that digits have a positive effect on the performance of short term memory (STM) span and it is called the digit superiority effect. This study aims to examine the effect of familiar stimuli (digits, colors, digit names, color names, and words) on STM span. In order to measure STM capacity, a memory span task was used including the digit, word, and color span lists. 91 participants (44 female, 47 male) aged between 18-27 (M = 21,43, SD = 1.50) participated in the study that consisted of three different experiments. Results of Experiment 1 revealed that there was a significant difference between the digit name and word with regard to span size and total span. In Experiment 2 and 3, the main effect of familiar stimulus type on total span and span size was significant, and also the difference between all types of stimuli was significant (Experiment II, digit name>word=color name; Experiment III, digit>digit name>color name>color). The common result obtained from all experiments is that digits are superior with regard to STM span than other familiar stimuli types such as words, color names, colors. This study confirmed that digit superiority effect is indispensable on verbal and visual STM span.

Kısa Süreli Bellek Uzamı Açısından Sayı Üstünlüğü Vazgeçilmez Mi?

Anahtar kelimeler
Sayı üstünlüğü, kısa süreli bellek, bellek uzamı

Öz
Sayıların kısa süreli bellek (KSB) uzamı performansı üzerinde olumlu etkisi olduğu bilinmekte ve bu durum sayı üstünlüğü etkisi olarak adlandırılmaktadır. Bu araştırmanın amacı, aşina uyarıcı türlerinin (sayı, renk, sayı ismi, renk ismi ve kelime) KSB uzamı üzerindeki etkisini incelemektir. KSB kapasitesini ölçmek için sayı, kelime ve renk uzam listelerinden oluşan bellek uzamı görevi kullanılmıştır. Üç deneyden oluşan araştırmaya yaşları 18-27 arasında (Ort = 21.43, SS = 1.50) toplam 91 katılımcı (44 kadın, 47 erkek) katılmıştır. Araştırma bulguları, Deney 1'de sayı ismi ile kelime arasında uzam genişliği ve toplam uzam açısından anlamlı fark bulunduğunu göstermektedir. Deney 2 ve 3'te aşina uyarıcı türünün toplam uzam ve uzam genişliği üzerindeki temel etkisi ve tüm uyarıcı türleri arasındaki fark anlamlıdır (Deney 2, sayı ismi>kelime=renk ismi; Deney 3, sayı>sayı ismi>renk ismi>renk). Üç deneyden ulaşılan ortak sonuç, KSB uzamı açısından sayıların kelimeler, renk isimleri ve renkler gibi aşina uyarıcı türlerinden daha üstün olduğudur. Bu çalışma, sözel ve görsel KSB uzamı üzerinde sayı üstünlüğü etkisinin vazgeçilmez olduğunu doğrulamıştır.

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Memory is a cognitive function with central importance for human cognition. Three different types of memory have been defined as sensory register, short-term memory (STM), and long-term memory (LTM) in the Modal Model (Atkinson & Shiffrin, 1968; as cited in Baddely, 1992). In the following years, STM was conceptualized as working memory (WM). In Baddeley's model, WM consists of three supporting systems under the supervision of central executive: visuospatial sketchpath, phonological loop, and episodic buffer. STM span overlaps with the phonological loop of Baddeley's model. As the focus of this study is the STM span, the term STM will be used instead of WM. According to the Modal Model, STM is a type of memory that is responsible for storing information at once in its original form within seconds and minutes the capacity of which is limited with 7±2 units. This limitation is represented by STM span. However, it is possible to increase the STM capacity by way of strategies such as chunking (Terry, 2013).

STM span is defined as the longest consecutive series of different items that can be recalled in correct order after a single presentation and it is used for measuring STM capacity. Traditionally, STM is measured via digit-span task. In this task, the participants are presented with a series of digits comprised of an increasing number of items, and they are asked to recall the digits in the presented order. Recalling the presented series of digits in the correct order (in two trials) is considered as the criteria for success. Studies that examine STM capacity using different types of stimulus (such as digits, colors, words) indicate that absolute span size varies concerning the type of stimuli used. Familiar items have a positive effect on performance in STM span measurement and digits have superiority with regard to STM span (Goldberg, 2003; Jones & Macken, 2015; Terry, 2013). For instance, Jones and Macken (2015) compared the performances for digit span and word span (comprised of familiar words) demonstrated the digit span superiority experimentally. Also, they argued that memory span reflects long-term associative memory rather than the capacity of STM, and as well digit superiority effect reflects participants' familiarity with random sequences. In line with Jones and Macken's (2015) study, the present study aimed to specify differences in the effects of linguistically familiar stimuli (digits, colors, name of digits, name of colors, and words) in the Turkish language on STM span, and more importantly and specifically, the digit superiority effect.

It is argued that in STM memory span tasks, the frequency for words has an impact on STM performance and that words with higher frequency are remembered better in comparison with lower ones (Deich, 1972; Griffin, 2003; Tekcan et al., 2002). However, it has been revealed that colors are superior for STM retrieval or STM span when colors and the names of the colors are taken into consideration as stimuli with similar familiarity (Allen, 1983). The superiority of colors over the names of the colors can be explained with the Dual-Coding Theory proposed by Paivio (1971). According to this theory, stimuli such as colors, pictures, or words are encoded in memory as both verbally (auditory) and imaginary; whereas color names are encoded only verbally leading to lower performance in remembering. On the other hand; digits, colors, and consonants are remembered more easily in comparison with other types of stimulus since we are more familiar with them (Brener, 1940; Schweickert & Boruff, 1986). The Dual Code Theory, which proposes two subcognition systems, namely verbal representations (abstract) and visual imagery (concrete), argues that concrete language has a natural advantage over abstract language (Pavio, 1991). Moreover, studies also demonstrated that working memory (WM) capacity is limited just like its sub-component of Visual Short-Term Memory (VSTM). This is because the short-term recall performance decreases for visual stimuli when the number of items to be stored is greater than three or four (Cowan, 2001; Luck & Vogel, 1997; as cited in Kool et al., 2014).

Turkish language is quite rich concerning the color names in comparison with other languages. While colors in some other foreign languages are varied with their characteristics such as lightness-darkness-opaqueness (light blue, dark green, etc.); living things in nature are utilized in Turkish language for deriving color names via analogies (camel hair, ivory, garnet etc.) (Akdoğan & Aydın, 1995). Similarly, it is possible to create the color names with a single compound name such as greenish blue or yellowish green instead of classifying the names in different categories such as blue and green. Studies implicated that such linguistic variations result in differences between the cognitive (Davidoff et al., 1999) and perceptual (Thierry et al., 2009) processes of individuals with different native languages. For example, Thierry et al. (2009) reported in their Event-Related Potentials (ERP's) study in which they show that colors are distinguished at the early stage (200 ms) of information processing that there is a statistically significant increase in the amplitude of the Miss Match Negativity (MMN) component that emerges about 200 ms after the presentation of the stimulus when colors are defined by a single word in that specific language which does not express continuity (e.g. as in Greek with "ghalazio" for light blue and "ble" for dark blue) instead of defining the colors with words that express continuity (e.g. as in English with light blue, dark blue, etc.).

Even though studies have been carried out before on the perception of color names in different languages or the impact of cultural differences on color perception (for a detailed review see Özgen, 2004), the number of studies examining the impact of the frequency for the color names in a specific language on cognitive functions (perception, memory, etc.) is limited. Neuroimaging studies showed that the left posterior temporoparietal area responsible for word association is activated when recalling the color names with high frequency in language; but that the same activation is not observed for color names with a lower frequency. On the other hand, it is known that the activation of language regions such as the Broca and Wernicke areas located in the left hemisphere which is dominant concerning linguistic skills is effective in the shaping of perception in the right visual area (Regier & Kay, 2009). In conclusion, both universal and language-specific factors play a role in the naming of colors.

Based on the aforementioned information, in this study, three experiments were conducted to examine the digit superiority effect on STM span using the stimulus set developed by researchers. In Experiment 1, we replicated the study of Jones and Macken (2015) to see the digit superiority findings would also observe when Turkish words and digit names were used. Furthermore, it is known that colors with a high level of familiarity in terms of language and culture are remembered better due to their verbal and visual coding. Also, research findings showed that linguistic environment is more effective than STM capacity. Thus, we aimed to investigate in the other two experiments whether the digit superiority effect is still valid when we add linguistically familiar stimulus such as color names (verbal) in Experiment 2, and colors (visual) in Experiment 3.

STM span has been investigated extensively with different stimuli. In contrast, very few studies have investigated visual and verbal STM span for set of colors and color names. Therefore, this study contributes to the literature in three ways. First, it provided a original Turkish stimulus set that can be used in future studies, including digit, word, adjective word, and color stimuli that are equivalent to each other in terms of their frequencies. Second, it showed that the paradigm used in the study of Jones and Macken (2015), also studied effectively with Turkish stimuli. Third, it confirmed that digit superiority effect is indispensable on verbal and visual STM span in three experiments even color and color names were added as variables.

Method

Participants

A total of 91 (N = 33 in Experiment 1, N = 31 in Experiment 2, and N = 27 in Experiment 3) volunteer university students at Hacettepe University participated in the study. Table 1 presents the demographic characteristics of the participants along with the mean and standard deviations for the scores they received from the aforementioned screening tests.

Table 1
Demographic Characteristics of the Participants and The Mean Values And Standard Deviations Of Screening Test Scores

	Experiment 1 (N = 33)	*Experiment 2 (N = 31)*	*Experiment 3 (N = 27)*
Age	M = 21.27, SD = 1.40	M = 21.84, SD = 1.44	M = 21.15, SD = 1.63
Gender	Female = 17, Male = 16	Female = 13, Male = 18	Female = 14, Male = 13
Hand Preference	Right = 29, Left = 4	Right = 30, Left = 1	Right = 24, Left = 3
BDI score	M = 8.33, SD = 4.09	M = 8.32, SD = 4.01	M = 8.15, SD = 4.11
BNT-TR score	M = 23.21, SD = 2.77	M = 24.52, SD = 2.28	M = 21.70, SD = 2.92

Note: BDI: Beck Depression Inventory; BNT-TR: Boston Naming Test-Turkish Version.

Measurements

Beck Depression Inventory: Developed by Beck et al. (1961), BDE is an inventory comprised of 21 items that are used for determining the level of depression. Studies have been carried out for the adaptation of BDE into Turkish as well as the validity and reliability studies (Hisli, 1988). The split-half reliability of the scale is 0.74, whereas the criterion-related validity coefficients are 0.74 and 0.63. It is known that depression negatively affects motor performance, cognitive effort (Cohen, 1982), and STM (Colby & Gotlib, 1988). Therefore, BDE was used in this study to control the depressive symptom severity of the participants. Those with BDE scores of 17 and above were not included in the study.

Boston Naming Test-Turkish version (BNT-TR): Developed by Kaplan et al. (1983), BNT is a neuropsychological tool used for evaluating linguistic skills including object naming and word retrieval (Miotto et al., 2010). BNT was used to evaluate the linguistic ability and/or experience of the participants. BNT is comprised of 60 pictures ordered in increasing difficulty. The pages in the test booklet with the 60 pictures are double-sided with the picture of the object at the front and multiple-choice items comprised of 4 items each (distractor pictures) at the back. The test starts at item 30 for children aged above 10 and non-aphasic adults in the standard test comprised of 60 items. In the present study, BAT-TR (31 original, 29 new items) (Ekinci & Cangöz, 2018), the Turkish version of BAT, was used and only spontaneous scores were taken into consideration.

Short Term Memory Span Task: To measure STM span, tasks comprised of 9 digit names and 9 words in Experiment 1; 9 digit names, 9 words (adjectives) and 9 color names in Experiment 2; 9 digits, 9 digit names, 9 color names and 9 colors in Experiment 3 have been prepared by the researchers (See, Figure 1). Words and color names were selected from the Dictionary of Word Frequency for Written Turkish (Göz, 2003); digits were selected from among numbers between 1-9. First, the frequencies were determined for the names of digits (such as one, two, three) corresponding to each digit between 1-9 after which the other 18 words (words and adjectives) and 9 color names were made equivalent with the aforementioned 9 digit names concerning frequency and number of letters (Table 2). The words used in Experiment 1 were determined by considering that they have the same number of letters and frequency with the names of digits from 1 to 9. Since the digit and color names used in Experiment 2 were adjectives by nature, the words were also comprised of adjectives. While it was considered that the words (adjectives) are equivalent with the digit names from 1 to 9 with regard to the number of letters and frequency; the color names could be made equivalent only with regard to frequency due to their limited number in Turkish. In addition to digit names and color names, the digits (e.g. 1, 2, 3) as the numerical correspondence of the digit names (e.g. one, two, three) and the colors corresponding to the color names (e.g. blue, green, yellow) were used in Experiment 3. Words that have synonyms were not used in any of the three experiments. Appendix 1 presents a list of the stimuli used within the scope of Experiments 1, 2, and 3.

There was no statistically significant difference between the digit names and words used as stimuli in Experiment 1 with regard to the number of letters ($t_{(16)} = .00$, $p > .05$) and frequency ($t_{(16)} = .86$, $p = .400$). There were no statistically significant differences between the digit names, words and color names used as stimuli in Experiment 2 with regard to the number of letters ($F_{(2, 24)} = 2.12$, $p = .142$) and frequency ($F_{(2, 24)} = .95$, $p = .400$).

Table 2
Digit, Word and Color Name Frequencies in Turkish for Stimuli Used in Experiment 1 and 2

Experiment 1				*Experiment 2*			
*Digit Name (TUR/ENG)**	*Freq.*	*Word (TUR/ENG)**	*Freq.*	*Word Adj. (TUR/ENG)**	*Freq.*	*Color Name (TUR/ENG)**	*Freq.*
Bir (One)	29286	Var (Exist)	4200	Çok (Very)	5405	Beyaz (White)	282
İki (Two)	2294	Yol (Road)	1994	Her (Each)	2924	Kırmızı (Red)	224
Üç (Three)	749	Ad (Name)	954	Şu (That)	843	Yeşil (Green)	204
Dört (Four)	328	Ağaç (Tree)	314	Ağır (Heavy)	316	Sarı (Yellow)	157
Beş (Five)	324	Saç (Hair)	331	Sağ (Right)	322	Siyah (Black)	153
Altı (Six)	45	Leke (Stain)	44	Ilık (Warm)	54	Gri (Grey)	37
Yedi (Seven)	184	Otel (Hotel)	183	Sert (Hard)	176	Mavi (Blue)	142
Sekiz (Eight)	95	Soğan (Onion)	95	Kalın (Thick)	98	Pembe (Pink)	52
Dokuz (Nine)	5	Firar (Escape)	5	Puslu (Hazy)	5	Bej (Beige)	9

** TUR: Turkish; ENG: English; Freq: Frequency.*
Note: Turkish words were used in experiments; their meaning in English were given in parentesis.

A total of four different series of the stimulus were used that represent different lengths (2-9 units) for digit names and words in Experiment 1; digit names, words (adjectives) and color names in Experiment 2 and digit, digit names, color names and colors in Experiment 3. Accordingly, the participants were randomly presented with a total of 64 stimuli (32 digit names, 32 words) series in Experiment 1; a total of 96 stimuli (32 digit names, 32 words, 32 color names) series in Experiment 2 and a total of 128 stimuli (32 digits, 32 colors, 32 digit names, 32 color names) series in Experiment 3. Since it was determined in Experiment 3 that the participants confuse the beige with the white; the beige with a frequency of 9 was replaced with the burgundy with a frequency of 4. A total of four different stimuli series were used in the experiments similar to the study by Jones and Macken (2015) instead of a single stimulus series for different lengths to be able to carry out comparisons. In Jones and Macken's (2015) study, unlike traditional STM span tasks such as WMS-R forward and backward sub-tests or Visual Aural Digit Span Test (VADS), the response is not produced verbally or in writing (recall) by the participant. Instead, it is produced by choosing from the stimuli seen on the screen. In order to compare the findings, Jones and Macken's (2015) response type was used as the dependent variable in our study.

Procedure

Ethics approval dated 27.09.2018 and numbered 245970 was obtained for the applications from Hacettepe University Ethics Commission. Demographic Information Form and screening tests (BDE and BAT-TR) were applied individually in random order during a different session. Beck Depression Inventory (BDE) was applied to the participants for determining their depression levels (Beck, 1961; Hisli, 1988) and Boston Naming Test-Turkish version (BNT-TR) (Ekinci & Cangöz, 2018; Kaplan et al., 1983) was applied for determining their linguistic skills. Different participants took part in each experiment. Each experiment started with a training session. The participants were presented during the practice session with 4 stimulus series comprised of 2 and 3 digits and those who were successful in at least 3 out of these stimulus series were included in the experiment stage.

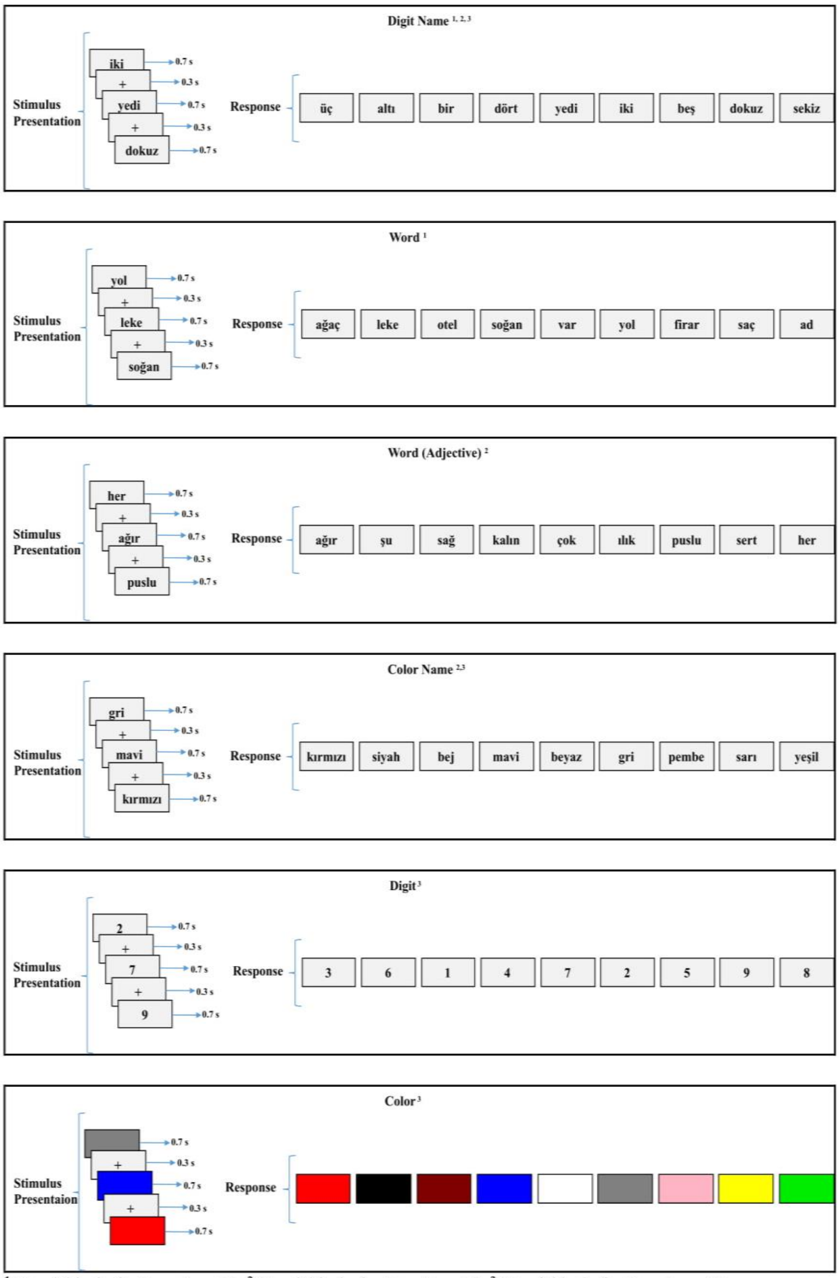
Different familiar stimulus series were presented to the participants in different blocks during Experiment 1, Experiment 2, and Experiment 3, and the order of presentation of the blocks was balanced between the participants. The screen time of each stimulus was determined as 0.7 sec with the screen time of the fixation screen determined as 0.3 sec. The participants were presented randomly at the center of the computer screen with digit name and word series of different lengths (between 2-9 units) during Experiment 1; with digit name, word (adjective) and color name series during Experiment 2 and with digit, digit name, color name and color series during Experiment 3. All stimuli were presented on the screen in random order after the presentation of each series and the participants were asked to click and select the stimuli they encountered in the previous screen in the correct order of presentation. In all experiments, the selection was represented with an asterix (*) corresponding to the option selected via the response coding method when the user clicked any one of the responses displayed on the screen. In this way, the participants were prevented from seeing their responses openly thereby preventing the situation where they can reduce the number of options thereby making it simpler to make a selection. Figure 1 presents the stimuli and related blocks used in the experiments.

During the experiment, if none of the four series with the same length in a single stimulus block is recalled correctly the task is finalized and instead of passing to the next span (e.g. passing from a 2 digit number series to 3 digit number series), the next user block (e.g. color series instead of digit series) is used.

Results

Digit name and word in Experiment 1; digit name, word, and color name in Experiment 2; digit, color, digit name, and color name variables in Experiment 3 were manipulated as within-subject. STM span size (length of longest series recalled correctly) and the total STM span (total stimulus series recalled correctly) were the dependent variables for all experiments.

The effect of familiar stimulus type (digit name and word) on STM span size and total span was analyzed via *paired sample t-test* in Experiment 1. Accordingly, there was a significant difference in Experiment 1 between the digit name and word stimuli with regard to span size ($t_{(32)}$ = 2,81, p < .05) and total span ($t_{(32)}$ = 6.17, p < .001).



[1]Stimuli blocks for Experiment 1, [2]Stimuli blocks for Experiment 2, [3]Stimuli blocks for Experiment 3
Note: Turkish words were used in experiments, their meanings in English were given in Table 2.

Figure 1. Flow chart showing the stimulus blocks used in Experiments 1, 2 and 3

While in Experiment 2, the effect of familiar stimulus type (digit name, word and color name) on STM span size and total span was analyzed via *repeated measure one-way ANOVA*. The main effect of familiar stimulus type on span size was determined to be significant as a result of *one-way ANOVA* ($F_{(2, 60)}$ =

36.04, $p < .001$, $\eta_p^2 = .55$). *Post hoc* analysis revealed that the differences between digit name ($M = 6.90$, $SD = 0.17$) and word ($M = 5.45$, $SD = 0.14$) stimuli ($MD = 1.45$, $SE = 0.17$, $p < .001$, $r = .74$) along with the difference between digit name and color name ($M = 5.58$, $SD = 0.17$) stimuli were significant ($MD = 1.32$, $SE = 0.21$, $p < .001$, $r = .63$). On the other hand, the difference between word and color name stimuli was not statistically significant ($MD = 0.13$, $SE = 0.18$, $p > .05$, $r = .09$).

Similarly, the effect of familiar stimulus type on STM total span was determined as significant ($F_{(2, 60)} = 54.71$, $p < .001$, $\eta_p^2 = .65$). Also, *post hoc* analysis revealed that the differences between digit name ($M = 19.48$, $SD = 0.54$) and word ($M = 14.84$, $SD = 0.43$) stimuli ($MD = 4.65$, $SE = 0.48$, $p < .001$, $r = .78$) along with the digit name ($M = 19.48$, $SD = 0.54$) and color name ($M = 15.00$, $SD = 0.50$) stimuli were statistically significant ($MD = 4.48$, $SE = 0.58$, $p < .001$, $r = .70$). On the other hand, the difference between word and color name was not statistically significant ($MD = 0.16$, $SE = 0.44$, $p > .05$, $r = .05$).

The effect of familiar stimulus type (digit name, digit, color name and color) on total span and span size was analyzed in Experiment 3 via *repeated measure one-way ANOVA*. Accordingly, the main effect of the type of familiar stimulus on span size was significant ($F_{(3, 78)} = 33.03$, $p < .001$, $\eta_p^2 = .56$). Span size of digit name ($M = 6.30$, $SD = 0.18$) was larger at a statistically significant level in comparison with the color name ($M = 5.59$, $SD = 0.23$) ($MD = 0.70$, $SE = 0.21$, $p < .05$, $r = .36$) and color ($M = 5.11$, $SD = 0.20$) ($MD = 1.19$, $SE = 0.22$, $p < .001$, $r = .52$) stimuli. Span size of digit ($M = 7.04$, $SD = 0.26$) was greater at a statistically significant level in comparison with the digit name ($MD = 0.74$, $SE = 0.22$, $p < .05$, $r = .36$), color name ($MD = 1.44$, $SE = 0.22$, $p < .001$, $r = .60$) and color ($MD = 1.93$, $SE = 0.21$, $p < .001$, $r = .72$). Span size of color name was greater than color ($MD = 0.48$, $SE = 0.16$, $p < .05$, $r = .32$).

Similarly, the main effect of familiar stimulus type on total span was statistically significant ($F_{(3, 78)} = 54.96$, $p < .001$, $\eta_p^2 = .68$). Total span for digit name ($M = 17.15$, $SD = 0.55$) was greater at a statistically significant level than color name ($M = 14.41$, $SD = 0.71$; $MD = 2.74$, $SE = 0.66$, $p < .05$, $r = .43$) and color ($M = 12.63$, $SD = 0.57$; $MD = 4.52$, $SE = 0.71$, $p < .001$, $r = .58$). Total span for digit ($M = 20.82$, $SD = 0.97$) was greater at a statistically significant level in comparison with the digit name ($MD = 3.67$, $SE = 0.83$, $p < .05$, $r = .45$), color name ($MD = 6.41$, $SE = 0.61$, $p < .001$, $r = .77$) and color ($MD = 8.19$, $SE = 0.73$, $p < .001$, $r = .78$) stimuli. Total span for color name was greater at a statistically significant level in comparison with color ($MD = 1.78$, $SE = 0.49$, $p < .05$, $r = .38$).

Table 3

Summary of Total Span and Span Size Means, Standart Errors and Posthoc Comparisons for Three Experiments

	Types of Stimuli	*Total Span*	*Span Size*	*PostHoc Comparisons*
Experiment 1	Digit Name	16.55 ± 3.47	6.00 ± 1.25	Digit Name > Word**
	Word	13.88 ± 2.69	5.33 ± 0.99	
Experiment 2	Digit Name	19.48 ± 0.54	6.90 ± 0.17	Digit Name > Word**
	Color Name	15.00 ± 0.50	5.58 ± 0.17	Digit Name > Color Name**
	Word	14.84 ± 0.43	5.45 ± 0.14	Color Name > Word
Experiment 3	Digit Name	17.15 ± 0.55	6.30 ± 0.18	Digit Name > Color Name*
	Color Name	14.41 ± 0.71	5.59 ± 0.23	Digit Name > Color**
	Digit	20.82 ± 0.97	7.04 ± 0.26	Digit > Color Name**
	Color	12.63 ± 0.57	5.11 ± 0.20	Digit > Color **
				Color Name > Color*

$*p < .05$; $**p < .001$.

Discussion

The effect of linguistically familiar stimuli types on STM span was examined in the present study via the developed stimulus/task set. We conducted three experiments to investigate whether memory spans differed across these familiar stimuli. We compared digit names and words in Experiment 1, digit names, words, and color names in Experiment 2, and digits, digit names, colors and color names in Experiment 3. Our findings showed that even when different types of stimuli were paired with different characteristics, digit superiority effect was observed in all three experiments. Also, digits and digit names had a greater memory span over the other stimuli. This study confirmed that familiarity and long-term linguistic knowledge were more effective than STM capacity in relation to LTM. Parallel to the studies in literature, our findings supported that performance in verbal STM showed the long-term linguistic knowledge to the experimental setting (Jones & Macken, 2015, 2018).

Consistent with the original study (Jones & Macken, 2015), Experiment 1 demonstrated that the superiority of the digits in STM span over the words was proven once again in the replication. Familiar stimuli types were paired methodically concerning frequency, number of letters which may be confounding variables as a result of which the superiority with regard to STM of digits was supported even in cases when the digit series were randomly presented in writing. Regarding STM span, the superiority of digits over the color names and words continued in Experiment 2. It is observed that digit names and words with high levels of familiarity are effective on STM span. Although, a statistically significant difference with regard to STM span or capacity could not be determined for the familiar stimuli of words and color names, it was observed that total span and span size of color names were greater than words. Even though color names have a high level of familiarity, this inconsistency may be due to the fact that their frequency is lower than those of the words used in Experiment 2, and that the adjective words and color names used in Experiment 2 are coded only verbally in compliance with the Dual-Coding Theory (Hulme et al., 1997). Also, a greater STM span for color names showed that familiarity might be more effective on verbal STM.

Another possible explanation for the results of Experiment 2 might be the classical account of the effect of long-term linguistic knowledge on short-term memory (Macken et al., 2015). According to this explanation, linguistic familiarity is affected by the measurement type of STM span. That is linguistically familiar stimuli such as color names can be found to be more effective on STM span when they are tested by serial recall instead of serial recognition. This distinction arises from the requirements of reproducing the previously presented stimuli in the recall tasks (Jefferies et al., 2009).

In Experiment 3, consistent with the previous two experiments, the superiority of digits concerning STM span over the other familiar stimuli of digit name, color name, and color continued. Following Paivio‘s (1971) Dual-Coding Theory, it is asserted that colors are recalled better since they are coded both verbally and visually; while color names are coded only verbally. However, in Experiment 3, color names were recalled better in comparison with colors. This is considered to be due to the interference effect between visual and verbal representations subject to the interaction between visual perception and language as well as the limited capacity of VSTM (Cowan, 2001; Luck & Vogel, 1997; as cited in Kool et al., 2014; Peteranderl & Oberauer, 2018).

In daily life different cognitive tasks such as remembering a telephone number, solving mathematical problems require serial order information. It is known that presentation in series and units with high frequency (digits) improves short-term serial recall in STM (Johnes & Macken, 2015; Peteranderl & Oberauer, 2018). STM span is also affected by a number of chunks that can be held in the STM store. Verbal STM span is improved by chunks that exist only in LTM. Chunking can facilitate better use of the STM capacity and memory advantage over an unfamiliar sequence of letters. However, chunking efficiency varies according to the amount of information that can be stored and the underlying representational vocabulary of the memory system (Norris & Kalm, 2021). Goldberg (2003) put forth as a result of STM span measurements that STM performance increases with the increasing similarity between the presented stimuli series and the long-term linguistic experiences of individuals in their native language. This may be due to the use of different strategies (such as chunking) for recalling the stimuli encountered in many different areas in daily life (e.g. a number series like 3, 1, 5, 2, 4 may be used for a student number, phone or bank password. STM span tasks require the recalling of item series in the same order. In this context, it is considered that familiarity to recall digits as a series in daily life may be effective on digit superiority since it is more advantageous than all the other conditions (color, color name, digit name) used in Experiment 1 and 2. However, since we will rarely be faced with words in daily life randomly due to the nature of syntactic processes, the fact that word stimuli (color name and word) in Experiment 2 are not superior may be due to this familiarity.

On the other hand, the superiority of digits in Experiments 1 and 2 support the opinion that STM feeds on LTM via the articulatory loop (Hulme et al., 1991). The information in LTM as the source of permanent memory as a result of learning and experiences may be recalled to STM when necessary by way of controlled or automatic processes (Terry, 2013). When considered from this perspective, the finding that revealed the superiority of digits may be explained by the automatic recall of representations for digits from LTM to STM (Hulme et al., 1991).

According to Gentner and Goldin-Meadow (2003), language which can be used as a tool to code the perceptive world has an impact on our cognition even in non-lingual cases. This impact can be observed in two ways as selectivity and augmentation of representational resources. Accordingly, while selectivity makes the components coded linguistically more important at the cognitive level when perceiving the world, it decreases the importance of components that we have not coded. Whereas the augmentation of representational resources enables the formation of more advanced internal representations (e.g., the color blue evoking the sea or the sky) superior to the visual or spatial representations of language. Language acts as a lens playing an active and functional role in the process of perceiving the world (Ünal & Papafragou, 2016). Representations on visual perception and language interaction can guide our thoughts and behaviors via WM. In this regard, it has been put forth that labeling via color code or location code visually-spatially affects the quality and quantity of the information stored in WM and hence increases the performance of WM (Souza & Skora, 2017). Accordingly, visual or verbal stimuli enable the activation of categorical codes even when presented by themselves thereby leading to the interaction of visual and verbal inputs in the mind (words "banana, blood, sea" activate color codes of "yellow, red, blue" respectively). This interaction takes place sometimes as the interference between verbal or visual representations (increase in response time since the color "yellow" is still activated when "banana" is presented not in yellow color but with a black-white-grey tone) and sometimes as an enhancement (increase in recall and/or recognition probability when it is both semantically and physically following the dual-coding effect). The difference between visual and verbal representations has not been fully understood; however, studies put forth that the interference effect of verbal interference on visual representations is greater than the interference effect of visual interference on verbal representations (Souza & Skora, 2017). Moreover, Peteranderl and Oberauer (2018) showed that there was an interfere effect of articulatory suppression on serial recall of colors, suggesting that serial-order memory of visual color stimuli could have been enhanced by using verbal tags. While the fact that color names are recalled better in Experiment 3 than colors can be explained by the interference effect of verbal representations on visual representations; it also shows that color names are coded only with a verbal tag, while colors are coded with a verbal tag that also includes the visual image. Our findings lead us to think that individuals internally repetition of the color names when they see the visual representations of colors which are due to the interference effect of verbal representations on visual representations.

The mutual interference effect between visual and verbal representations can also be explained via proactive interference (PI). PI is defined as the interference effect of previous recalls on future recalls when the color and color names presented in the same block are asked to be recalled afterward and it is examined via the PI paradigm (proactive inhibition paradigm). In a study that makes use of this paradigm, the recall priority between color names (CN) and colors (C) was changed meaning that the (CN-C) task was run in one condition and (C-CN) in the next after which the two conditions were compared concerning PI. Whereas the PI effect is observed in the (CN-C) condition; the PI effect was not observed in the (C-CN) condition. It has been put forth that the asymmetric result obtained in this study is due to the difference between the coding of the colors and color names. In addition, this difference has been interpreted to be due to the improved familiarity with the printed/written color names in daily life in comparison with the colors. Accordingly, the effect of PI related to coding processes on stimuli coded more frequently in daily life decreases (Allen, 1983, 1984 & 1995). Different from these studies, even though color and color names have been presented to the participants in separate blocks in the scope of the present study, it has been put forth that PI may have a greater effect on colors even between different blocks.

A number of limitations to current study need to be acknowledged. First, it is known that color names are fewer in number than words, and their lengths are different in Turkish and English languages. In Experiment 2, therefore, pairing color names with digit names in terms of their frequencies was more limited than pairing digit names with words. Second, In Experiment 2, we determined the color name corresponding to the “nine” (dokuz in Turkish) digit name as “beige” due to its higher frequency. However, when we presented the colors visually in Experiment 3, we noticed that the participants failed to distinguish between white and beige. Therefore, we replaced beige color with burgundy to eliminate the difficulty in visual discrimination.

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Appendix 1

Stimuli Lists

Experiment 1		*Experiment 2*			*Experiment 3*			
*Digit Name (TUR/ENG)**	*Word (TUR/ENG)**	*Digit Name (TUR/ENG)**	*Word(Adj) (TUR/ENG)**	*Color Name (TUR/ENG)**	*Digit*	*R.G.B Code***	*Digit Name (TUR/ENG)**	*Color Name (TUR/ENG)**
Bir (One)	Var (Exist)	Bir (One)	Çok (Very)	Beyaz (White)	1	(255-255-255)	Bir (One)	Beyaz (White)
İki (Two)	Yol (Road)	İki (Two)	Her (Each)	Kırmızı (Red)	2	(255-0-0)	İki (Two)	Kırmızı (Red)
Üç (Three)	Ad (Name)	Üç (Three)	Şu (That)	Yeşil (Green)	3	(0-238-0)	Üç (Three)	Yeşil (Green)
Dört (Four)	Ağaç (Tree)	Dört (Four)	Ağır (Heavy)	Sarı (Yellow)	4	(255-255-0)	Dört (Four)	Sarı (Yellow)
Beş (Five)	Saç (Hair)	Beş (Five)	Sağ (Right)	Siyah (Black)	5	(0-0-0)	Beş (Five)	Siyah (Black)
Altı (Six)	Leke (Stain)	Altı (Six)	Ilık (Warm)	Gri (Grey)	6	(128-128-128)	Altı (Six)	Gri (Grey)
Yedi (Seven)	Otel (Hotel)	Yedi (Seven)	Sert (Hard)	Mavi (Blue)	7	(0-0-255)	Yedi (Seven)	Mavi (Blue)
Sekiz (Eight)	Soğan (Onion)	Sekiz (Eight)	Kalın (Thick)	Pembe (Pink)	8	(255-181-197)	Sekiz (Eight)	Pembe (Pink)
Dokuz (Nine)	Firar (Escape)	Dokuz (Nine)	Puslu (Hazy)	Bej (Beige)	9	(128-0-0)	Dokuz (Nine)	Bordo (Burgundy)

* TUR: Turkish; ENG: English; ** R.G.B. Codes : Red, Green, Blue Code.
Note: Turkish words were used in experiments, their meaning in English were given in parentesis.