The Effects of Duration Words and Spatial-Temporal Metaphors on Perceived Duration

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This is to certify that I have examined this copy of a master's thesis by

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STATEMENT OF AUTHORSHIP

This thesis contains no material which has been accepted for any award or any other degree or diploma in any university or other institution. It is affirmed by the candidate that, to the best of her knowledge, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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ABSTRACT

Numerous studies have reported that subjective duration estimates are positively related to the magnitude of various non-temporal stimuli presented in different modalities. The subjective estimates of time are stretched as a function of increasing number (Xuan et al., 2007), stimulus size (Ono & Kawahara, 2007), luminosity (Goldstone, Lhamon & Sechzer, 1978), and complexity-intensity (Schiffman & Bobko, 1974). Our study investigated whether the temporal and spatial magnitude information conveyed by linguistic stimuli would affect perceived duration in a temporal reproduction task. In Experiment 1, we used duration words referring to different distinct durations (e.g. *second, week*), which implied a temporal magnitude. In Experiment 2, we used adjectives that were part of the spatial-temporal metaphors (e.g. *long vs. short*), referring to indistinct temporal as well as spatial magnitudes. Our results indicated a migration effect, meaning that participants over-reproduced the shorter target duration (2.4 s) and under-reproduced the longer target duration (4.8 s) in all conditions in both experiments. In Experiment 1, participants under-reproduced the longer target duration more when they saw "*week"* in the training and "*year"* in the reproduction. Yet, we did not observe this same semantic magnitude effect in other word pairs across two experiments. Overall, we did not find supporting evidence for magnitude information conveyed by language affecting subjective time estimates. Possible reasons for these results will be discussed.

Keywords: time perception, language, duration words, spatial-temporal metaphors

ÖZET

Pek çok çalışma, süre algısı ile bu süreyi temsil eden uyaranın farklı özelliklerinin büyüklüğü arasında pozitif bir ilişki göstermektedir. Örneğin; öznel süre algısının artan rakamsal değerler (Xuan ve ark., 2007), uyaran büyüklüğü (Ono & Kawahara, 2007), parlaklığı (Goldstone, Lhamon & Sechzer, 1978), karmaşıklığı ve yoğunluğu (Schiffman & Bobko, 1974) ile arttığı gözlemlenmiştir. Bu çalışmada, zamansal yeniden üretim görevi kullanarak, dil uyaranı ile verilen zamansal ve uzamsal büyüklük / küçüklük bilgisinin kişilerin öznel zaman algısını etkileyip etkilemeyeceğini araştırdık. İlk deneyde, belirli bir süre anlatan zaman kelimeleri (örneğin; *saniye, hafta*) kullandık. İkinci deneyde ise, hem uzamsal hem de süre olarak büyüklük anlatan uzamsal-zamansal dil metaforları (örneğin; *uzun ve kısa*) kullandık. Sonuçlar, tüm katılımcıların kısa süreyi daha uzun, uzun süreyi ise daha kısa yeniden ürettiğini gösterdi. Ayrıca, ilk deneyde, "hafta" kelimesinin hedef sürede, "sene" kelimesinin ise hedef sürenin yeniden üretildiği esnada göründüğü durumda, katılımcıların uzun süreyi diğer tüm durumlara göre daha da az ürettikleri bulundu. Fakat diğer durumlarda kelimeler yolu ile belirtilen bu anlamsal büyüklük-küçüklük bilgisinin algılanan süreyi etkilediği görülmedi. Bulgular ile ilgili olası sebepler tartışılmıştır.

Anahtar kelimeler: zaman algısı, dil, zaman kelimeleri, uzamsal – zamansal metaforlar

DEDICATION

To my mother and my father,

for their endless support

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TABLE OF CONTENTS

STATEMENT OF AUTHORSHIP iii
ABSTRACT iv
ÖZET v
DEDICATION vi
ACKNOWLEDGEMENTS vii
TABLE OF CONTENTS viii
LIST OF FIGURES x
CHAPTER 1 1
INTRODUCTION 1
1. The Interaction Between Non-Temporal Stimulus Magnitude and Perceived Duration.... 1
2. Interaction Between Language Processing and Low-Level Perceptual/Sensory Processing 5
CHAPTER 2 8
EXPERIMENT 1 8
1.Method 8
1.1. Participants 8
1.2. Task and Stimuli 9
Session 1 10
Session 2 11
2. Procedure 11
3. Data Analyses 12
4. Results 14
CHAPTER 3 20
EXPERIMENT 2 20
1.Method 20
1.1. Participants 20
1.2. Task, Procedure & Stimuli 21
Session 1 21
Session 2 21
2. Data Analyses 22
3. Results 22
CHAPTER 4 28

GENERAL DISCUSSION 28
REFERENCES 34
APPENDICES 41
APPENDIX A 41

LIST OF FIGURES

Figure 1. A typical trial of the temporal reproduction task 10
Figure 2. Mean normalized reproduction scores for word pair 1 (A) and word pair 2 (B) across two target durations. Error bars denote the standard errors of the mean. 15
Figure 3. The mean normalized reproduction time as a function of the order of the word referring to a shorter duration (training vs. reproduction) for 2.4 s (A) and 4.8 (B) s. The error bars denote the standard errors of the mean. 16
Figure 4. The averaged normalized scores for same and different word pairs across two target durations. 17
Figure 5. The coefficient of variations (CV) for each word pair across two target durations. The error bars denote the standard errors of the mean. 18
Figure 6. Mean normalized reproduction scores for word pair 1 (A) and word pair 2 (B) across two target durations. Error bars denote the standard errors of the mean. 23
Figure 7. The mean normalized reproduction time as a function of the order of the word referring to a shorter duration / smaller magnitude (training vs. reproduction) for 2.4 s (A) and 4.8 (B) s. The error bars denote the standard errors of the mean. 24
Figure 8. The averaged normalized scores for same and different word pairs across two target durations.. 25
Figure 9. The coefficient of variations (CV) for each word pair across two target durations. The error bars denote the standard errors of the mean. 26

CHAPTER 1

INTRODUCTION

The perception of time is one of the key features in many biological and behavioral processes. Although accurate timing is essential to many daily tasks, substantial evidence shows that the subjective experience of time is not perfectly isomorphic to the physical time (Eisler, 1976; Fraisse, 1984; Zakay, 1993). Rather, perceived durations are contracted or stretched depending on many factors, including subtle changes in non-temporal stimulus properties. In this study, we investigated how perceived durations are modulated by the temporal magnitude information given in the medium of language.

In the following sections, we will first talk about the effects of non-temporal stimulus magnitude on perceived duration. Later, we will discuss how language processing interacts with low-level perceptual and sensory processing. And lastly, we will present the current study.

1. The Interaction Between Non-Temporal Stimulus Magnitude and Perceived Duration

Numerous studies have reported that subjective duration estimates are positively related to the magnitude of various non-temporal stimuli presented in different modalities. In visual studies, the longer judged durations as a function of increasing number (Xuan et al., 2007; Oliveri et al., 2008; Vicario, 2011, 2013), stimulus size (Ono & Kawahara, 2007), stimulus's luminosity (Goldstone, Lhamon & Sechzer, 1978) and complexity (Schiffman & Bobko, 1974) has been established. For example, Oliveri and colleagues (2008) asked participants to determine whether a visually presented digit (test cue) had been presented for a time interval longer or shorter than a reference digit (i.e., “5”) presented for a standard duration (i.e., 300 ms). The test cue was either a digit bigger (“9”) or a smaller (“1”) than the reference one. Results showed that subjective duration judgments were influenced by the quantity expressed by the test stimulus. Independent of their actual duration, when the test cue was a smaller number than the reference cue, its duration was underestimated compared to the neutral condition in which the test and the reference cue were the same digit. Participants were also more accurate and faster when classifying the duration of a number for smaller magnitude numbers presented for a shorter time (congruent trials) than smaller magnitude numbers presented for a longer duration (incongruent trials) in a Stroop-like paradigm (Xuan et al., 2007). However, the main effect of numerical magnitude on perceived duration was present only for the target intervals of 2000 and 2200 ms, but not observable for 700 and 900 ms in a temporal bisection task (a temporal discrimination task, in which participants are asked to compare several probe durations compared to short and long standard durations), suggesting that this main effect might be present only for supra-second (longer than 1000 ms) intervals (Vicario, 2011). It is important to note that this relationship between numerical processing and perceived duration was asymmetric. When people were asked to compare either the duration or the numerosity of sequences of flashing dots in a bisection task, the number magnitudes interfered with the temporal processing, but the durations of sequences of flashing dots did not interfere with the numerical processing, suggesting that the relation is not bidirectional (Dormal et al., 2006). All these suggest the implicit asymmetric effect of quantity represented in number magnitudes on perceived duration.

The effect of stimulus size on perceived duration has also been documented in many studies (Xuan et al., 2007; Ono & Kawahara, 2007). Investigating the effect of numerosity on duration judgments, Xuan and colleagues (2007) also asked whether judgments of durations were influenced by the size of an open square by using the same Stroop-like paradigm.

Results showed that larger squares were judged temporally longer than the smaller ones. When categorizing the durations of stimuli of different sizes by pressing one of four keys ("1" for short and "4" for long) in a temporal categorization task, larger visual stimuli were found to be perceived as lasting longer compared to smaller visual stimuli with the equivalent duration (Ono & Kawahara, 2007).

All the aforementioned studies used a comparative duration judgment, forcing the participants to make decisions about whether the test duration is longer or shorter than target duration or classifying it as a pre-determined interval category. However, the use of comparative duration judgments does not necessarily imply that the stimuli size affects the perceived duration, because it might simply bias decisions in categorization criterion about the duration (Nicholls et al., 2011). To alleviate this problem, a very recent study (Rammsayer & Verner, 2014) investigated the effects of stimulus size on duration estimations by using a temporal reproduction task that was assumed to provide a more direct measure of the subjective experience of time (Danzinger & Du Preez, 1963). In this temporal reproduction task, the participants were asked to reproduce the presentation duration of each stimulus by pressing a pre-designed button and releasing it when they thought the reproduced interval was temporally equal to the corresponding target duration. The results showed that the average of the reproduced durations were greater for larger target stimuli compared to the smaller ones, but this main effect was only observable for the supra-second intervals of 1000- and 1200 ms, which was in accordance with Vicario's (2011) study on the effect of numerical magnitude on duration estimates.

In the literature, there are two alternative explanations for these temporal illusions. The first one is that different quantitative dimensions such as size, intensity and number are represented and processed in a common analog magnitude system (Walsh, 2003). According to "A Theory of Magnitude", proposed by Walsh (2003), space, time and quantity (or number), as well as various other magnitudes (see Bueti & Walsh, 2009), are translated into an abstract magnitude code in the parietal cortex (Hubbard et al., 2005; Cappeletti, Muggleton, & Walsh, 2009; Hayashi et al., 2013), and thus, multiple inputs of magnitude information may interact with each other. However, this theory falls short in explaining the asymmetric relation between time and other spatial and numerical magnitudes (Dormal et al., 2006). The second explanation linking stimulus magnitude with these illusions of time comes from a prominent model of interval timing, "The Scalar Timing Theory" (Gibbon, Church & Meck, 1984). This theory defines sources and forms of timing variability that are derived from clock, memory, and decision processes and assumes a pacemaker-accumulator model. In this model, pacemaker generates pulses that are gated to an accumulator by a switch that is regulated by attention and arousal. Then in the decision stage, these accumulated pulses in the working memory are compared to a random sample from the reference memory representation that is previously stored in the long-term memory. At the end of a given interval, a decision is made based on the pulses recorded and stored in the accumulator, if this response is reinforced; the time value recorded in working memory on that trial is stored in a more permanent reference memory for reinforced values. This model suggests possible mechanisms for explaining these temporal illusions based on some predictions about the modulations of model's components by the non-temporal stimulus properties. One prediction is that attention and arousal induced by stimuli can speed up or slow down timing by either modulating the speed of the pacemaker or the functioning of the switch (Merchant, Harrington & Meck, 2013).. The switch mechanism shows some alterations in its opening and closing latencies (Zakay & Block, 1995) and also, its functioning is probabilistic (Lejeune, 1998). For example, heightened levels of physiological arousal increase pacemaker rate that is thought to expand subjective duration (Mella et al., 2011; Wittmann et al, 2010). Also, the level of attention paid to the timing task itself effects the amount of pulses accumulated by modulating the closing of the switch (Zakay & Block, 1995). Reducing the level of attention paid to the timing task itself compresses the perceived duration (Yarrow, Haggard & Rothwell, 2004).

Although all these studies cited above investigated the effects of non-temporal magnitude information implied by the stimulus on perceived duration and its possible mechanisms, to our knowledge, no study so far has investigated the effects of the magnitude of duration information implied by the word stimuli on time perception. If there is an effect of magnitude on subjective time estimations, then, we would be able to see the same effect of magnitude information derived from the semantic representations activated by the linguistic stimuli. However, how semantic representations of duration and magnitude information encoded by the words interact with the representation of duration, and timing system namely, is mostly unknown.

To alleviate this, the current study aimed to investigate the effects of implicit temporal magnitude information encoded in words on the perception of supra-second intervals of time by employing temporal reproduction task and using 1) temporal words referring to distinct durations (e.g. *week, minute*) or 2) adjectives that are part of the spatial-temporal metaphors referring to indistinct durations and implying magnitude (e.g. *short vs. long*).

2. Interaction Between Language Processing and Low-Level Sensory/Perceptual Processing

Although how language comprehension interacts with duration perception is mostly unknown, a growing body of research investigating the interaction between language processing and sensory/perceptual processing suggests that the semantic representations activated as we process linguistic stimuli affects the content-specific domain of low-level sensory and perceptual processing (Glenberg, Kaschak, 2002, 2003; Zwaan, 2004; Kaschak et al., 2005). In the theories of embodied language processing, language comprehension is regarded as the perceptual and motor simulation of the described situation in the linguistic input (Barsalou, 1999; Glenberg & Kaschak, 2002, 2003; Zwaan, 2004, 2008). According to this recently developed account of language comprehension, sentences and words are understood by the reactivation of the traces of perceptions and actions of the described situation. Thus, comprehension of words referring to a particular modal event should have an interaction with the low-level perceptual processing of that event (Glenberg & Kaschak, 2002, 2003; Zwaan, 2004; Kaschak et al., 2005). However, this interaction between language processing and perceptual processing is assumed to be content-specific. For example, words referring to motion such as *rise* and *fall*, recruit and interact with the sensory systems that are used in motion perception, whereas words referring to motor actions, such as *hit* and *kick*, are assumed to recruit the motor systems used to carry out those actions. The view that comprehension recruits the sensorimotor information has been supported by many studies. Neuroimaging studies revealed that processing of words activated the same brain regions that are active when we process the referents of those words (Pulvermüller, 1999, 2002; Isenberg et al., 2000; Kellenbach, Wijers & Mulder, 2000; Martin & Chao, 2001; Kan et al., 2003). Also, neuropsychological research showed that brain lesions in patients with selective semantic impairment affect perceptual representations that are relevant to the impaired content-specific semantic knowledge (Farah & McClelland, 1991; McRae, de Sa & Seidenberg, 1997; Miceli et al., 2001). Furthermore, many behavioral studies have provided evidence for an interaction between comprehension and perceptual processing, suggesting that higher-level semantic knowledge influences low-level sensory processing in visual perception (Spivey et al., 2001; Stanfield & Zwaan, 2001; Zwaan, Stanfield & Yaxley, 2002; Richardson et al., 2003; Zwaan et al., 2004; Kaschak et al., 2005, 2006; Lupyan et al., 2007; Meteyard, Bahrami & Vigliocco, 2008; Lupyan & Spivey, 2008, 2010) and emotion perception (Barrett, Lindquist & Gendron, 2007; Gendron et al., 2012).

In the embodied language processing literature, even though the role of semantic information activated by language on a wide range of cognitive processing domains has been investigated, the effects of the duration magnitude representations activated by the duration words and metaphors on the content-specific area of perceptual processing, namely duration perception, has not been studied.

The present study aimed to fill a gap in the literature, providing evidence both to duration perception and language processing studies. To this end, in two experiments, we investigated how participants' reproduced duration estimations of a target interval are modulated when they are presented with different word types referring to either 1) distinct amount of duration (i.e. duration words; *week* vs. *year*) or 2) indistinct magnitude or duration (i.e. spatial-temporal metaphors; *long* vs. *short*).

CHAPTER 2

EXPERIMENT 1

In Experiment 1, we investigated how the duration magnitude implied by the external linguistic stimuli affected participants' subjective duration estimations. To this end, in this experiment, we used words referring to different distinct amounts of duration (e.g. *second, year*). We hypothesized that (1) when the word stimulus in the training refers to a shorter duration compared to the word presented in the reproduction (e.g. seeing "second" in the training and "minute" in the reproduction), participants would under-estimate (i.e. over-reproduced) the target interval, (2) when the word stimulus in the training refers to a longer duration compared to the word presented in the reproduction (e.g. seeing "year" in the training and "week" in the reproduction), participants would over-estimate (i.e. under-reproduce) the target interval, (3) there would not be any systematic difference in the reproduced duration estimations when participants are presented with the same words both in the reproduction and training, and (4) there would not be any interaction between target duration and condition, meaning that the hypothesized overestimation and underestimation of the target duration in (1) and (2) would not differ depending on the target duration.

1. Method

1. Participants

In Experiment 1, there were 25 participants (16 females, M_{age}=21.7, SD_{age} =3.77, age range=18-31) from Koç University and compensated with course credit. All participants were right-handed, had normal or corrected-to-normal vision and were tested in both of the sessions. All of them participated the two experimental sessions. We discarded one female subject since her average coefficient of variation (cv) was high (average cv across conditions = .51). Thus, we proceeded with 24 participants for further analyses. All participants provided informed consent prior to the experiment for their participation for two experimental sessions. All the experiments were approved by the Institutional Review Panel for Human Subjects of Koç University.

2. Task and Stimuli

In this experiment, we used a temporal reproduction task. In this task, we asked participants to reproduce a given target duration by pressing a pre-designated response button as close to the target duration as possible. Visual stimuli signaling the target duration to be reproduced were written words on the computer screen. The interval between the onset and the offset of the appearance of the word was the target interval.

In the task, two different target intervals (2400 ms and 4800 ms) were used. On each trial, the participant first saw a word appearing on the screen ("training word") for one of the target intervals. At the end of the target interval, a blank screen was presented for 1 second, followed by a fixation cross presented for a random interval between 500 ms and 1500 ms. After the disappearance of the fixation cross, participants were instructed to initiate the reproduction interval by pressing the space bar and release it when the reproduced interval was perceived as temporally equivalent to that of the target interval. During the reproduction interval, another word ("reproduction word") appeared at the center of the screen and stayed there as long as the participant kept pressing the space bar to reproduce the target interval. Following the termination of the reproduction interval, the next trial was presented after a random interval between 1000 and 2000 ms. A random interval from an exponential distribution with a mean of 500 ms and an upper limit of 1000 ms was chosen and 1000 ms was added to that random interval to specify the inter-trial interval (ITI). The time course of a typical trial is depicted in Figure 1.

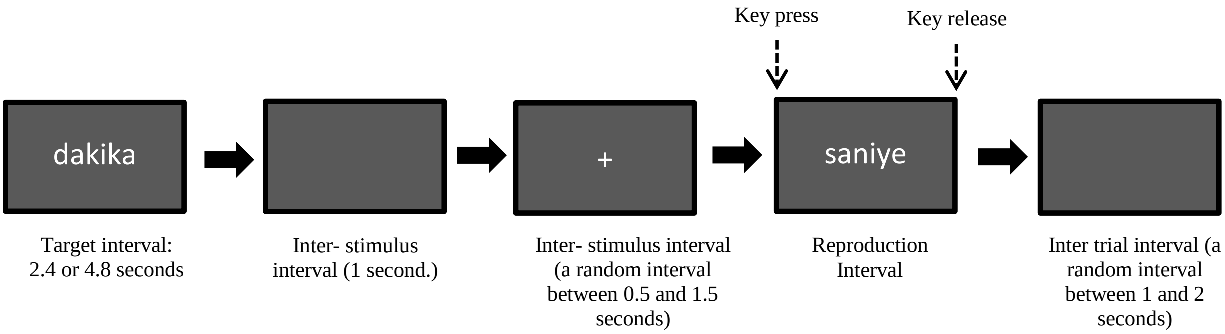


Figure 1: A typical trial of the temporal reproduction task. A target word ("dakika", "*minute*") appears at the center of the screen for the target interval of either 2400 or 4800 ms. After inter-stimulus interval of a blank screen, the participants see a fixation cross for an interval ranging from 500 ms and 1500 ms. The disappearance of the fixation cross indicates the beginning of the reproduction interval. Participants press the space bar to reproduce the target duration. In the meanwhile, as the participant keeps pressing the key, the reproduction word ("saniye", "*second*") appears on the screen and stays there as long as the reproduction phase. The participants release the space bar when he/she thinks the

In each experiment, there were two conditions given in two different sessions. In Condition 1, the words appeared in training and reproductions were different (different word pairs) and in Condition 2, the same word appeared both in the training and the reproduction intervals (same word pairs). In each session there were 4 word pairs (the details of the word pairs are written in detail in the "*Stimuli*" section.) Although the procedure was exactly the same in each session, the nature of the presented words as well as the types of training-reproduction word pairs was different.

In the Experiment 1, we chose 4 words that are referring to different concrete durations: *saniye* ("*second*"), *dakika* ("*minute*"), hafta ("*week*") and sene ("*year*").

Session 1

In Session 1, we used different word pairs. In this condition, participants were trained with the target duration by a word and presented another different word as they reproduced the target interval. The word pairs were: saniye ("second") vs. dakika ("minute") and hafta ("week") vs. sene ("year"). We paired the selected words accordingly so as to make them equal in the number of syllables. In these word pairs, the order of the words referring to the shorter duration also changed. Thus, in some trials participants saw the word referring to the shorter duration in the training (e.g. “hafta” in training and “sene” in reproduction) and vice versa (e.g. “sene” in training and “hafta” in reproduction). Each different word pair was presented 30 times for each one of the target durations in random order.

Session 2

In Session 2, we used same word pairs. In this condition, participants saw the same word both in the training and the reproduction intervals. We created 4 pairs with the selected words: saniye (“second”) vs. saniye, dakika (“minute”) vs. dakika, hafta (“week”) vs. hafta and sene (“year”) vs. sene. Each same word pair was presented 30 times for each one the target durations in random order.

2. Procedure

At the beginning of the first session, each participant filled out a questionnaire regarding their age, sex, number of years of education they completed and whether they used any psychiatric medication. After completing the questionnaire, participants were seated at a distance of approximately 60 cm from the screen, in a dimly lit room and used Apple iMac keyboard to provide their responses. All stimuli were presented on a 21.5’’ Apple iMac G4 computer, generated in Matlab using the Psychtoolbox extension. Before starting the experiment, participants were given instructions about the task and instructed not to count, engage in any rhythmic activity or generate any kind of conscious strategy when estimating the target intervals during the task. After the instruction, each participant completed 4 practice trials, in which visual feedback was given as the normalized distance between the given and the reproduced intervals.

All words were presented at the center of the screen, printed in white on a black background. There were 30 presentations for each and every training word-reproduction word pairs for each of the target durations. Hence, in each session, for 2 target durations and 4 word pairs, there were 240 experimental trials. We also added 24 trials (%10 of the actual experimental trials) in which the target words appeared for a random interval between 500 and 5000 ms in order to avoid participants to unconsciously label the selected target intervals as “short” and “long” durations. Thus, in each session, there were 264 trials in total, 240 of which were used in the analyses. All trials were presented randomly. The word pairs and their corresponding presentation times for each condition could be found in Table 1 in Appendix.

Additionally, to check whether participants looked at the screen, we asked them to report the last word they saw on the screen randomly on 12 of the trials. Participants who could not correctly identify the words 3 or more times were discarded.

Each participant completed the two sessions and the order of the sessions was counterbalanced across subjects. Each experimental session lasted 50-60 minutes and was separated by a minimum of 1 and a maximum of 5 days.

3. Data Analyses

For every participant, we calculated the normalized reproduced time (i.e. the reproduced duration divided by the target duration) and averaged those scores for each word pair - target duration combination to get the mean normalized reproduction scores. Trials in which the reproduced intervals were greater than three times, or smaller than one third of the target duration were excluded from the analyses (Karsılar & Balcı, under revise; average percentage of cases per participant: Target Interval of 2.4 s: *M*= 3.44 %; Target Interval of 4.8 s: *M*= 4.68m %). Also, the mean normalized reproduction scores above and below three standard deviations of the sample mean for any of the word pairs for a specific target duration were treated as outliers and excluded from further analyses (average percentage of cases per condition: 2.4 ms: M= 0.25 %; 4.8 ms: M= 0.37 %). Also, for each participant, we calculated the coefficient of variation (CV; i.e. standard deviation of each condition divided by its mean) for each condition. The CV scores above and below three standard deviations for any of the word pairs for specific target duration were treated as outliers. None of the CV scores was discarded following this criterion.

For different word pairs (Session 1), we conducted a three-way repeated measures ANOVA with target duration (2 levels; 2.4 and 4.8 seconds), different word pairs (2 levels; saniye ("second") vs. dakika ("minute") and hafta ("week") vs. sene ("year"), and the order of the word referring to the shorter duration (2 levels; shorter duration presented in training vs. reproduction) as the within-subject factors, and the mean normalized reproduced duration as the dependent measure. For any interaction, we conducted follow up two-way repeated measures ANOVA with word pairs and the order of the shorter duration as the two within-subject factors separately for two target durations. For same word pairs (Session 2), we conducted a two-way repeated measures ANOVA with target duration (2 levels; 2.4 and 4.8 s) and same word pairs (4 levels; saniye ("second") vs. saniye; dakika ("minute") vs. dakika; hafta ("week") vs. hafta and sene ("year") vs. sene) as the within-subject factors and the mean normalized reproduced intervals as the dependent measure. To compare same and different word pairs for specific target duration, we conducted one-way repeated measures ANOVA with all word pairs separately for each target duration. Finally, to investigate whether there is an effect of change in word from training to reproduction, we averaged the mean normalized reproduced durations for different and same word pairs separately for each target duration and conducted a two-way repeated measures ANOVA with the word pair type (2 levels; same vs. different) and target duration (2 levels; 2.4 s and 4.8 s) as the within-subject factors.

For multiple hypotheses testing, we used Bonferroni adjusted alpha levels in pairwise comparisons. We applied Greenhouse-Geisser correction when sphericity assumption was violated in all analyses.

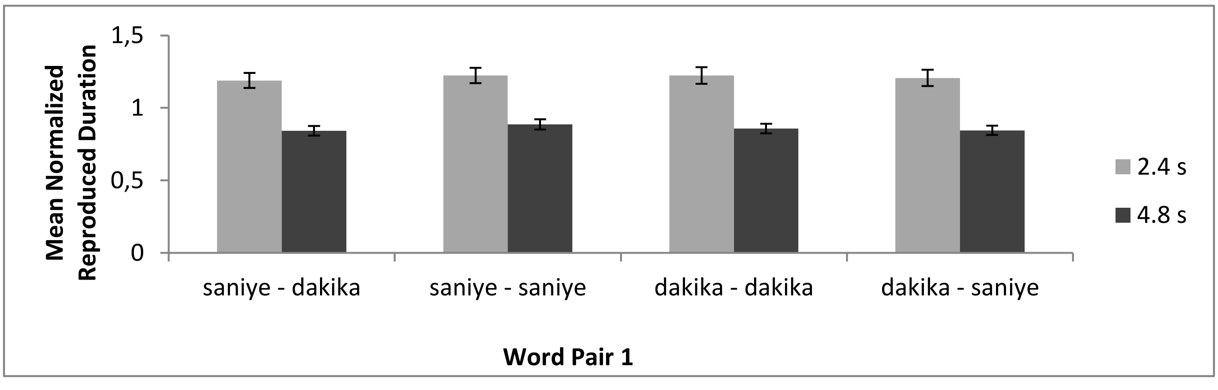
For brevity in reporting the results, we would call the word pair of saniye “second” vs. dakika “minute” as the first word pair and hafta “week” vs. sene “year” as the second word pair from now on.

4. Results

First, we analyzed the mean normalized reproduction times across target durations for word pair 1 (Figure 2A) and word pair 2 (Figure 2B) separately in order to see any systematic under- or over-reproduction of the target durations. The two bar graphs suggest the over-reproduction of the 2.4 s duration and an under-reproduction of 4.8 s duration regardless of the word pair type (same vs. different) or the specific word pairs presented.

To investigate the effect of sex and the order of the sessions, a multivariate ANOVA was conducted. The results showed that neither the sex of the participant (all *p*s >.185) nor the order in which they participated the two sessions (all *p*s >.179) affected the reproduced durations in any of the word pair – target duration combinations. Also, there were no interaction between sex and the session order (all *p*s > .217).

2A)



2B)

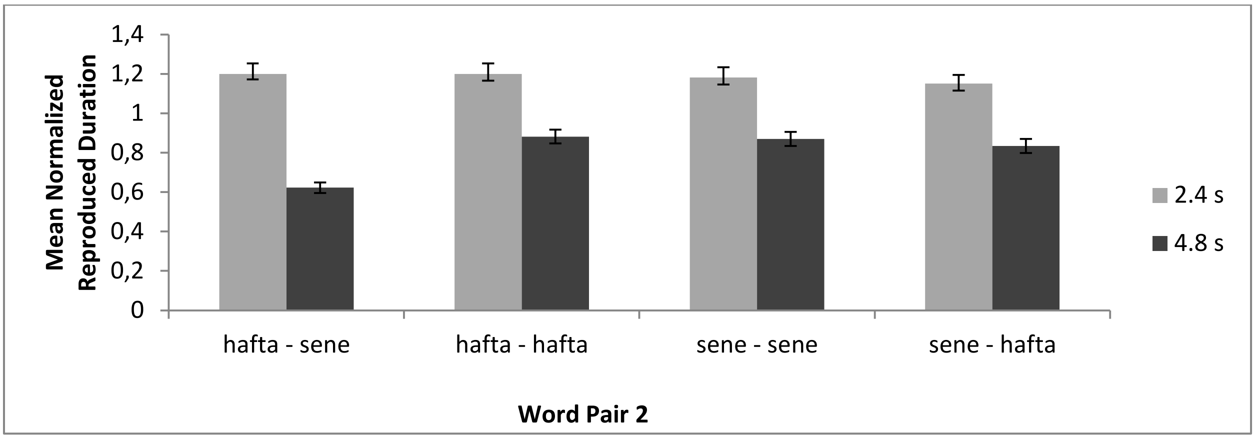
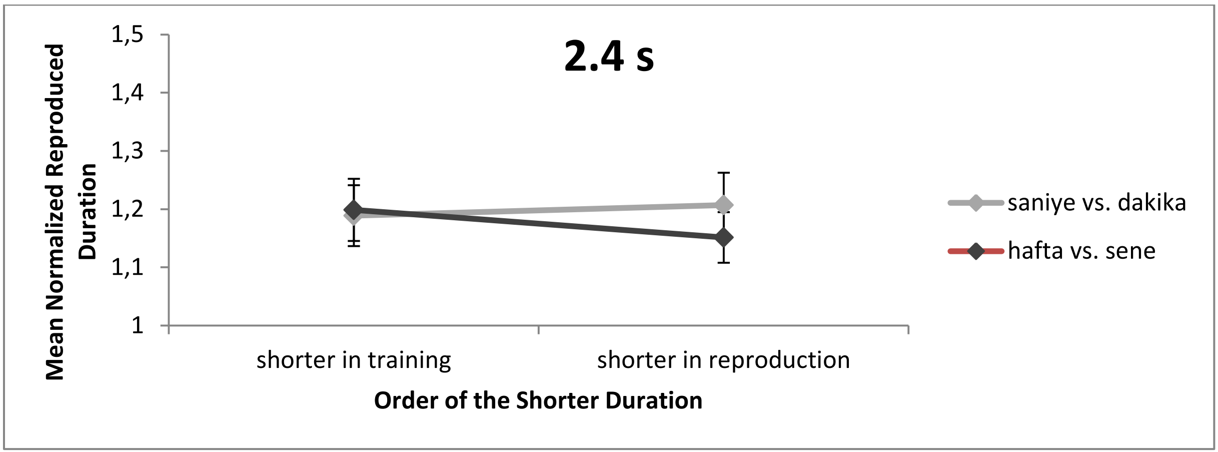


Figure 2: Mean normalized reproduction scores for word pair 1 (A) and word pair 2 (B) across two target durations. Error bars denote the standard errors of the mean.

For different word pairs (Session 1), we conducted three-factor repeated measures ANOVA. The results showed that word pairs, F (1, 20) =116.56, p<.001, η^2_p=.85, target duration, F (1, 20) =110.72, p<.001, η^2_p=.84, and the order of the word referring to a shorter duration, F (1, 20) =40.60, p<.001, η^2_p=.67, have significant main effects. Pairwise comparisons revealed that word pair 1, M_{diff} = .067, p<.001, the target duration of 2.4 s, M_{diff} =.037, p<.001 and the presentation of the shorter duration word in the reproduction, M_{diff} = .046, p<.001 yielded higher mean normalized reproduced durations. However, these main effects were qualified by an interaction between all three repeated factors, F (1, 20) =49.66, p<.001, η^2_p=.71. Further comparisons showed that, for the second different word pair, the reproduced durations were greater when the shorter duration was given in reproduction (sene→hafta, M=.80) compared to training (hafta→sene, M=.60) only when they were presented in the target duration of 4.8 s. The same order effect was not observable for word pair 2 (saniye vs. dakika). The mean normalized scores for each word pair as a function of whether the shorter duration was presented in the training or reproduction is depicted in Figure 3 separately for 2.4 s (Figure 3A) and 4.8 s (Figure 3B).

3A)



3B)

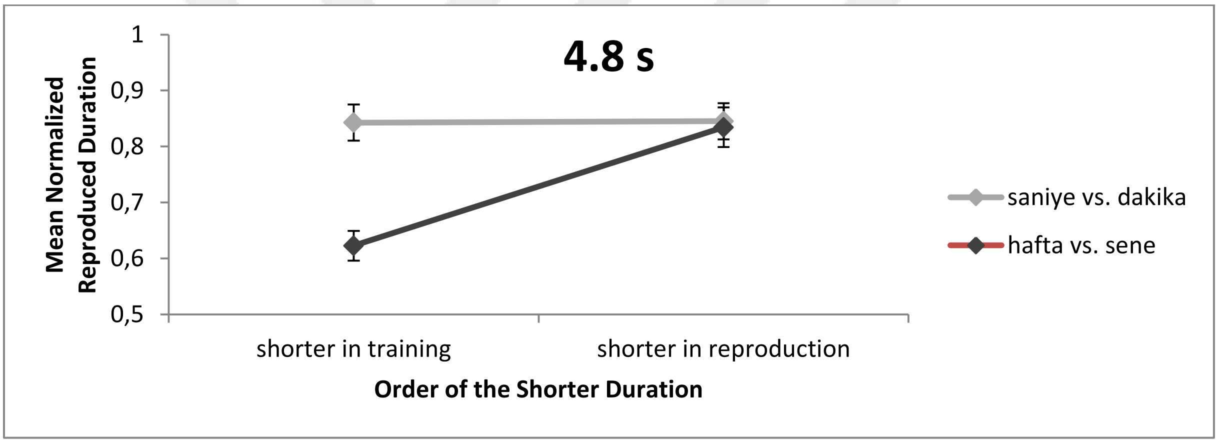


Figure 3: The mean normalized reproduction time as a function of the order of the word referring to a shorter duration (training vs. reproduction) for 2.4 s (A) and 4.8 (B) s. The error bars denote the standard errors of the mean.

For the same word pairs, our analysis showed a main effect of the target duration, F (1, 21) = 73.35, p<.001, η^2_p=.78, and the same word pairs, F (3, 63) = 4.38, p=.007, η^2_p=.173. Pairwise comparisons showed that the mean normalized reproduced durations were greater for 2.4 s for all same word pairs compared to 4.8 s (M_{diff}=.34, p<.001). For the main effect of same word pairs, when we consider Bonferroni adjusted alpha levels of .008 per test (.05/6) in the pairwise comparisons, there were no significant differences between any of the same word pairs. There was also no interaction between target duration and same word pairs, F (3, 63) = 1.50, p=.22.

To see if there is a difference between any word pair regardless of the word pair type (same vs. different) and the order of the shorter duration, we conducted a one-way repeated measures ANOVA separately for each target duration. The results revealed that in 2.4 s, there was no significant difference between any word pair, F (7, 140) = .822, p=.570. However, in the target duration of 4.8 s, there was a main effect of word pair, F (7, 133) =45.97, p <.001, η^2_p=.71. Pairwise comparisons revealed that the mean normalized reproduced durations were lower when participants *saw hafta "week"* in the training and *sene "year"* in the reproduction compared to all other word pairs (all M_{diff} < -.209, all ps <.001) in 4.8 s.

To investigate the difference between the same and different word pairs, we averaged the mean normalized scores for the same and different word pairs separately and conducted two-way repeated measures ANOVA. The results showed only a main effect of target duration, F (1, 19) =92.18, p<.001, η^2_p=.831. There was no difference between same and different word pairs, F (1, 19) =3.09, p=.095 and interaction between word pair type and target duration, F (1, 19) =3.26, p=.087. The averaged reproduced durations for same and different word pairs across two target durations are depicted in Figure 4.

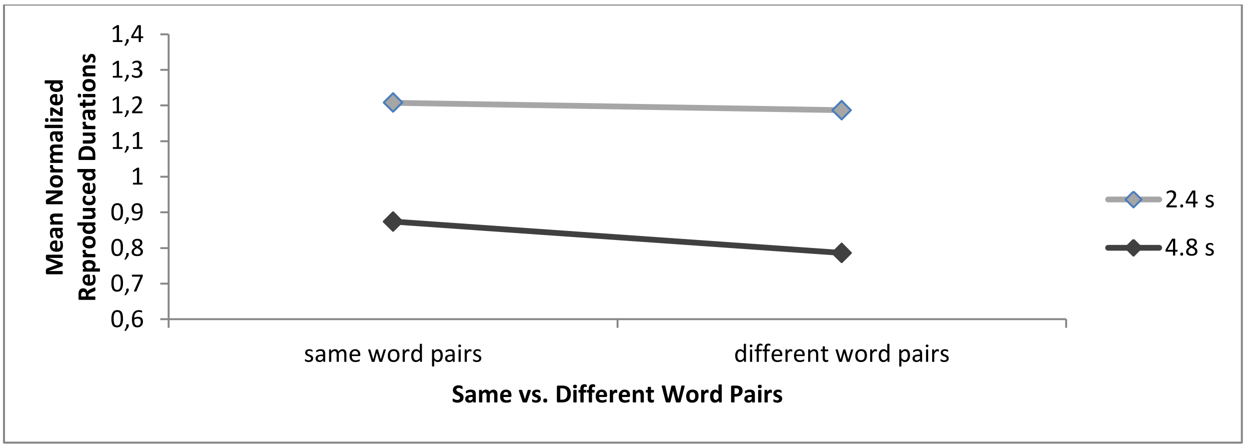


Figure 4: The averaged normalized scores for same and different word pairs across two target durations.

The one way ANOVA with all word pairs regardless of the word pair type (same vs. different) and the order of the shorter duration was conducted with participants' coefficient of variation (CV) scores separately for each target duration. In the target duration of 2.4 s, there was no significant effect of word pair on CV scores, F (4.14, 95.18) = 1.30, p =.251. However, in the target duration of 4.8 s, there was a significant main effect of word pair, F (7, 161) = 78.65, p<.001, η^2_p=.77. Pairwise comparisons revealed that CVs were greater when participants saw hafta "week" in the training and sene "year" in the reproduction compared to all other word pairs in 4.8 s (all M_{diff} > .173, all ps <.001).

To see whether variability in perceived durations differed between same and different word pairs, we computed grand total CVs for the same and different word pairs separately for each target duration and conducted two-way repeated measures ANOVA. Results revealed a significant main effect of target duration, F (1, 19) = 92.18, p <.001, η^2_p=.83. The CVs were greater in the target duration of 2.4 s (M= 1.172) compared to 4.8 s (M= .806). There were no main effect of the word pair type (same vs. different), F (1, 19) = 3.09, p= .095. There was also no interaction between two, F (1, 19) = 3.26, p=.087.

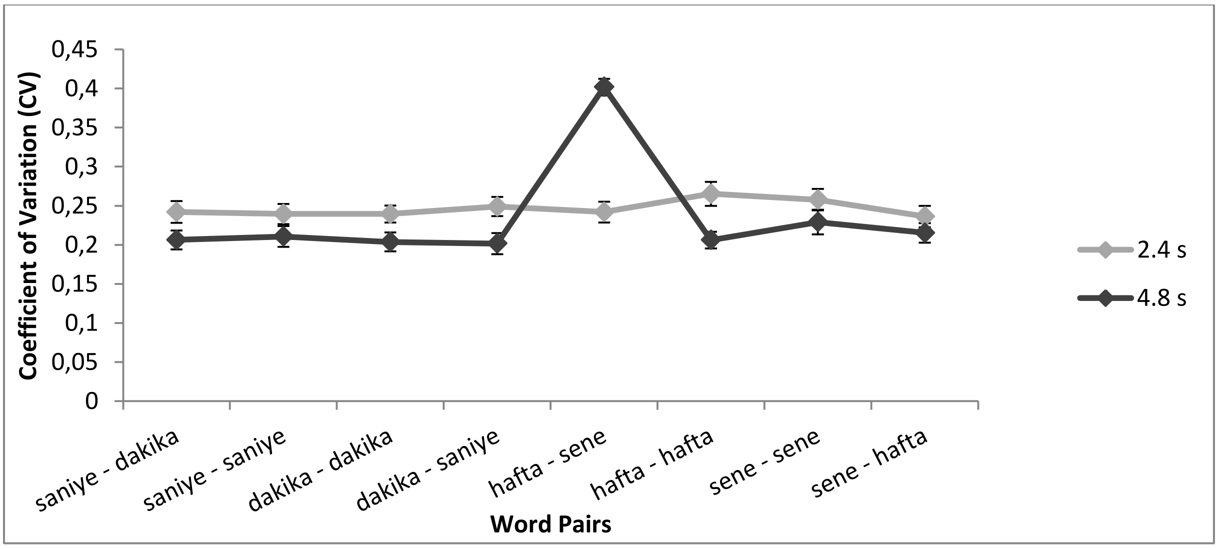


Figure 5: The coefficient of variations (CV) for each word pair across two target durations. The error bars denote the standard errors of the mean.

In sum, in Experiment 1, we found that regardless of the word pair type and specific order, participants over-reproduced the target duration of 2.4 s and under-reproduced 4.8 s. We also found that participants under-reproduced 4.8 s more when they saw hafta “week” in the training and sene “year” in the reproduction compared to all word pair conditions. The CV was also greater for that word pair (hafta – sene) compared to all other.

CHAPTER 3

EXPERIMENT 2

In the first experiment, we used words that implied only temporal magnitude. In Experiment 2, we investigated how participants' subjective duration estimations were modulated by words implying both a temporal magnitude as well as a spatial magnitude. To this end, in this experiment, we used adjectives that were part of the spatial-temporal metaphors, referring to different indistinct amounts of duration as well as spatial magnitudes (i.e. the size of an object; e.g. *long vs. short*). As in the Experiment 1, we hypothesized that (1) when the word stimulus in the training refers to a shorter duration or a smaller spatial magnitude compared to the word presented in the reproduction (e.g. seeing "short" in the training and "long" in the reproduction), participants would under-estimate (i.e. over-reproduce) the target interval, (2) when the word stimulus in the training refers to a longer duration or a bigger spatial magnitude compared to the word presented in the reproduction (e.g. seeing "wide" in the training and "narrow" in the reproduction), participants would over-estimate (i.e. under-reproduce) the target interval, (3) there would not be any systematic difference in the reproduced duration estimations when participants are presented with the same words both in the reproduction and training, and (4) there would not be any interaction between target duration and condition, meaning that the hypothesized overestimation and underestimation of the target duration in (1) and (2) would not differ depending on the target duration.

1. Method

1.1. Participants

In Experiment 2, there were again 25 participants (14 females, Mage=21, SDage = 1.68, age range=19-26 years) from Koç University students and compensated with course credit.

All of them were right handed and had normal or corrected-to-normal vision. All participants were tested in both sessions. One male subject was discarded since he did not pay attention to the word stimuli as he did very poorly in identifying the last word he saw on the screen and, one female subject was discarded since her mean normalized reproduced scores were outliers in 10 out of the 16 conditions. Thus, we proceeded with 23 participants for further analyses. All participants provided informed consent prior to the experiment for their participation for two experimental sessions. All the experiments were approved by the Institutional Review Panel for Human Subjects of Koç University**.**

1.2.Task, Procedure & Stimuli

The task and the procedure were identical to Experiment 1, except for the word stimuli used in Temporal Reproduction Task. In Experiment 2, we used spatial adjectives and adverbs that are part of the spatial-temporal metaphors referring to indistinct durations. We chose 4 words: uzun (“long”), kısa (“short”), geniş (“wide”) and dar (“narrow”).

Session 1

In Session 1, we used different word pairs. In this condition, participants were trained with a spatial-temporal adjective and were presented with the antonym of that word in the reproduction interval. The word pairs were: uzun (“long”) vs. kısa (“short”) and geniş (“wide”) vs. dar (“narrow”). As in Experiment 1, the order of the words also changed from trial to trial. Each different word pair for a specific order was presented 30 times for each of the two target durations in random order.

Session 2

In Session 2, we used the same word pairs. Thus, participants were presented with the same spatial-temporal adjective both in training and reproduction. There were 4 same word pairs: uzun (“long”) vs. uzun, kısa (“short”) vs. kısa, geniş (“wide”) vs. geniş and dar (“narrow”) vs. dar. Each same word pair was presented 30 times for each of the two target durations randomly.

2. Data Analyses

As in Experiment 1, we treated trials in which reproduced durations were larger than three times or smaller than one third of the target duration as outliers and excluded them (mean percentage of cases per participant: 2.4 s: *M*=2.8%; 4.8 s: *M*=3.2%). Mean normalized reproduced scores that were above and below three standard deviations from the sample mean of any word pair – target duration combination were excluded from further analyses (mean percentage of cases per condition: 2.4 s: *M*= .22 %; 4.8 s: *M*= .22 %). In CVs, there were no outliers. In Experiment 2, we conducted the same analyses described in Experiment 1.

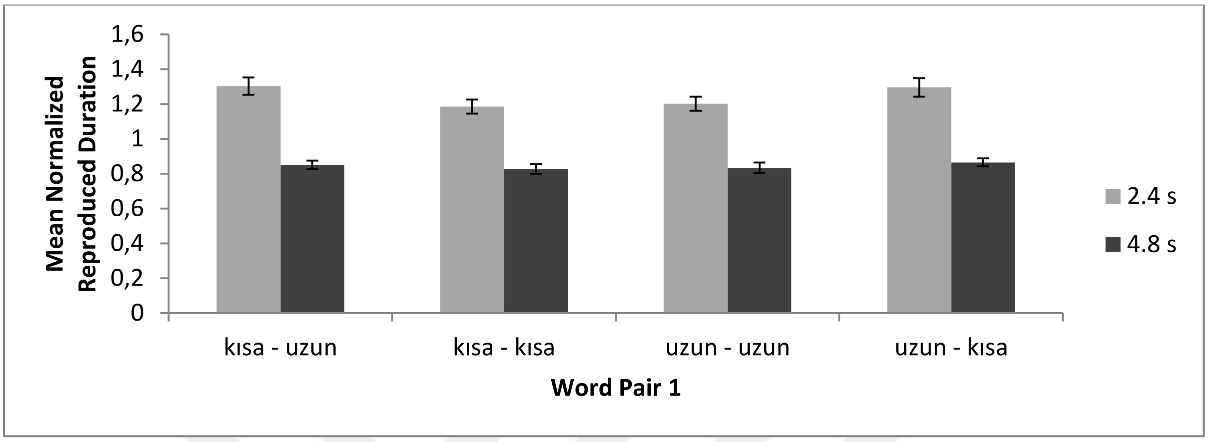
For brevity in reporting the results, we would call the word pair of kısa “short” vs. uzun “long” as the first word pair and dar “narrow” vs. geniş “wide” as the second word pair from now on

3. Results

The visual inspection of Figure 6 suggests the over-reproduction of 2.4 s and an under-reproduction of 4.8 s in both word pair 1 (Figure 6A) and word pair 2 (Figure 6B) regardless of the specific ordered word pair conditions.

We conducted a multivariate ANOVA with all 16 word pairs – target duration conditions as the dependent measures and the sex and the order in which participants attended the two sessions as between-subject variables to investigate any differences between these groups. Neither the sex (all *p*s >.121) nor the session order (all *p*s >.099) effected the normalized reproduction scores. Also, there was no interaction between sex and the session order in any of the conditions (all *p*s >.151).

6A)



6B)

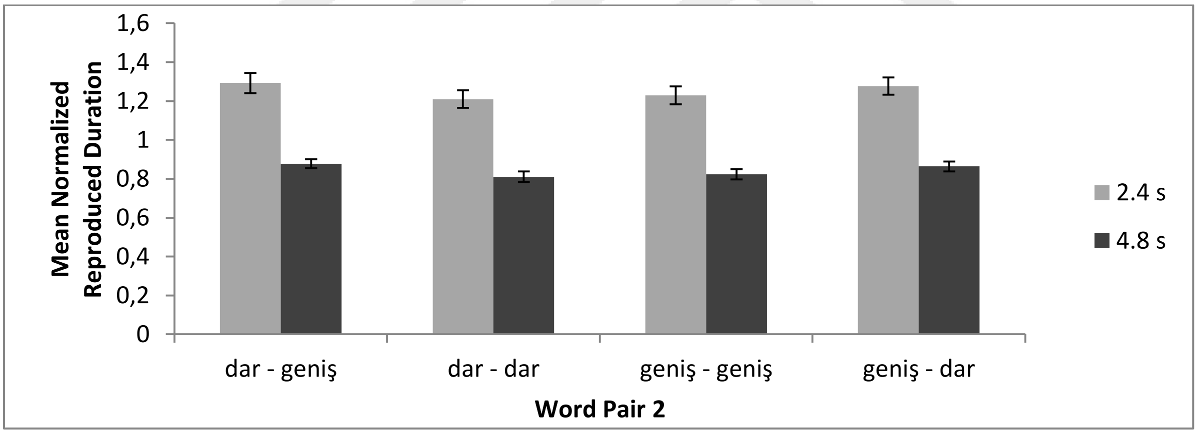
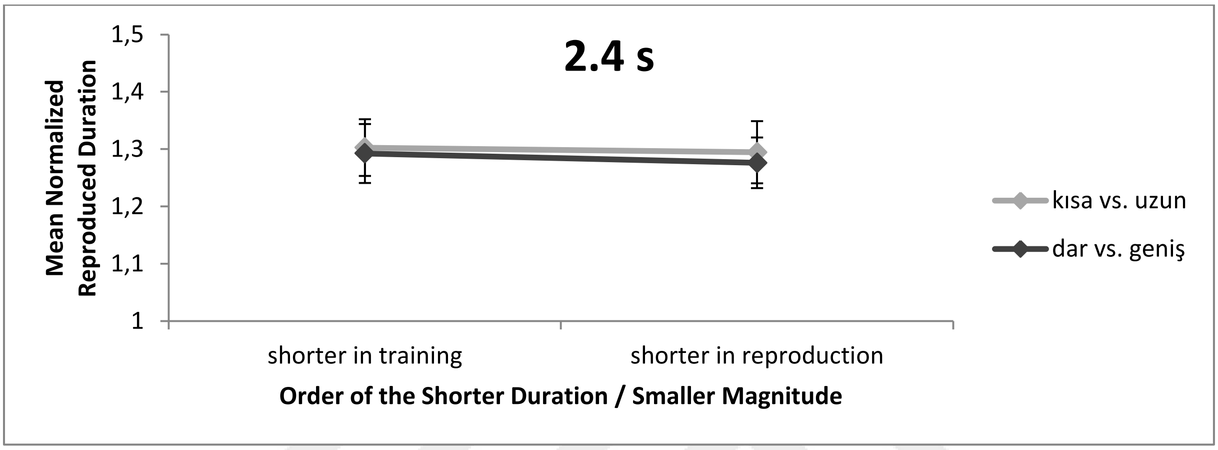


Figure 6: Mean normalized reproduction scores for word pair 1 (A) and word pair 2 (B) across two target durations. Error bars denote the standard errors of the mean.

For different word pairs (Session 1), we conducted three-way repeated measures ANOVA. The results revealed only a main effect of target duration, F (1, 19) =122.96, p<.001, η^2_p=.87. The mean normalized reproduction scores were greater in 2.4 s (*M*=1.29) compared to 4.8 s (*M*=.86) for all different word pairs. There were no main effects of the specific word pair (word pair 1 vs. 2), F (1, 19) =.286, p=.599, or the order of the shorter duration, F (1, 19) =.147, p=.706. Also, there was no interaction between all three repeated factors, F (1, 19) = .013, p=.910. The mean normalized scores for each word pair as a function of whether the shorter duration was presented in the training or reproduction is depicted in Figure 7 separately for 2.4 s (Figure 7A) and 4.8 s (Figure 7B).

7A)



7B)

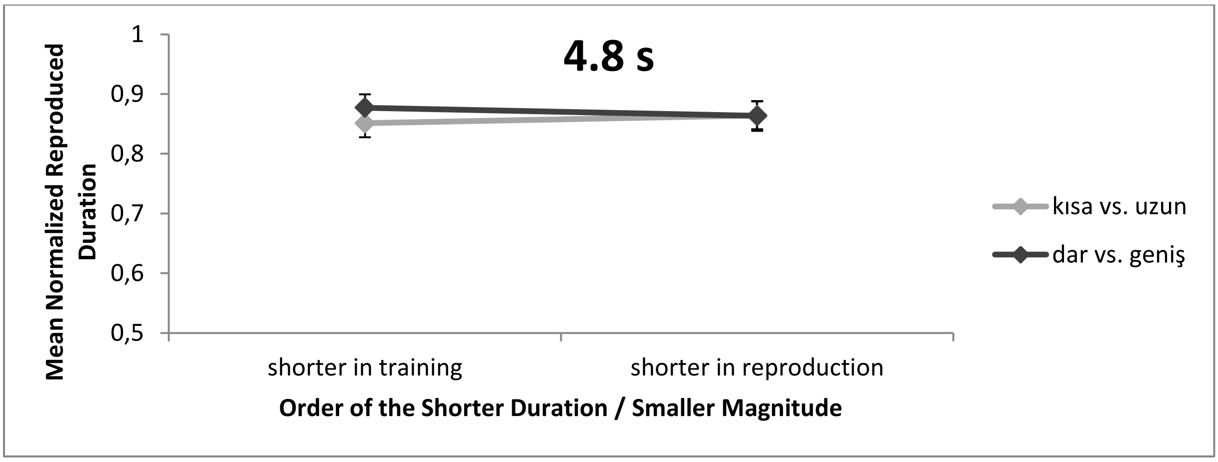


Figure 7: The mean normalized reproduction time as a function of the order of the word referring to a shorter duration / smaller magnitude (training vs. reproduction) for 2.4 s (A) and 4.8 (B) s. The error bars denote the standard errors of the mean.

For the same word pairs (Session 2), our analysis revealed only a main effect of target duration, F (1, 20) =69.56, p<.001, η^2_p=.78. Pairwise comparisons showed the mean normalized reproduced durations were greater in the target duration of 2.4 s (*M*= 1.18) compared to 4.8 s (*M*= .81). There was no main effect of the same word pairs, F (3, 60) = 2.095, p= .110. There was also no significant interaction between same word pairs and target duration, F (3, 60) =2.39, p=.078.

A one-way repeated measures ANOVA with all word pairs regardless of the word pair type (same vs. different) and the order of the shorter duration / smaller magnitude was conducted separately for each target duration. There was no significant main effect of any word pair both for 2.4 s and 4.8 s, F (1.10, 37.10) = 1.57, p =.221 and F (1.69, 32.01) = 2.07, p =.149, respectively.

To investigate the difference between the same and different word pairs, we averaged the mean normalized reproduced durations for the same and different word pairs separately for each target duration and conducted two-way repeated measures ANOVA. The results showed only a main effect of target duration, F (1, 17) = 87.54, p <.001, η^2_p=.837. There was no significant difference between the averaged normalized reproduced durations for same and different word pairs, F (1, 17) =2.70, p=.119. Also, there was no interaction between two repeated factors, F (1, 17) = .999, p= .334. The averaged reproduced durations for same and different word pairs across two target durations are depicted in Figure 8.

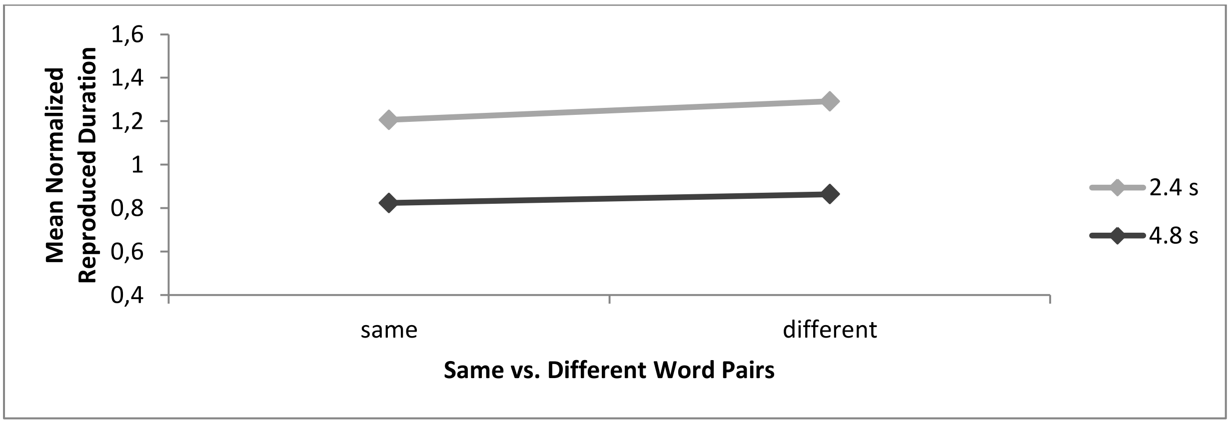


Figure 8: The averaged normalized scores for same and different word pairs across two target durations.

With participants' CV scores, we conducted two-way repeated measures ANOVA with all word pairs and the target duration as the two repeated factors and the CVs as the dependent measure. The results showed a significant effect of target duration, F (1, 22) = 35.338, p <.001, η^2_p=.616. Pairwise comparisons revealed that CVs were greater in the target duration of 2.4 s (M= .260) compared to the target duration of 4.8 s (M = .213). There was no difference between any word pair, F (3.31, 72.83) = .639, p =.607. However, these results are qualified by a significant interaction between two, F (7, 154) = 2.674, p =.012, η^2_p=.108. To see which word pairs differ between 2.4 s and 4.8 s, we conducted multiple t-tests. The results yielded that, when we consider Bonferroni adjusted alpha levels (.05/8 =.0062), CV scores were greater in 2.4 s compared to 4.8 s for all 4 different word pairs as well two of the same word pairs ("*geniş – geniş*" and "*dar – dar*"). Meaning, the CVs were greater in 2.4 s for word pairs "*uzun – kısa*" (M =.271), "*geniş-dar*" (M =.276), "*kısa –uzun*" (M =.259), "*dar – geniş*" (M =.265), "*geniş –geniş*" (M= .252) and "*kısa – kısa*" (M =.255) compared to the target duration of 4.8 s (M =.207, .204, .201, .211, .208, .218; respectively). These results are graphed in Figure 9.

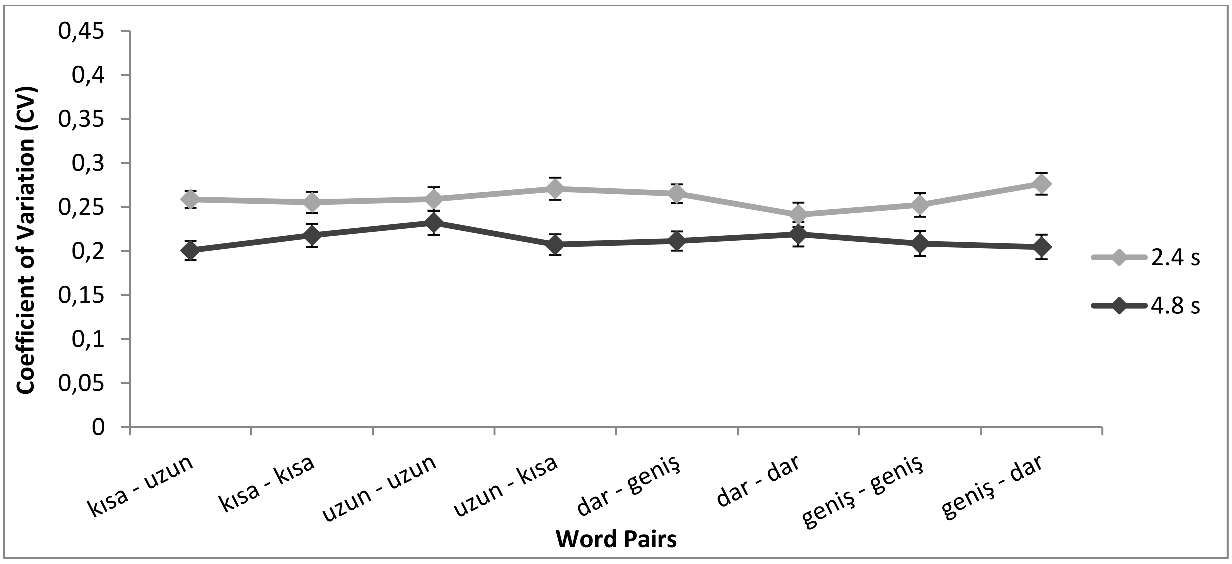


Figure 9: The coefficient of variations (CV) for each word pair across two target durations. The error bars denote the standard errors of the mean.

In sum, in Experiment 2, we found an over-reproduction of 2.4 s and an under-reproduction of 4.8 s regardless of the word pair conditions, as in Experiment 1. However, we did not find any difference in mean normalized reproduced duration between any of the word pairs. We also found that CVs were greater in 2.4 s compared to 4.8 s for all 4 different word pairs as well as 2 of the same word pairs (kısa – kısa and geniş – geniş).

CHAPTER 4

GENERAL DISCUSSION

In this study, we asked how language affects time perception. Specifically, we investigated how temporal magnitude (Experiment 1; duration words) and temporal / spatial magnitude (Experiment 2; spatial-temporal metaphors) implied by words influenced subjective time estimates. We hypothesized that increasing the magnitude conveyed by words from training to reproduction would lead to the over-reproduction of the target duration, and vice versa. We found that (1) in two experiments, participants over-reproduced 2.4 s and under-reproduced 4.8 s, regardless of the implied temporal / spatial magnitude of words (Figure 2 and Figure 6), (2) CVs were greater in 2.4 s compared to 4.8 s in both experiments (Figure 5 and Figure 9) and (3) participants' reproduced duration was smaller and CV was greater when they saw hafta "week" in the training and sene "year" in the reproduction in 4.8 s compared to all other conditions in Experiment 1. Last, (4) we did not find any systematic effect of the temporal/spatial magnitude implied by words on perceived duration in Experiments 1 and 2.

The over-reproduction of 2.4 s and the under-reproduction of 4.8 s in our current study are in line with Vierordt's Law (for a review; Lejeune & Wearden, 2009) and found in many timing studies in literature across multiple timing tasks (e.g. Gu & Meck, 2011; Yarmey, 2000). This migration effect, which is the regression of duration estimates toward the mid-range of the target duration series, might be due to the fact that all word pair – target duration conditions were presented randomly (i.e. interleaved) rather than in blocks.

We also saw a trend that CVs were greater in 2.4 s compared to 4.8 s. According to Weber's Law, although the variation of the reproduced duration increases proportionally with the to-be-timed intervals, these results might be best explained by an additive source of variability rather than a proportional one. If the variability were same across two target durations, the additive effect would be more propounded in shorter intervals compared to longer ones under the generalized form of Weber's Law.

In Experiment 1, we found that the word pair *hafta –sene* was under-reproduced more when presented in 4.8 s compared to all other word pairs. It means that participants thought the target duration of 4.8 s as shorter when *hafta "week"* in the training was followed by a word implying a larger temporal magnitude, which was *sene "year"*. However, we did not see the same effect in other distinct duration word pairs in Experiment 1 and spatial – temporal metaphor pairs in Experiment 2. It might be due to the larger temporal magnitude difference between these two words is larger compared to the other word pair, which is *saniye "second"* vs. *dakika "minute.*" But, it might also be a random effect, which needs further investigation.

Overall, we could not find supporting evidence for the effect of language on time perception. Both temporal magnitude (Experiment 1) and temporal/spatial magnitude (Experiment 2) information conveyed by words did not affect perceived duration, (other than the word pair of *hafta – sene* in 4.8 s). In a recent study, Bottini and Casasanto (2010) investigated the effects of implicit spatial length information encoded in different object nouns (e.g. cigarettes, clothesline, footpath) on perceived duration and found an effect of language on time perception. They found a significant positive impact of implicit spatial length information on duration estimates, meaning that although presented for the same amount of time, object noun whose implicit spatial length was smaller (e.g. cigarette) was reproduced less compared to other nouns whose implicit spatial length was larger (e.g. footpath). However, we did not find the same effect of temporal/spatial magnitude given by the means of language on duration estimates. It is interesting when we consider that we used the direct spatial magnitude information in Experiment 2, rather than an implicit one as in Bottini and Casasanto (2010). One possibility for falling short to replicate the findings of this study might be that the previously documented effects of magnitude on time perception are only for spatial and numerical magnitude (i.e. non-temporal) and not for temporal magnitudes. In other words, those findings might be present only for cross-domain effects. In the current study, however, we tested the impact of duration magnitude on duration perception, which is a within-domain interaction. Yet, in Experiment 2, we used spatial – temporal metaphors that implied both temporal and spatial magnitudes. The reason why we did not find this cross – domain effect in this experiment might be the everyday use of those spatial –temporal metaphors. Space and time are so intertwined that spatial adjectives are commonly understood as temporal concepts especially in the context of time reproduction task (Lakoff & Johnson, 1980).

Firstly, one possible explanation for not being able to support our hypothesis in both experiments, in magnitude – time context, might be the nature of our to-be-timed stimulus. As we mentioned in the Introduction (Section 1.1.), larger magnitude, more complex and intense stimuli expand perceived duration (Eagleman, 2008). One mechanism for this effect is the modulation of attention and arousal by the non-temporal properties of the to-be-timed stimulus. For example, intense negative sounds expand subjective duration since they heighten physiological arousal (Mella et al., 2011). Other studies investigating those temporal illusions used different stimuli that are free from emotional valence. One recent study investigated the effects of different degrees of motion coherence of randomly moving dots on perceived duration in a temporal reproduction task (Karşılar & Balcı, under revision). Increasing the coherence level from training to reproduction resulted in the over-reproduction of the target interval and this effect increased as the difference between the coherence levels of training and reproduction increased. If we think of the coherence level in this study as the magnitude of the motion, we would expect to find the similar results in the current study as the temporal/spatial magnitude increased from training to reproduction. One reason for the lack of consistency in results between these two studies might be the nature of the to-be-timed stimulus. As argued in this study, higher motion coherence levels in a highly dynamic moving dot array might capture more attention to the non-temporal properties of the stimulus at the expense of attention to the timing task itself. In our study, the magnitude is not inherently perceptible in the to-be-timed stimulus; rather it is implied by words. More direct and visual magnitude information as an inherent property of the external stimuli might affect perceived duration as they modulate the attentional resources over the stimuli's non-temporal properties and time. This attentional modulation might also explain the trend of decrease in mean normalized reproduced durations for the same word pairs compared to different word pairs in Experiment 2 (Figure 6A and 6B). The change of the word from training to reproduction (a.k.a. change detection) might modulate the attention to the stimuli, causing a slight change in the estimated duration.

Secondly, there is insufficient information about how duration and spatial magnitude activated by language are represented. It is also not clear how and at what level these semantic representations interact with the timing system. We expected to see an interaction between two as many behavioral and neuroimaging studies show that semantic representations interact with and modulate their domain-specific low-level perceptual processing, mainly visual and motor perception (e.g., Zwaan, 2004; Kaschak et al., 2005). The semantic information conveyed by words is reflected in brain responses (Barsalou, 1999, 2008; Pulvermüller, 2001, 2005; Martin, 2007). Fine-grained differences between semantic categories such as actions and tools are also visible in specific brain activation patterns (Martin & Chao, 2001). For example, words referring to motor actions such as kick activate the motor circuitry in motor cortex. Thus, one explanation for the interaction between semantics and motor perception in behavioral findings might be the modulation of the brain responses in motor cortex by the words referring to motor actions, because they activate the same brain region as we process the actual referents of those words. Although there is a core timing system in brain including basal ganglia, thalamus and the dopaminergic projections from them responsible for interval timing across multiple timing contexts and tasks (for a review; see Merchant, Harrington and Meck, 2005), the timing system also engages a more distributed brain network. Neuroimaging studies show that timing mechanism engages a distributed brain system including supplementary motor area (SMA), parietal and prefrontal cortices, cerebellum and basal ganglia as well other context-dependent areas that are selectively engaged by different behavioral contexts (Buhusi & Meck, 2005). For example, the timing circuitry engages cerebellum for motor timing tasks and visual cortex when the to-be-timed stimulus is visually presented (for a review; Merchant, Harrington & Meck, 2013). It is hard to strictly argue the level of interaction between the temporal/spatial magnitude information conveyed by words and interval timing. Timing engages a distributed circuitry and it is not known where exactly the semantics of different word categories (i.e., temporal words) are represented in the brain. Yet, the inferior parietal cortex (IPC) might be an option, because, it is essential for representing and integrating different analogical magnitude information. In particular, right IPC is critical for spatial and temporal processing (Cohen & Dehaene, 1996). If duration magnitude and spatial magnitude information implied by words are transformed to analogical magnitude representations in IPC, then these magnitude representations might modulate the brain responses in right IPC, leading to the modulation of perceived duration. As stated earlier, although we might argue about that, there is no conclusive evidence for the interaction between semantic and timing representations. Future studies might investigate this with neuroimaging methodology.

Thirdly, the task we used might not be appropriate enough to unleash the possible effects of language on perceived duration. Other tasks, like temporal bisection (Allan & Gibbon, 1991) or categorical timing (Wearden, 1992), making the participants to decide on whether the target duration is perceived shorter or longer compared to a reference interval, might capture their decisions more clearly.

In sum, the current study did not support the hypothesis that temporal and spatial magnitude information conveyed by linguistic stimuli influences subjective duration estimations. It might either because of the fact that higher-order linguistic representations do not interact with one of the low-level domains of cognitive processing of interval timing or because of the possible shortcomings of the current study.

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APPENDIX

APPENDIX A.

	EXPERIMENT 1* (duration words)		**EXPERIMENT 2**** (spatial-temporal metaphors)	
	Session 1 (different word pairs)	**Session 2** (same word pairs)	**Session 1** (different word pairs)	**Session 2** (same word pairs)
2400 ms	saniye – dakika (30 trials) dakika – saniye (30 trials) hafta – sene (30 trials) sene – hafta (30 trials)	saniye – saniye (30 trials) dakika – dakika (30 trials) hafta – hafta (30 trials) sene – sene (30 trials)	kısa – uzun (30 trials) uzun – kısa (30 trials) geniş – dar (30 trials) dar – geniş (30 trials)	kısa – kısa (30 trials) uzun – uzun (30 trials) geniş – geniş (30 trials) dar – dar (30 trials)
4800 ms	saniye – dakika (30 trials) dakika – saniye (30 trials) hafta – sene (30 trials) sene – hafta (30 trials)	saniye – saniye (30 trials) dakika – dakika (30 trials) hafta – hafta (30 trials) sene – sene (30 trials)	kısa – uzun (30 trials) uzun – kısa (30 trials) geniş – dar (30 trials) dar – geniş (30 trials)	kısa – kısa (30 trials) uzun – uzun (30 trials) geniş – geniş (30 trials) dar – dar (30 trials)
	240 trials	**240 trials**	**240 trials**	**240 trials**

Table 1: The word pairs and their corresponding presentation times across target intervals for each condition.

*saniye *("second"),* dakika *("minute"),* hafta *("week"),* sene *("year").*

**uzun *("long"),* kısa *("short"),* geniş *("wide"),* dar *("narrow").*