KADIR HAS UNIVERSITY
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LEFT TO RIGHT OR RIGHT TO LEFT? EFFECT OF WRITING DIRECTION ON TIME PERCEPTION IN BILINGUAL ADULTS

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APPROVAL

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DECLARATION ON RESEARCH ETHICS AND PUBLISHING METHODS

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In addition, I acknowledge that any claim of irregularity that may arise in relation to this work will result in a disciplinary action in accordance with the university legislation.

Elif ALTIN

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Date (20/07/2022)

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EFFECT OF WRITING DIRECTION ON TIME PERCEPTION IN BILINGUAL ADULTS

ABSTRACT

How do we perceive time? Is there a flow of time, and if so, does it have a direction? Questions such as how time is perceived, expressed, and its relationship with language and culture has been extensively investigated. Individuals need physical world and concrete concepts (e.g., calendars, clocks, timelines) to understand and represent abstract concepts. Spatialization of time, which is a highly abstract concept, is not independent from reading & writing habits. While previous research demonstrated that time can be represented on several axes (vertical, horizontal, and sagittal), this study focused on the horizontal axis and the relationship between writing direction and spatial time representation in three different bilingual groups (L1-Turkish – L2-English, L1-Turkish – L2-Arabic, L1-Arabic – L2-Turkish). We aimed to investigate (1) if the bias parallel to writing direction is replicable in Turkish-Arabic sample, (2) whether learning another language written in a different direction changes the perception of time direction, and (3) which language dominates the directional bias for participants who are familiar with writing in both directions. We examined the effect of L2 writing direction on bilinguals in three different fields (spatial, pictorial, and verbal) based on percentage of time arrangement (spatial pointing task) and reaction time (pictorial and verbal time flow tasks) measurements. Pictorial and verbal tasks showed that regardless of language group, congruent trials were responded faster than incongruent trials indicating a tendency to represent time in line with L1. Spatial pointing task revealed that L1-Turkish speakers tended to arrange time from left to right, and L2 influenced the L1 bias only for the L1-Arabic – L2-Turkish group. This finding suggests that acquired writing habits can influence spatial representation of time when L2 is the society language. Overall findings indicate that L1-writing direction is a determining factor for spatio-temporal representation and the influence of L2 depends on other factors.

Keywords: Time perception, Spatial cognition, Writing direction, Bilingualism

İKİ DİLLİLERDE İKİNCİ DİL YAZI YÖNÜNÜN ZAMAN ALGISINA ETKİSİ

ÖZET

Zamanı nasıl algılarız? Zamanın bir akışı var mıdır, varsa hangi yöndedir? Zamanın nasıl algılandığı ve ifade edildiği, dil ve kültürle ilişkisi gibi sorular psikoloji alanında yoğun bir şekilde araştırılmaktadır. Bireyler soyut kavramları anlamak ve temsil etmek için fiziksel dünyaya ve somut kavramlara (örn., takvim, saat, zaman çizelgesi) ihtiyaç duyarlar. Son derece soyut bir kavram olan zamanın uzamsallaştırılması okuma alışkanlığından ve yazı sisteminden bağımsız değildir. Önceki araştırmalar zamanın birkaç eksende (dikey, yatay ve sajital) temsil edilebileceğini gösterirken, bu çalışma yatay eksene ve üç farklı iki dilli grupta (D1-Türkçe - D2- İngilizce, L1-Türkçe – L2-Arapça, L1-Arapça – L2-Türkçe) yazı yönü ve uzamsal zaman ilişkisine odaklanmaktadır. Bu amaçla (1) Türkçe-Arap örnekleminde yazma yönüne paralel yanlılığın tekrarlanabilir olup olmadığı, (2) farklı bir yönde yazılmış başka bir dili öğrenmenin zaman yönü algısını değiştirip değiştirmediği ve (3) her iki yönde de yazmaya aşina olan katılımcılar için hangi dilin yön yönüne hakim olduğu sorularını sorduk. İkinci dil yazma yönünün iki dillilerin zaman temsiline etkisini üç farklı alanda (uzaysal, resimsel ve sözel) oran (uzamsal işaretleme görevi) ve tepki süresi (resimli ve sözel zaman akışı görevleri) ölçümlerine göre inceledik. Resimli ve sözlü görev performansları, dil grubundan bağımsız olarak, uyumlu denemelere, uyumsuz denemelere göre daha hızlı yanıt verildiğini, ve bu sayede zamanın D1 ile uyumlu olarak temsil edildiğini göstermiştir. Uzamsal işaretleme görevi, D1-Türkçe konuşanların zamanı soldan sağa temsil etme eğiliminde olduğunu ve ikinci dilin yalnızca D1-Arapça – D2-Türkçe grubunda zaman temsilini etkilediğini ortaya koymuştur. Bu bulgu, ikinci dil baskın toplum dili olduğunda, edinilmiş yazma alışkanlıklarının, ana dilin tersi yönünde zamanın uzamsal temsilini etkileyebileceğini göstermektedir. Genel bulgular, birinci dil yazma yönünün uzamsal-zamansal temsil için belirleyici bir faktör olduğunu ve ikinci dilin etkisinin diğer faktörlere bağlı olduğunu göstermektedir.

Anahtar Sözcükler: Zaman algısı, Uzamsal biliş, Yazı yönü, İki dillilik

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LIST OF ACRONMYMS AND ABBREVIATIONS

AR-TR : L1-Arabic – L2-Turkish

EF: Executive Function

L1: First Language

L2: Second Language

PPVT: Peabody Picture Vocabulary Test

RT: Reaction Time

TR-AR: L1-Turkish – L2-Arabic

TR-EN: L1-Turkish – L2-English

1. INTRODUCTION

Does language shape thought? Do people who speak different languages think differently? The relationship between language and thought have long been investigated by many scientists. On the other hand, there are disagreements about which factors determine the relationship between language and thought and whether language reflects or shapes thought. *Linguistic relativity*, also known as the *Sapir–Whorf hypothesis* (Whorf, 1956), holds that language can influence how people perceive and conceptualize the world, and *linguistic determinism* holds that language determines basic mental categories, and thus speakers of different languages think differently (Wolff & Holmes, 2011). The question of whether individuals who speak different languages think differently has been examined in many languages and in many areas such as time, space, quantity, color, emotion, and movement (e.g., Athanasopoulos, 2009; Maass & Russo, 2003; Pavlenko, 2002). Furthermore, the relationship between language and thought was investigated, with a focus on the possibility of acquiring a new worldview through the acquisition of a new language with contrasting linguistic categories (e.g., Bassetti and Cook, 2011; Pavlenko, 2011). The present study will focus on time perception to examine this relationship between language and thought using bilingualism to understand this relationship.

1.1 Time and Space

Individuals need the physical world and concrete concepts to be able to understand and represent abstract concepts. In relation to this, Lakoff and Johnson (1980) stated in *Conceptual Metaphor Theory* that it is possible to understand one conceptual abstract field through another concrete field. In this sense, as one of the most basic abstract concepts, time is spatialized with cultural products such as calendars, clocks, hourglasses, and timelines (Boroditsky, 2011).

The space-time conceptual metaphor has been extensively studied in linguistic relativity studies in terms of the effect of language on the mental representation of time (Boroditsky, Fuhrman, and McCormick, 2011; Chan & Bergen, 2005). Languages construct time through spatial metaphors (e.g., past is behind, good days are ahead) or organizational patterns in cultural elements (e.g., writing direction) (Boroditsky, 2011). For example, individuals refer to spatial expressions (e.g., forward, backward, long, short, large, small) while representing time (Pitt & Casasanto, 2020). It has been observed that individuals speaking different languages sometimes represent time by distance (e.g., short/long time expression used in English and Indonesian) and sometimes by quantity (e.g., less/more time used in Greek and Spanish) (Casasanto et al., 2004). Representing time as flowing in a direction is also accepted as an effort to comprehend the concept of time with space. The movement of time from right to left, left to right, front to back, or back to front can be expressed as the direction of the time flow. While time can be represented on several axes, this study concentrates on the spatial representation of time on the horizontal axis. Following a review of several aspects of time representation and mental timeline in the introduction, the current study is focused on the relationship between writing direction and spatial time representation in three different bilingual groups.

1.2 The Role of Language on Spatial Representation of Time

Time could be represented as flowing in three axes along the egocentric coordinates: front-back (sagittal), right-left (transverse), and up-down (longitudinal). For example, Spanish speakers represent the future ahead, while Aymara speakers represent the past in front of them and the future behind them (Núñez & Sweetser, 2006). Similarly, Taiwanese speakers prefer to line up sequential events on the vertical axis, whereas English and Arabic speakers line up the events side by side on the horizontal axis (Chan and Bergen, 2005; Tversky et al., 1991). Although the majority of them use egocentric coordinates, allocentric coordinates such as cardinal direction (e.g., north, south, east, west) and environmental direction (e.g., uphill/downhill) are also used by some cultures to represent time (Núñez et al., 2012). With this consideration, we can say that even

though spatial time mapping is universal, there are distinct ways to spatialize time differing across languages and cultures.

The fact that people express time spatially may imply that they think spatially as well. For example, it is known that Mandarin Chinese speakers and English speakers think differently about time as Mandarin Chinese speakers often use vertical metaphors while English speakers generally use horizontal metaphors (Zhang & Ding, 2003). When the non-linguistic studies examined how the English and Mandarin-speaking participants spatialize time via implicit measures, it was found that Mandarin Chinese speakers represent time on the vertical line and the English speakers represent on the horizontal line, in line with the metaphors they used. Boroditsky (2001) showed that English speakers verify a sentence about time sequence (e.g.: March comes earlier than April) faster when they are formed with a horizontal event (prime effect), and Mandarin Chinese speakers verify sentences faster with a vertical stimulus. These results show that the expressions used to represent time are also parallel to spatial thinking. When the temporal diagram task was applied to two Spanish and Darija Arabic speaking groups, it was discovered that, while the past tense in Darija was represented in the "behind" using metaphors, the past was represented in the "front" (De la Fuente et al., 2014). Based on these findings, it is possible to conclude that spatial thought can predict spatial expression, but that these two processes are not always parallel. Although there is no horizontal representation in spatial expression and linguistic metaphors, it has also been observed that time is spatially represented from left to right or right to left. Based on this, it was concluded that the use of language (writing direction) can be more indicative than the expressions in the language (Huang & Tse, 2017).

1.2.1 Writing system and mental time direction

Reading and writing are two of the most common ways for individuals to communicate with the world. (Bergen & Lau, 2012). It has been determined that reading habits and writing systems influence cognition in a variety of ways in both low and high cognitive processes. Even artists may create bias in various aspects, ranging from their aesthetic preferences to their level of arousal (Roman, El Fathi, & Santiago, 2013). For example,

it has been discovered that the direction of writing is linked to the mental representation of numbers. In some European languages written from left to right, such as English and French, the numerical magnitude representation is associated with the left-right axis. Larger numbers are responded faster on the right, while smaller numbers are represented on the left (Bergen & Chan Lau, 2012).

Similarly, "STEARC" (spatial-temporal association of response codes) was defined over the mental timeline as an effect similar to the effect that represent numerical magnitude with the left-to-right organization. According to this view, while the previous times are represented on the left side, the later times are represented on the right direction. (Ishihara, Keller, Rossetti & Prinz, 2008). This effect, which is an indicator of the horizontal representation of time and, was later associated with the writing direction and it was claimed that there was a mental timeline flowing in a different direction for individuals speaking different languages. (Fuhrman & Boroditsky, 2007)

Language is based not only on expressions but also on sensorimotor experiences (Casasanto & Jasmin 2012). Abstract concepts can be represented and grounded through conceptual metaphors by embodied experience and the sensorimotor system (Gibbs, Costa Lima, & Francozo, 2004). It has been claimed that the writing direction, as a feature of the language, influences people's use of space-time metaphors, and thus their representation of time. However, when the writing direction and the metaphor direction contradict each other, the writing direction have a more decisive role than the linguistic expression (Huang & Tse, 2017). This is consistent with the embodied cognition viewpoint, which serves as a basis for representing abstract concepts including time based on spatial knowledge. Metaphors are used in the language since they are available in thought, and thought is shaped by sensorimotor and embodied experiences. Hence, the embodied/physical experience can be activated more quickly than the linguistic expression and overcome the influence of linguistic expression (Huang & Tse, 2017).

To reveal the effect of writing direction on time representation independent from the linguistic expressions, Chen and O'Seaghdha (2013) recruited participants from Taiwan and a region of China that speak the same language but write in different directions.

These two languages with the same linguistic expressions differed and thus demonstrated the independent effect of writing direction experience on time representation. In another study, the effect of writing direction on the mental timeline was demonstrated by an experiment that shows causal relations (Casasanto & Bottini, 2014). It was discovered that Dutch participants in different groups who received the experimental instruction in four different writing styles, such as mirror reading or 90-degree angles, answered the questions in accordance with the direction of the instruction, evaluating "before" and "later" by using the right and left keys. These studies revealed that writing direction, as a feature of language, has an independent impact on time representation.

1.2.2 Representation of time flow on the horizontal axis

It has been claimed that the space-time metaphor is acquired through learning (e.g., Casasanto & Bottini, 2014; Cai, Connell & Holler, 2013). Casasanto and Bottini (2014) showed that the mental timeline could be changed with stimuli and instructions in different directions. Cai, Connell, and Holler (2013) found that the spatial representation of time did not originally have a direction. Many studies have shown that the mental timeline follows the direction of writing using both implicit and explicit measurement methods (e.g., Fuhrman & Boroditsky, 2010; Ishihara, Keller, Rossetti, & Prinz, 2008; Weger & Pratt, 2008). The spatial organization of time parallel with the writing direction was demonstrated in these studies in a variety of ways by using tasks such as organizing the sequence of events, early and late concepts, use of gestures, spatial relationship, and auditory measurements (Tversky et al., 1991; Núñez & Sweetser, 2006; Casasanto and Jasmin, 2012). To investigate the relationship between mental timeline and writing direction, Tversky, Kugelmass, and Winter (1991) asked school-age children to locate stickers for breakfast, lunch, and dinner. It was found at the end of the study that Arabic and English speakers arranged them in opposite directions in line with their written languages. In another study investigating directional bias in spatial thinking, Italian and Arabic speaking participants were asked to draw the action scenes that they heard. While Italian speakers drew actions from left to right, Arabic speakers drew the opposite direction, placing the agent to the right of the object (Maass & Russo,

2003). In another comprehensive study that requires the arrangement of the temporal sequence of natural events, Fuhrman and Boroditsky (2010) asked two groups of Hebrew and English-speaking adult participants to arrange events first, and then conducted an additional implicit study to eliminate the possibility of participants thinking in accordance with the experimenter's request. Following the presentation of one of three-stage event sequences, participants were asked to determine whether the second image occurred before or after the first image. Among the participants who used the keys to answer this question, those who speak English responded faster when the "before" was responded by left key, while those who speak Hebrew responded faster when the right key corresponded to "before". Santiago, Lupiáñez, Perez, and Funes (2007) conducted the first study showing the automatic activation of the left-right axis in the processing of temporal concepts. They manipulated the location side where the words appeared on the screen while displaying the words associated with the past and future and asking them to represent past or future with the left or right keys. As a result, when past-related words were displayed on the left and future-related words were displayed on the right, faster and more accurate answers were obtained. These responses were consistent with the Spanish writing direction. Overall, several previous studies on monolinguals demonstrated that time representation follows writing direction in the horizontal axis.

Non-linguistic gestures and motor movements measured in different studies have also supported the claim that time flows parallel with the writing direction. Miles, Betka, Pendry, and Macrae (2010) investigated the relationship between spatial and temporal dimensions using motor movements and discovered that participants tended to position the past to their left, as revealed by their computer hand movements. It has also been questioned whether these spatial associations affect our performance in other non-linguistic areas, such as visual attention. Ouellet, Santiago, Funes, and Lupiáñez (2010) tested whether words with temporal references direct attention to specific points in space using a visual cue paradigm. According to the findings, activation of the past and future concepts both directed attention and motor responses to either right or left. In other words, even though they did not process or produce the language, participants represented time in space. However, this representation did not always match up with

the representation in language. In an experiment in which they investigated whether individuals think about time as the way they speak, Casasanto and Jasmin (2012) discovered that the spatial axes of metaphors and hand gestures of English-speaking participants differed. When participants were instructed to use hand gestures consciously, they displayed past and future events in the sagittal axis (front-back) as used in language (e.g., the future is in front of us, the past is behind us), whereas in spontaneous use, they used the transverse axis (left-right) more. This spontaneous use can also be shown as evidence for the claim that the direction of writing is more decisive than the linguistic expressions in time representation. Unlike the previously mentioned findings, Bostan et al. (2016) discovered that the sagittal axis, along with vertical axis gestures, was the most commonly used for spontaneous temporal gestures in Turkish. This study demonstrates that the compatibility of gestures with writing direction varies depending on the language.

Overall, studies using various tools that investigate spatio-temporal cognition mostly revealed that individuals who write in horizontal axis represent time in the same axis following writing direction.

1.2.3 The influence of L2 writing direction on spatial time representation

If writing direction, as a sociolinguistic convention, shapes temporal thought, then how do bilinguals with two different direction represent time? Regarding this question, several research examined whether bidirectional bilinguals have dual mental time line (e.g., Boroditsky et al., 2011; Miles et al., 2011; Fuhrman et al., 2011). Taking bilingual flexibility into consideration, Miles et al. (2011) conducted two experiments to see whether Mandarin and English speakers can accommodate different representations. They discovered that Mandaring-English bilinguals have two mental time lines in their minds that lead to arranging time in both vertical and horizontal lines. The second experiment interestingly demonstrated that the Eastern and Western context provided by Jet Li and Brad Pit photographs influenced the tendency to represent time in vertical or horizontal axis. Participants used a vertical axis in the Western context and a horizontal

axis in the Eastern context, demonstrating that the L2 effect might be context dependent.

To investigate the determinants of the effect of language on time representation, Boroditsky (2001) worked with Mandarin and English-speaking bilingual participants taking two predictive factors into account: age of acquisition and exposure duration. This study hypothesized that if learning a new language changes their way of thinking, participants exposed to English at a younger age or exposed more, will think less in Mandarin and thus less vertically. As expected, bilingual participants who learned English at older age had more vertical biases, but no relation was found between their biases and the duration of the English experience. Fuhrman et al. (2011) used a three-dimensional time task which asks participants to press a key along three axes to represent earlier or later time points. They aimed to examine Mandarin and English-speaking participants of varying second language proficiency to measure the previous language effect and the immediate language effect, and discovered that those with higher Mandarin proficiency thought more vertically based on response times. At the same time, it was discovered that the language used during the experiment shaped the way of thinking. The following sub-factors, according to these studies, determine the axis of thought (horizontal or vertical): level of proficiency in the second language, age of learning the language, language of instruction, and cultural context. However, a recent study on Mandarin and English speakers found that Mandarin-English bilinguals had temporal thinking patterns similar to Mandarin monolinguals, regardless of whether they were elementary or advanced L2 English speakers (Yang et al., 2022). In this study, authors investigated the L2 effect on Mandarin English bilinguals using both sagittal and vertical axis through pictures of temporal congruency categorization task. While they replicated the studies showing that L1-Mandarin and L1-English speakers think about time differently, they did not find an effect of L2 in reconstructing representation of time. To sum up, while there is no consensus on the role of L2, the research presented thus far demonstrates the impact of L1 writing direction in spatial time representation.

Contrary to the aforementioned studies, there are studies claiming that language does not have an effect on time orientation and cannot replicate the demonstrated effect (Chen, 2007; January & Kako, 2007; Tse & Altarriba, 2008). For example, when Chen (2007) replicated Boroditsky's (2001) work, he discovered that, contrary to what Boroditsky claimed, Chinese speakers did not have a different time representation than English speakers in two of the four studies. According to January and Kako (2007), the findings were contradictory because, while one study shows that time flow is determined by L1, another shows that time flow direction can be replaced with a new language. Another criticism is that the arrangement of sequential events tasks in the horizontal axis on request is not sufficient to demonstrate that the internal time representation is structured, and we cannot conclude that the underlying mechanism is language (January & Kako, 2007). To be able to interpret and provide clarity on different claims and conflicting findings, different methodological approaches (both different tasks and different bilingual participant groups) are required in this case. By measuring time representation in different domains (spatial, pictorial, verbal) using different bilingual groups, this study aims to shed light on the contradictory findings regarding the effect of L1 and acquired second language on the perception of time flow.

1.3 Present Study

The aim of this thesis is to investigate the relationship between language writing direction and time perception through second language acquisition. For this purpose, answers are sought for three main research questions:

(1) Does time flow in the congruent direction with L1 writing direction?

(2) Does the acquisition of a second language written in a different direction compared to L1 can change the perception of time flow direction?

(3) Whether the context of acquiring second language (academic purposes vs. society language) influences which language direction predominates the bias for individuals who are familiar with writing in both directions?

Previously, it was assumed that participants who were exposed to two conflicting direction experiences before would acquire contradictory directional habits, and as a result, lateral biases would be weaker, and this assumption was supported in different

cognitive domains (Roman et al., 2013; Berch et al., 1999, Dobel et al., 2007). We also expected that directional time bias would become less strict for participants who learn a second language written in a different direction on the same axis. In order to investigate the research questions about the role of first and second language on spatial representation of time, we compared three groups of bilinguals: (1) bilinguals (L1-Turkish – L2-English) who had never been exposed to a different direction; (2) bilinguals (L1-Turkish – L2-Arabic) whose L1 is written from left to right and second language is written from right to left; and (3) bilinguals (L1-Arabic – L2-Turkish) whose L1 is written from right to left and second language from left to right.

This thesis aimed to contribute to the literature and fill the gaps in several ways. We aimed to examine whether the writing direction is a strong factor in the representation of the time flow direction and whether this effect can be stretched with the second language. Therefore, finding an effect of L2 would thus support the claim that the writing direction has an effect on the spatial representation of time and that this effect can be updated. This result would also be consistent with the claim that there is no time flow direction originally (Huang & Tse, 2017), and factors such as linguistic expression and writing direction give time representation a direction. Furthermore, because writing direction concretizes the abstract concept of time, showing the effect of writing direction on time representation would support Conceptual Metaphor Theory.

If the directional time bias congruent with L1 does not stretch in line with the L2 writing direction, it would be possible to conclude that the L1 is decisive and permanent in the perception of time flow direction. If groups with different first languages would not differ at all, the relationship between time flow and writing direction could be questioned.

The thesis was designed to measure and distinguish space-time associations across three major domains (spatial, pictorial, and verbal), allowing us to capture how time is spatialized across three fields. The tasks were selected to correspond to three distinct references (space, picture, word). The spatial pointing task is a free choice task that participants are asked to choose a coordinate with no restrictions. Other two tasks examine the time representation by measuring response time, through the meaning of words (past/future) in written form or through the images. Participants do not process

any language in the pictorial task, so the automatic spatial time representation can be revealed at the level of non-linguistic cognition. Furthermore, by using reaction time measurements, we can detect implicit bias differences within and between groups.

Another distinguishing feature of this thesis is that it will be the first time bilinguals who learn the second language in different contexts, with different writing directions on the same axis, will be compared (L1-Turkish – L2-Arabic and L1-Arabic – L2-Turkish). Different contexts refer to the motivation (work, education, migration) and environment (country, school/work environment) for learning a second language. In the literature, majority of participants live in different regions and have no or as little exposure to the written language in the other direction (De la Fuente et al. 2014; Fuhrman & Boroditsky, 2010; Ishihara et al., 2008). Bilingual participants, who are relatively few in the literature, do not have a second language written from right to left (Boroditsky, 2001; Maass & Russo, 2003; Roman et al., 2013; Yang et al., 2022). We can distinguish the effect of second language by recruiting bilingual groups who speak the same pair of languages in a different order. Moreover, Bergen and Chan Lau (2012) asserted that as a result of numerous studies we can see that writing direction affects different spatial representations of time, but we cannot directly attribute these differences to writing direction. Different daily life practices and cultural elements of the studied languages and populations may also influence these representations. In studies with participants familiar with only one direction and one culture, which were mostly preferred in the literature, it is not possible to achieve a language/writing direction effect that is independent of the cultural effect of the country. The study is expected to contribute to the literature by working with bidirectional bilingual groups that have previously unstudied features, living in the same region with different first languages, and having the habit in both directions (Right-Left, Left-Right). In this study, "bidirectional bilingual" groups speak two languages written in opposite directions, with L1 of one bilingual group corresponding to L2 of the other. In this way, it will be possible to compare the acquisition of both right-to-left and left-to-right languages simultaneously. Findings are expected to strengthen theoretical implications. Acquiring second languages in different contexts (for academic purposes or as a society language) will also allow us to see how their impact varies.

Based on our research questions, we tested three main hypotheses as following:
(TR-EN will refer to L1-Turkish – L2-English, TR-AR will refer to L1-Turkish – L2-Arabic, AR-TR will refer to L1-Arabic – L2-Turkish group)

Hypotheses on time flow direction within different bilingual groups

1. L1-Turkish groups will tend to represent time from left to right in congruent with their L1 writing direction. AR-TR group is expected to represent time in both directions while being faster in L1 congruent trials. In the spatial pointing task L1

1.1. Turkish groups will represent time dominantly (more than 50%) from left to right. Since the spatial pointing task determines only the dominant direction, a very strong effect is expected to suppress the L1 bias only when the L2 writing direction is the society language (AR-TR).

1.2. In the pictorial time flow task L1-Turkish groups (TR-EN, TR-AR) are expected to be faster when representing the earlier stage with the left key and later stage with the right key which is congruent with the their L1. AR-TR group is expected to be faster in reverse mapping.

1.3. In the verbal time flow task, L1-Turkish groups (TR-EN, TR-AR) will be faster when words related to the past are on the left or when the left key is used to express the past. When future words are represented on the right side or responded with the right key, the two groups will be faster than when they are represented on the left side or responded with the left key. L1- Arabic speakers (AR-TR) will be faster in reverse mappings.

Hypotheses on time flow direction across different bilingual groups

2. TR-AR speakers are expected to be less strict in representing time in one direction than TR-EN speakers because they have exposure in both directions. Right to left bias is expected to be seen strongly and mostly in the participants whose L1 is Arabic (AR-TR).

2.1. There will be no significant difference in left to right time arrangement scores between L1- Turkish groups in the spatial pointing task (TR-EN & TR-AR). AR-TR group is expected to arrange time from right to left significantly more, and from left to right significantly less than L1-Turkish groups.

2.2. In the time flow task measured with pictures (pictorial time flow task), the response time of the TR-AR participants will be faster than the TR-EN bilingual participants when representing the earlier stage with the right key and later stage with the left key which is incongruent with the their L1 but congruent with their L2 writing direction. In these trials, AR-TR bilingual participants will have the fastest response time since there is no incompatibility with their L1 writing direction.

2.3. In the task that measures the time flow through words (verbal time flow task), when words related to the past are on the right or when the right key is used to express the past, the measured response time will be faster in those whose second language is Arabic (TR-AR) than in those who did not expose to a right-to-left direction (TR-EN). Likewise, when words related to the future are on the left or when the future is represented by the left key, the response time will be the fastest for AR-TR speakers and slowest for those not exposed to the Arabic language (TR-EN).

2.4. In both of the time flow tasks, when incongruent trials of three groups are compared in terms of RT, we expect AR-TR group to be faster than L1-Turkish – L2-Arabic and TR-EN respectively. We expected this result due to higher exposure of second writing direction for AR-TR.

Hypotheses on the context of L2 learning (comparing TR-AR and AR-TR speakers)

3. Bidirectional bilinguals whose second language is the dominant (society) language (AR-TR) are expected to be more influenced by the L2 writing direction than those whose L1 is the society language and L2 is acquired for academic purposes (TR-AR). In other words, L1 direction biases of L1-Arabic – L2-Turkish group will reduce more than TR-AR group.

3.1. In spatial time representation task, the percentage of placements congruent with L2 writing direction will be significantly higher in AR-TR than TR-AR speakers.

3.2. AR-TR speaking participants will have faster response times in trials incongruent with their L1 in both tasks measured with pictures and words, compared to the TR-AR group.

2. METHOD

2.1 Participants

One hundred ninety-five adults aged between 18 to 41 participated in this study in exchange for either course credit or payment. We used G-Power (Faul et al., 2007) statistical power analysis in order determine the sufficient sample size. The optimal sample size was computed as 180 (sixty participants for each group). Participants were recruited in three groups as following:

(1) L1-Turkish speakers with no exposure to opposite writing direction (L1-Turkish – L2-English) (N=67, M_{age}=21.48, *SD*=1.53),

(2) L1-Turkish speakers with the second language written in a different direction (L1-Turkish – L2-Arabic) (N=63, M_{age}= 23.87, *SD*= 2.78),

(3) L1-Arabic speakers acquired the second language written in a different direction (L1-Arabic – L2-Turkish) (N=65, M_{age} =23.19 , *SD*=3.64)

Descriptive data for each group is provided in the Table 2.1.

Table 2.1 *Descriptive information for age and gender*

	Group	N	Mean	SD	Min	Max	Number of Females/Males
Age	TR-EN	67	21.5	1.52	19	27	58/5
	TR-AR	63	24.1	3.5	19	41	46/16
	AR-TR	65	23.2	3.58	18	35	19/46

All participants completed a demographic and language background questionnaire. Participants completed the questionnaire by listing all of the languages they have learned (along with biographical information such as age of onset and countries lived in) and rating their L2 proficiency on a scale of 1 to 10 (1 = very weak, 10 = excellent). They reported their experiences with reading, writing, and speaking in particular. The questionnaire also provided information for how much participants used different factors (friendship communication, reading-writing, studying) while learning L2 (see Table 2.2).

Table 2.2 *Descriptive statistics for L2 questionnaire*

	Mean			SD			Min			Max		
Group	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN
PPVT	117.67	126.24	-	44.86	47.69	-	23	7	-	174	171	-
Speaking proficiency	5.76	7.46	6.52	1.79	1.67	1.53	1	0	3	9	10	10
Understanding proficiency	6.83	8.38	7.48	1.59	1.4	1.26	2	3	5	9	10	10
Reading proficiency	7.14	7.89	7.50	1.63	1.5	1.13	3	4	5	10	10	10
Age of Onset (learning L2)	15.5	18.02	9.19	3.36	4.53	2.96	2	2	4	21	29	19
Age of Onset (writing L2)	15.45	18.67	11.15	4.16	4.15	3.41	5	5	5	22	29	19
Age of Onset (reading L2)	18.08	20.47	11.15	3.33	3.84	3.41	7	11	5	24	33	19
Duration_exposure (year)	7.16	2.35	11.96	5.47	2.1	3.84	2	1	2	40	12	20
Duration_country (month)	4.53	69.6	15.87	15.74	55.16	56.01	0	0	0	120	324	252
Duration_school/work (month)	33.34	29.95	40.78	36.2	23.05	49.17	0	0	0	168	84	180
Friendship communication (use)	5.69	7.89	5.90	2.56	1.92	2.48	0	2	0	10	10	10
Reading-writing (use)	7.71	7.51	7.54	1.87	2.03	1.94	3	2	0	10	10	10
Studying (use)	7.78	8.02	7.71	2.12	2.4	1.63	1	1	3	10	10	10

Three participants were excluded from the study, either because their third language writing direction differed from their L1 writing direction or because they reported that their L1 is not the group's target language. We discarded the first data from additional three participants who completed the experiment twice.

Since the tasks we used required computer skills which may affect response times and accuracy percentages, we made sure that all participants had higher education (i.e., university) exposure. All participants were either university graduates or undergraduate students.

2.2 Materials

We used three different temporal representation tasks (spatial, pictorial, and verbal), as well as a working memory test (Corsi Block Tapping) and a language proficiency test (PPVT-IV).

2.2.1 Spatial pointing task

The task is adapted from the 3D pointing test applied by Fuhrman and Boroditsky (2010). In this task, participants saw a circle shown in the middle of screen (see Figure 2.1) and they were asked to click to a point around that circle to answer questions that they heard in their native languages (e.g., "if this is today, where would you locate tomorrow?"). Then, their response coordinates in the x and y axes were coded. Similar questions were asked in terms of different categories such as months and meals (e.g., if this is September, where would you locate October). The questions consist of 12 temporal sequences (see Appendix A). In this study, the dependent variable was the location side they choose for the forward and backward time concept, which is after reported as a percentage of preference (left to right or right to left) . Since the effect of writing direction is questioned, only the horizontal answers are considered.

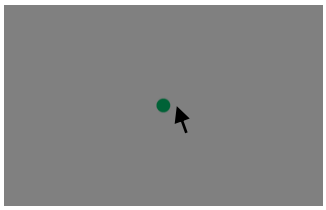


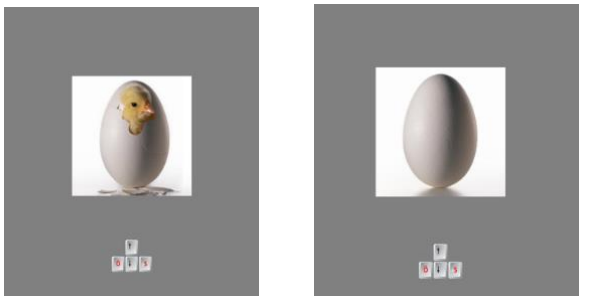
Figure 2.1 *Display of the screen in Spatial Pointing Task*

2.2.2 Pictorial time flow task

The material consisted 18 triplets expressing a three-stage temporal sequence (e.g., youth, middle age, old age) with points ‘early’, ‘middle’, and ‘late’. All stimuli are

provided in Appendix B. A sample stimuli and a representative response click is displayed in Figure 2.2

Following Fuhrman and Boroditsky (2010), participants completed two test blocks of 72 trials. While left key represented “earlier” and right key represented “later” in one block, other block had reversed mapping. The block order was counterbalanced for each participant. All trials started with a fixation cross displayed for 500 msec and it was replaced by an image. The first picture -displayed for 2 secs which always depicted the middle point of one triplet, followed by the picture of the previous or next stage. Second picture remained until participants responded. They were asked to respond with either right or left key tagged as “earlier” or “later” in the instruction. First letter of these tags remained in the screen during the block to remind the instruction. In each block, there were 10 practice trials with feedback before the main experiment. The practice images were different than the images used in main blocks. In this task, the dependent variable was the reaction time of congruent and incongruent trials. While congruent trials for L1-Turkish speakers (TR-AR, TR-EN) was when “earlier” and “later” is represented by left and right key respectively, this block was incongruent for AR-TR speakers.



Note. First image followed by earlier stage

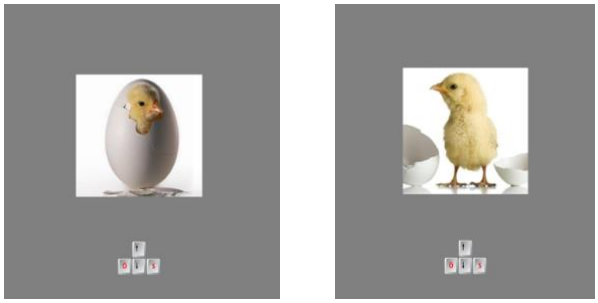


Figure 2.2 *Examples of Stimuli Used in Pictorial Time Flow Task*

2.2.3 Verbal time flow task

Following Santiago et al. (2007), 48 words referring to past and future were used. The 48 words used by Santiago et al. (2007) were adapted to Turkish and Arabic by using the word frequency dictionary of Tekcan and Göz (2005) and keeping the frequency and number of syllables balanced between the past and future words (see the Table 2.3).

Table 2.3 *Verbal Time Flow Task*
Turkish Version (Translations in brackets)

Past	Future
geçmiş (past)	gelecek (future)
önce (before)	sonra (after)
öncesinde (priorly)	sonrasında (thereafter)
dün (yesterday)	yarın (tomorrow)
önceki (previous)	sonraki (next)
geçen yıl (last year)	gelecek yıl (next year)
önceden (beforehand)	sonradan (afterwards)
evvelden (afore)	bilahare (later on)
sağladılar (they provided)	sağlayacak (he/she will provide)
gelebildim (I was able to come)	vereceğim (I will give)
öğrenebilirdik (we could learn)	sürebileceğiz (we can drive)
yaşadınız (you lived)	bulacağız (we will find)
uzaklaştınız (you went away)	deneyeceksin (you will try)
istedi (he/she wanted)	çıkacak (he/she will leave)
yararlandım (I benefitted)	aşacağım (I wil overcome)
başladılar (he/she started)	başlayacak (he/she will start)
düşündünüz (you thought)	yaşayacak (He will live)
başladım (I started)	kalacağım (I will stay)
sordular (they asked)	soracak (he/she will ask)
öğrendin (you learned)	sürecek (will drive)
istedik (we wanted)	çıkacağız (we will leave)
yararlandın (you benefitted)	aşacaksın (you will overcome)
oluşturdun (you created)	inanacaksın (you will believe)
sürebildiler (they could drove)	öğrenecekler (they will learn)

Arabic Version

Past	Future
ماضي	مستقبل
قبل	بعد
قبل فاصل	بعد الفاصل
امس	غدا
قبله	بعده
سنة سابقة	سنة قادمة
سابقا	التالي
قالت	سيقول
وجدت	سأجيد
استفاد	سنستفيد
بحثتن عنه	سنبحث عنه
حاولتن	ستحاولن
ذهبت	ستذهب
حضرت	سأحضر
رأيت	سيرى
اعتقدت	سأعتقد
نظرت	سأنظر
سأل	سيسأل
شكلتن	ستشكل
أردنا	سنريد
فعلت	ستفعل
آمنت	ستؤمن
قدنا	سنقود
عاشتنا	ستعيش

The task consists of 8 practice trials and 96 main trials which are presented in two identical blocks with the exception of the response keys. The 48 words were divided into two lists, each with an equal number of past and future related words. Each word was displayed on the screen 4 cm to the right or 4 cm to the left of a fixation point in the center. After seeing this point for 500 msec, participants read a word on the left or right side of the screen, either past or future related. Participants were asked to determine whether the 48 words displayed on the screen were from the past or the future. Regardless of this request, the spatial location that the word is displayed (right-left) was manipulated. Words that refer to the past or future were displayed on the left or right

side of the screen, and participants were instructed to press two keys (f-j) with their left or right hand to indicate whether the word was related to the past or future. The effect of this manipulation in bilinguals was investigated because it has been observed that words related to the past are evaluated faster when they appear on the left and/or are answered with the left hand, and words related to the future are evaluated faster when they appear on the right and/or are answered with the right hand (Santiago et al., 2007).

The effect of second languages acquired in different directions on spatial representations of the past and future was to be investigated in three different groups based on response time latencies on accurate trials. There were both congruent and incongruent trials during the task. Congruent trials occur when past and future related words appear in the direction congruent with the L1 (position congruency) or are answered with the button in the congruent direction (key congruency). On the other hand, incongruent trials occur when words related to the past and future appear incompatible with the L1 of participants or are answered with the button in the incompatible direction. The dependent variable in this task is RT latencies.

Note. Incongruent position mappings of past word for L1-Turkish and L1-Arabic groups.

Note. Incongruent key mapping for L1-Turkish / Congruent key mapping for L1-Arabic (past with J, future with F)

Note. Congruent key mapping for L1-Turkish / Incongruent key mapping for L1-Arabic (past with F, future with J)

Figure 2.3 *Examples of Stimuli Used in Pictorial Time Flow Task*

2.2.4 Corsi block-tapping task (Forward and Backward)

Corsi Block-Tapping (Corsi, 1973), a visuospatial short-term working memory task, was used this task to control individual executive function differences between groups because all tasks are spatially oriented. We included this measurement to make sure that the groups did not differ in terms of general potential. In this task, the participant attempts to imitate the sequence followed by the various colored blocks for a total of nine steps (see Figure 2.4). The maximum number of moves that participant can follow determines their final score. The EF is measured in two blocks of forward and backward Corsi Block-Tapping Task. Participants first completed the forward version of the task. They noticed a fixation cross on a gray background, followed by nine white squares. They performed the task until they failed to follow the sequence three times after being instructed to click on the blocks in the same sequence with red lights. After completing this section, they proceeded to the backward version of the task, which is identical except for the request to follow the squares in reverse order.

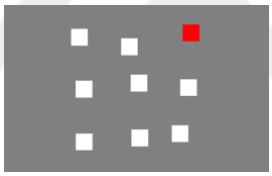


Figure 2.4 *Corsi Block Tapping Task*

2.2.5 Language measures and demographical information

Peabody Picture Vocabulary Test-IV (PPVT-IV)

PPVT-IV is a standardized picture vocabulary which is used to measure second language proficiency (Dunn and Dunn, 2007). The test was modified for use on an online platform (Pavlovia) by PsychoPy software (Peirce et al., 2019). Participants were instructed to follow the steps on their own. In this test, participants hear a recorded word that corresponds to one of four images displayed on the screen. They were told to press the corresponding key to select the image that matches up to the word they heard (1,2,3, or 4). The A form of the test was translated into Turkish to measure second language proficiency, while the equivalent B form was translated into Arabic to control the

Turkish participants' Arabic second language proficiency. Both languages were translated using the translation-back translation method by native speakers of Turkish and Arabic.

Demographic-Linguistic Form

The form requests demographic information as well as language background information such as their gender and age, the context in which they acquired the second language, the age of acquisition, the duration of exposure to the second language in various areas such as reading, writing, and speaking, and their proficiency levels in a third language. While the first two groups (L1-Turkish) provided L2-English and L2-Arabic language information, the L1-Arabic group filled out the form for both Turkish and English as a second language because both languages are written from left to right (see Appendix D).

2.3 Procedure

The same experiment was completed by all participants, who were given instructions in their native language. They were asked to perform various online tasks that implicitly measure their perception of time. The experiment was implemented in PsychoPy software (Peirce et al., 2019). Participants were informed that the experiment is about the relationship between language and thought and there were no correct or incorrect answers. All tasks were completed in three steps using three different links.

In the first session, they completed the four different tasks in the designated order: (1) spatial pointing task, (2) pictorial time flow task, (3) verbal time flow task.

To begin, we asked them to complete the "spatial pointing task" in order to investigate the dominant time direction bias in bilingual participants. The first task was then followed by two others in order to measure the representation of past/early and future/late via reaction time, which is one of the essential tools used in the implicit evaluation of the time flow direction. The first of these tasks, named as the "pictorial time flow task," measured time representation over sequential pictures, while the second, named as the "verbal time flow task", measured time flow direction over words

with past and future meanings. In the first session, time perception and EF tasks were completed. This session lasted about 30-40 minutes.

In the second session, which lasted about 20 minutes, they performed the PPVT-IV, which assesses participants' second language proficiency. The Arabic version of the PPVT-IV was given to participants whose second language is Arabic (L1-Turkish – L2-Arabic), and the Turkish version was administered to participants whose second language is Turkish (L1-Arabic – L2-Turkish).

Finally, all participants completed a language background questionnaire about the languages they have been exposed to, the age of acquisition, years of education, country of residence, and proficiency.

3. RESULTS

Results are presented in two sections. The first section includes descriptive information and preliminary analyses which compares the three groups' working memory, L2 proficiency and age. And the second section covers analysis of the three main tasks (spatial, visual, verbal) comparing three groups: TR-EN, TR-AR and AR-TR. We included subsections of the accuracy analyses for both the verbal and visual tasks in addition to the main analyses with reaction latencies. In these tasks, we conducted two different ANOVAs since the congruency categories were different for L1-Arabic speakers and L1-Turkish speakers. We categorized each condition as congruent or incongruent for each group after comparing the conditions with mixed ANOVAs.

3.1 Descriptive Statistics

There were 67 males (35%) and 123 females (65%) among all participants who reported their gender. Thirty-two TR-AR speakers reported that Arabic is their second language, while 27 reported that Arabic is their third language. Turkish was reported as the second language for 43 AR-TR speakers, while it was the third language of 18 participants. Descriptive statistics for all measurements are provided in Table 3.1.

Table 3.1 *Descriptive Statistics for all tasks/measures*

	Mean			SD			Min			Max		
Group	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR
Corsi_F	6.23	6.79	6.86	1.67	1.46	1.40	1	1	4	9.0	9.0	9.0
Corsi_B	5.33	6.16	5.77	1.80	1.65	2.05	1	1	1	9.0	9.0	9.0
Spatial Pointing Task												
Left to right (pointing)	0.86	0.86	0.51	0.13	0.18	0.33	0.5	0.0	0.0	1.0	1.0	1.0
Right to left (pointing)	0.14	0.15	0.49	0.13	0.18	0.33	0.0	0.0	0.0	0.5	1.0	1.0
Pictorial Time Task												
Pictorial_congruent (RT)	1.36	1.27	1.44	0.32	0.35	0.35	0.7	0.6	0.7	2.0	2.1	2.4
Pictorial_incongruent (RT)	1.47	1.44	1.52	0.34	0.41	0.39	0.8	0.7	0.8	2.3	2.5	2.4
Verbal Time Task												
Past-Left-Left (RT)	1.04	0.98	1.09	0.15	0.19	0.22	0.8	0.6	0.7	1.5	1.5	1.6
Past-Left-Right	1.06	1.01	1.07	0.16	0.17	0.19	0.8	0.7	0.7	1.4	1.5	1.5
Past-Right-Left	1.06	0.97	1.07	0.16	0.16	0.19	0.8	0.7	0.7	1.5	1.4	1.5
Past-Right-Right	1.06	0.99	1.06	0.19	0.18	0.19	0.7	0.7	0.7	1.6	1.4	1.5
Future-Left-Left (RT)	1.04	0.98	0.96	0.18	0.16	0.18	0.7	0.7	0.6	1.4	1.4	1.4
Future-Left-Right (RT)	1.03	0.95	0.98	0.15	0.15	0.17	0.8	0.7	0.7	1.4	1.4	1.4
Future-Right-Left (RT)	1.03	0.97	0.98	0.18	0.16	0.17	0.7	0.6	0.6	1.6	1.4	1.4
Future-Right-Right (RT)	0.98	0.91	0.95	0.15	0.17	0.17	0.7	0.6	0.6	1.4	1.5	1.3
Key_congruent (RT)	1.02	0.96	1.02	0.14	0.16	0.17	0.8	0.7	0.7	1.4	1.4	1.4
Key_incongruent (RT)	1.05	0.99	1.02	0.16	0.15	0.17	0.7	0.7	0.7	1.5	1.3	1.4
Position_congruent (RT)	1.03	0.97	1.01	0.14	0.15	0.15	0.8	0.7	0.7	1.3	1.4	1.4
Position_congruent (RT)	1.05	0.97	1.02	0.14	0.15	0.16	0.8	0.7	0.7	1.4	1.4	1.4
Overall RTs												
Pictorial_overall_RT	1.42	1.35	1.48	0.29	0.34	0.32	0.8	0.7	0.8	2.1	2.1	2.1
Verbal_overall_RT	1.04	0.99	1.03	0.16	0.18	0.17	0.7	0.7	0.8	1.7	1.7	1.7

Note. The conditions in the verbal time flow tasks named in the following order : Meaning-Position-Key (e.g. Past-Left-Right)

3.1.1 Preliminary analysis

The comparison between the three groups revealed a significant age difference [$F(2, 192) = 12.7$, $p < .001$, $\eta^2_p = 0.117$)], Corsi forward test difference [$F(2, 190) = 3.42$, $p = .035$, $\eta^2_p = 0.035$)] and Corsi backward test difference [$F(2, 192) = 3.31$, $p = .039$, $\eta^2_p = 0.033$)]. TR-EN group ($M = 21.49$, $SD = 1.52$) was significantly younger than TR-AR group ($M = 24.11$, $SD = 3.49$) $t(192) = -4.97$, $p < .001$ and AR-TR group ($M = 23.16$, $SD = 3.58$) $t(192) = -3.21$, $p = .005$.

There was a significant difference in Corsi forward scores between TR-EN group ($M = 6.22$, $SD = 1.70$) and AR-TR group ($M = 6.86$, $SD = 1.40$) $t(190) = -2.39$, $p = .053$. Corsi backward scores were significantly lower in TR-EN speakers ($M = 5.32$, $SD = 1.80$) than TR-AR speakers ($M = 6.15$, $SD = 1.65$) $t(192) = -2.57$, $p = .033$.

Since the TR-EN group does not speak any language in different direction, PPVT scores and L2 background information were only compared for TR-AR and AR-TR groups. The two groups did not significantly differ in PPVT scores [$t(114) = -0.99$, $p = .32$] and in the duration of months spent in L2 speaking school/work environment [$t(120) = 0.62$, $p = .53$)]. There was a significant difference between these two bidirectional bilinguals in their self-reports for age of onset (L2), L2 exposure duration, the duration of stay in the country where their L2 is dominant language, and L2 proficiency (reading, understanding and speaking). TR-AR group ($M = 15.5$, $SD = 3.36$) started to learn their L2 earlier than AR-TR group ($M = 18.0$, $SD = 4.53$) $t(118) = -3.45$, $p < .001$. TR-AR group reports revealed that they were exposed to their L2 for more years ($M = 7.16$, $SD = 5.47$) than AR-TR group ($M = 2.35$, $SD = 2.10$) $t(117) = 6.35$, $p < .001$. TR-AR group ($M = 4.53$, $SD = 15.74$) reported that they stayed less months in a country that speaks their L2 less than AR-TR group ($M = 69.90$, $SD = 55.16$) $t(122) = -8.74$, $p < .001$. TR-AR group reported that they are less proficient in L2 reading ($M = 7.14$, $SD = 1.63$) than AR-TR group ($M = 7.98$, $SD = 1.50$) $t(118) = -2.96$, $p = .004$. Similarly, the reports revealed that L1-Turkish group was significantly more proficient in L2 speaking ($M = 5.76$, $SD = 1.79$) and understanding ($M = 6,83$, $SD = 1.59$) than L1-Arabic group in

speaking (M = 7.46, SD = 1.67) and understanding (M = 8.38, SD = 1.40) [speaking: $t(118) = 5.36$, $p < .001$; understanding: $t(118) = 5.65$, $p < .001$].

3.2 Spatial Pointing Task

One hundred ninety-five people ($N_{TR-EN} = 67$, $N_{TR-AR} = 63$, $N_{AR-TR} = 65$) participated to this task. They responded to the 24 questions (e.g., if this is today, where would you locate yesterday?) by clicking anywhere around the circle. We measured the coordinates of the responses. Responses that fell on the green circle which represents the first sentence in the middle of the screen were omitted. Responses of 33 participants in total (17%) were discarded due to high error on the task (clicking to the circle in the middle more than half of the trials) implying that they did not comprehend the task. From the remaining participant responses, eleven participants were also discarded (based on their response coordinates) because they clicked to the same point throughout the task.

For the analysis, since we were interested in writing direction differences, we only focused on the responses that fell on the horizontal axis. We created a composite score from two responses for earlier and later time as one item that represents whether time is perceived to flow right to left or left to right. We calculated the sum of responses when the past was pointed to the left and the future was pointed to the right to create the left to right arrangement score. The sum of reverse mappings provided the score for right to left arrangement. Dividing these composite scores by the number of valid trials (placements that the participant did not click to the reference circle) for each participant provided us the proportion of left to right or right to left arrangements in percentage. For example, if a participant pointed past on the left side 10 times and future on the right side 5 times, his composite score for left to right arrangement was 15. Dividing this score by his 20 valid trials (out of 24), provided us the percentage of left to right arrangement (15/20). To provide descriptive information, percentages for future and past words were also calculated separately (See Table 3.2). These percentages reflect the number of times participants represented the future and past on either the right or left sides of the screen. “Future on left” corresponds to the number of trials in which the future is located on the left in proportion to the number of valid trials of future

condition. For example, if a participant placed future on the left on nine out of the ten valid trials, then the score for representing future on left is nine divided by ten (0.9).

Table 3.2 *Mean, SD and min max values for percentage time arrangement score*

	Mean			**SD**			**Min**			**Max**		
	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR
Future on Left	0.12	0.13	0.47	0.13	0.17	0.36	0.0	0.0	0.0	0.5	0.9	1.0
Future on Right	0.88	0.88	0.53	0.13	0.17	0.36	0.5	0.1	0.0	1.0	1.0	1.0
Past on Right	0.15	0.17	0.51	0.17	0.22	0.33	0.0	0.0	0.0	0.7	1.0	1.0
Past on Left	0.85	0.84	0.49	0.17	0.22	0.33	0.3	0.0	0.0	1.0	1.0	1.0
Right-to-Left	0.14	0.15	0.49	0.13	0.18	0.33	0.0	0.0	0.0	0.5	1.0	1.0
Left-to-Right	0.86	0.86	0.51	0.13	0.18	0.33	0.5	0.0	0.0	1.0	1.0	1.0

There was an effect of writing direction in transverse axis as depicted in Figure 3.1. In the horizontal axis, TR-EN speakers placed earlier event to the left of the point and later event to the right of the point (laid time out from left to right) 86% of the time (*SE*=0.02). TR-AR speakers did so 86% of the time (*SE*=0.02) and AR-TR speakers did so 51% of the time (*SE*=0.06). We compared three groups' proportions of left to right responses by one way ANOVA which showed that the difference of three groups was significant $F(2, 148) = 38.8$, $p < .001$, $\eta^2_p = 0.34$. Post hoc comparisons of left-right arrangement and group interaction using the Bonferroni correction indicated that there was a significant difference between TR-EN and AR-TR groups ($t(148) = -8.13$, $p < .001$) and similarly between TR-AR and AR-TR groups $t(148) = -7.72$, $p < .001$. AR-TR group ($M = 0.51$, $SD = 0.33$) laid time out from left to right significantly less than TR-EN group ($M = 0.86$, $SD = 0.13$) and from TR-AR group ($M = 0.86$, $SD = 0.18$). When we added Corsi scores as a covariate in a one-way ANCOVA, there was still a significant difference between groups $F(2, 145) = 40.78$, $p < .001$, $\eta^2_p = 0.36$. And similarly, Post hoc comparisons of left-right arrangement indicated that there was a significant difference between TR-EN and AR-TR groups ($t(148) = -8.39$, $p < .001$) and similarly between TR-AR and AR-TR groups $t(148) = -7.71$, $p < .001$. AR-TR group laid time out from left to right significantly less than TR-EN group and from TR-AR group . The covariate, Corsi scores, was significantly related to left to right arrangement percentage $F(2, 145) = 5.12$, $p = .025$, $\eta^2_p = 0.34$.

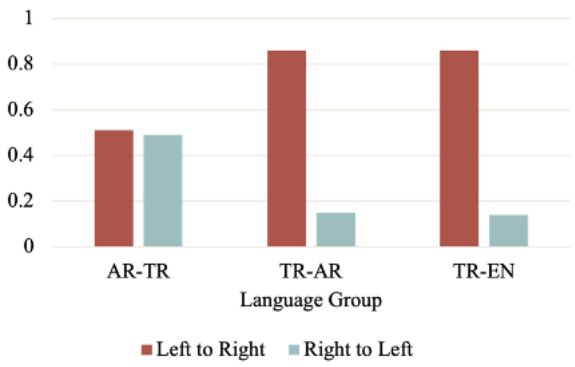


Figure 3.1 *Percentage time arrangements scores across groups*

3.3 Pictorial Time Flow Task

The same 195 people ($N_{TR–EN}$ = 67, $N_{TR–AR}$ = 63, $N_{AR–TR}$ = 65) participated in this task right after the spatial pointing task. As the first step, the accuracy for each participant was calculated. Following Fuhrman and Boroditsky (2010), responses were considered only for participants who has accuracy rate more than 75%. The accuracy below 75% was considered as high error rate. Therefore, responses of seventeen participants (3.6%) were discarded (TR-EN:14, TR-AR:4, AR-TR:5). Average accuracy rate for the remaining 178 participants was 93%. Only accurate trials were included in the analysis. Reaction times were calculated for both of the conditions (left key is designated as earlier or later). We also discarded the top and bottom 2% of reaction times of all correct responses (3.81%) from the analysis and included only the responses between 2%-98%. In this way, we eliminated trial-based outliers. Lastly, responses of six participants (TR-EN:1, TR-AR:2, AR-TR:3) were discarded following Fuhrman et al. (2011) since their overall RT means were still exceptionally away (2SD) from the language group mean.

To compare the effect of writing direction on representation of time, we performed 3x2x2 mixed ANOVA (Language group x Block order x Key Mapping) while language group and block order (whether the block that they see first designated the right key for earlier or later stage) were between subjects independent variables, key mapping

(whether the right key represents earlier or later stage) was within subject variable (see Table 3.3 and Figure 3.2).

In addition to this analysis, in order to examine the group differences between congruent and incongruent trials, we conducted 3x2 mixed ANOVA (Language group x Congruency). While "left is earlier" block was congruent for L1-Turkish groups, the mean RT in this condition was treated as incongruent score of the L1-Arabic – L2-Turkish group (see Figure 3.3).

Table 3.3 *Descriptive statistics for reaction times in each condition (pictorial time flow task)*

	Mean			SD			Min			Max		
	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR	TR EN	TR AR	AR TR
Right is earlier	1.47	1.44	1.44	0.34	0.41	0.35	0.8	0.7	0.7	2.3	2.5	2.4
Left is earlier	1.36	1.27	1.52	0.32	0.35	0.39	0.7	0.6	0.8	2.0	2.1	2.4

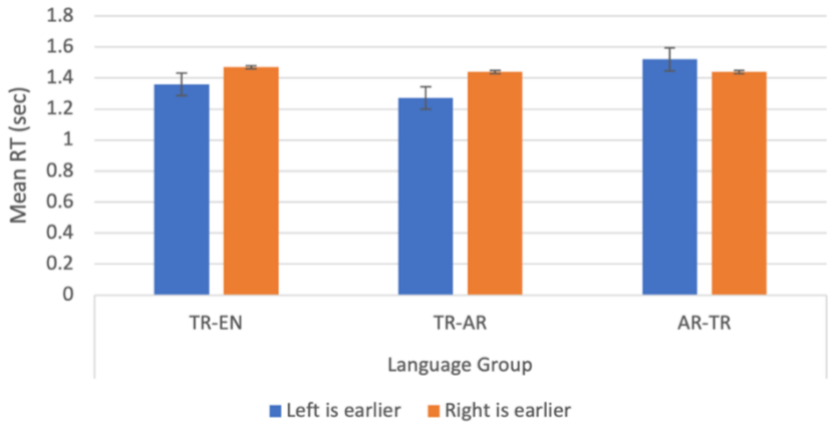


Figure 3.2 *Mean latency (RT) in each key mapping across groups*

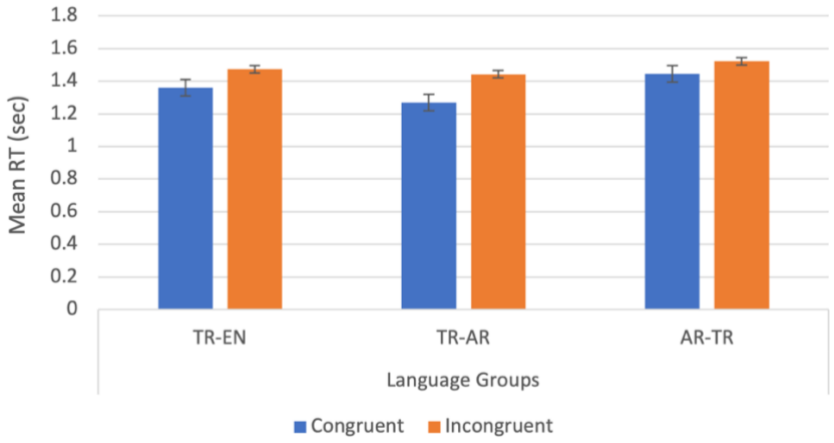


Figure 3.3 *Mean latency (RT) for congruent and incongruent trials*

3.3.1 Effects of writing direction on reaction times

In line with the predictions, there was a significant Language group x Key Mapping interaction: $F(2, 160) = 5.86$, $p = .003$, $\eta^2_p = 0.068$ (see Figure 3.4). And post hoc comparisons revealed that TR-AR speakers ($M = 1.27$, $SD = 0.35$) responded significantly faster than AR-TR speakers ($M = 1.52$, $SD = 0.39$) when "later" is represented with the right key which is congruent with writing direction of Turkish but incongruent with Arabic $t(160) = -3.051$, $p = .040$. None of the other comparisons were significant after Bonferroni correction (all ps >.05).

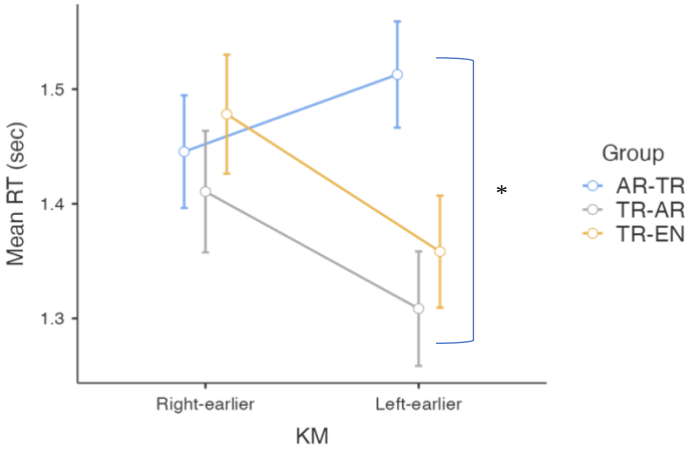


Figure 3.4 *Key Mapping x Group interaction*

There was also an interaction effect of key mapping and block order $F(1,160) = 21.87$, $p < .001$, $\eta^2_p = 0.120$. Participants that were asked in the first block to represent "earlier" with right key, responded significantly slower in "right is earlier" condition regardless of language group ($M = 1.49$, $SD = 0.37$) relative to "left is earlier" condition ($M = 1.32$, $SD = 0.34$) $t(160) = 4.96$, $p < .001$. None of the other comparisons were significant after Bonferroni correction (all ps >.05). Results indicated a marginally significant language group, key mapping x block order interaction $F(2, 160) = 2.97$, $p = .054$, $\eta^2_p = 0.036$.

There was no significant effect of language group $F(2,160) = 1.83$, $p = .16$, $\eta^2_p = 0.022$ and block order $F(1, 160) = 0.139$, $p = .071$, $\eta^2_p = 0.001$. There was main effect of key mapping $F(1, 160) = 4.44$, $p < .037$, $\eta^2_p = 0.027$. When "later" was represented with the right key and "earlier" was represented with the left key ($M = 1.39$, $SD = 0.37$), the overall reaction times were faster relative to the opposite key mapping regardless of language group ($M = 1.44$, $SD = 0.37$) $t(160) = 2.11$, $p = .037$.

When Corsi scores were added as a covariate in a 3x2x2 mixed ANCOVA analysis, key mapping was no longer significant, $F(1, 157) = 1.23$, $p = .268$, $\eta^2_p = 0.008$. Key mapping x block order interaction $F(1,157) = 20.72$, $p < .001$, $\eta^2_p = 0.117$ and key mapping x language group interaction were still significant $F(2, 157) = 6.39$, $p = .002$, $\eta^2_p = 0.075$. Furthermore, language group x key mapping x block order interaction was still marginally significant $F(2, 157) = 2.96$, $p = .055$, $\eta^2_p = 0.036$. The interaction between key mapping and Corsi scores was not significant $F(1, 157) = 2.44$, $p = .121$, $\eta^2_p = 0.015$.

3.3.2 Analysis of congruency

According to results of 3x2x2 mixed ANOVA (Language Group x Block Order x Congruency) there was a main effect of key mapping congruency $F(1,160) = 14.92$, $p < .001$, $\eta^2_p = 0.085$ revealing that congruent trials ($M = 1.36$, $SD = 0.35$) were responded significantly faster than incongruent trials ($M = 1.48$, $SD = 0.38$). There was no main effect of language group $F(2,163) = 2.25$, $p = .109$, $\eta^2_p = 0.027$. Additionally,

congruency x block order x language group interaction was significant $F(2,160) = 13.621$, $p < .001$, $\eta^2_p = 0.145$. Bonferroni post hoc comparisons revealed that when they first see the block that represents left key as earlier AR-TR group was faster in congruent trials than incongruent trials $t(160) = -3.59$, $p = .029$. When the participants see firstly the block that represents right key as earlier, TR-AR group was faster in congruent trials than incongruent trials $t(160) = -5.76$, $p < .001$.

When Corsi scores were added as a covariate in 3x2x2 mixed ANCOVA analysis, the main effect of key mapping lost its significance $F(1,157) = 0.59$, $p = .441$, $\eta^2_p = 0.004$. Congruency x block order x language group interaction was still significant $F(2,157) = 12.818$, $p < .001$, $\eta^2_p = 0.140$. Bonferroni post hoc comparisons revealed that when they first see the block that represents left key as earlier AR-TR group was faster in congruent trials than incongruent trials $t(157) = -3.57$, $p = .031$. When they see firstly the block that represents right key as earlier, TR-AR group was faster in congruent trials than incongruent trials $t(157) = -5.49$, $p < .001$.

3.3.3 Analysis of accuracy

Overall accuracy rate was 93% after outliers were discarded. To test if the RT differences stem from speed accuracy trade-off, we followed Fuhrman and Boroditsky (2010) and run error rate analysis. We did not find a significant language group x key mapping interaction in terms of accuracy rates, $F(2,160) = 0.60$, $p = .48$, $\eta^2_p = 0.009$.

3.4 Verbal Time Flow Task

Reaction time on correct trials was recorded and analyzed by mixed ANOVA with 3x2x2x2 Group (TR-EN, TR-AR or AR-TR) x Meaning (past or future) x Position (left or right screen position) x Key (left or right) design.

In addition to this analysis, since we have different L1 groups, we performed a separate 3x2 mixed ANOVAs (Language group x Key congruency and Language group x Position congruency) to be able to compare groups for congruent and incongruent trials (RT). Congruency of trials was determined based on the groups' L1 writing direction.

Congruent key score, for example, was calculated in L1-Turkish groups as the mean RTs of the trials when past words were responded with the left key and future words with the right key. Lastly, we run accuracy analysis to see if congruency affects accuracy and if our data has Simon-type effects (Simon and Rudell, 1967) assuming that when response and stimuli are on the same side, individuals respond faster and more accurate.

3.4.1 Analysis of RT latency

First of all, we calculated the accuracy rates for all participants. We only considered responses of participants who has accuracy rate more than 75% in total. Out of correct trials, we considered reaction times below 0.25 and above 2.5 sec as outliers following Santiago et al. (2007). In total, 4.84% trials were outliers and discarded from reaction time analyses. Reaction times were calculated for eight conditions of meaning, position, key mapping separately. In addition, we calculated latencies for congruent and incongruent trials for both response key and screen position. While congruent and incongruent conditions were the same in the first two groups, they were calculated for L1-Arabic speakers in reverse mapping. For example, congruent key mapping for L1-Turkish speakers was when past word is responded with left key and future word is responded with right key while it was when past word is responded with the right key and future word with the left key for AR-TR group. And congruent position score was calculated in L1-Turkish groups as the mean RTs of the trials when past words were displayed on the left side of the screen and future words displayed on the right. The reverse mapping was congruent for L1-Arabic speakers. After all calculations were made, the overall mean RT and SD of the task were determined on a group basis. And the responses of the five participants 2.85% (two from the TR-EN group, two from the TR-AR group and one from the AR-TR group) who were 2SD away from the group mean were discarded following Fuhrman and Boroditsky (2011). The reaction time means are reported for each condition in Table 3.4.

Table 3.4 *Mean Latency (RT) and Percent Errors (%Error) per Condition*

		Screen Position							
		Left				Right			
		Past		Future		Past		Future	
	Key	RT	%Error	RT	%Error	RT	%Error	RT	%Error
TR	Left	1.04	0.07	1.04	0.14	1.06	0.09	1.03	0.14
EN	Right	1.06	0.12	1.03	0.11	1.06	0.10	0.98	0.09
TR	Left	0.98	0.05	0.98	0.08	0.97	0.08	0.97	0.08
AR	Right	1.01	0.09	0.95	0.08	0.99	0.09	0.91	0.06
AR	Left	1.09	0.11	0.96	0.07	1.06	0.13	0.98	0.08
TR	Right	1.07	0.12	0.98	0.09	1.05	0.12	0.95	0.08

The analysis of latency demonstrated that there was main effect of language group on overall reaction times $F(2,171) = 3.27$, $p = .041$, $\eta^2_p = 0.037$. Post hoc comparisons revealed that TR-AR group ($M = 0.97$, $SD = 0.18$) was significantly faster than TR-EN group ($M = 1.04$, $SD = 0.16$). Meaning, position and key also had main effects on overall RTs [Meaning: $F(1,171) = 97.93$, $p < .001$, $\eta^2_p = 0.364$; Position: $F(1,171) = 13.58$, $p < .001$, $\eta^2_p = 0.074$; Key: $F(1,171) = 5.52$, $p = .02$, $\eta^2_p = 0.032$]. Post hoc comparisons revealed that future words ($M = 0.98$, $SD = 0.16$) were responded significantly faster than past words ($M = 1.04$, $SD = 0.18$) $t(171) = -9.90$, $p < .001$. Participants also responded faster when the word is displayed on the right of the screen ($M = 1.00$, $SD = 0.17$) than when it is on the left of the screen ($M = 1.02$, $SD = 0.17$) $t(171) = -3.69$, $p < .001$. Furthermore, participants responded significantly faster when they responded with the right key ($M = 1.00$, $SD = 0.17$) instead of the left key ($M = 1.01$, $SD = 0.18$) $t(171) = -2.35$, $p = .02$. There was a significant interaction between meaning and language group [$F(2, 171) = 14.32$, $p < .001$, $\eta^2_p = 0.143$]. Although there were no significant between group differences after Bonferroni test, all groups were significantly faster when the word is related to future relative to past words (see Table 3.5).

However, when Corsi scores were added as a covariate in 3x2x2x2 mixed ANCOVA analysis, language group $F(2,169) = 2.73$, $p = .068$, $\eta^2_p = 0.031$, position $F(1,169) = 1.25$, $p < .266$, $\eta^2_p = 0.007$ and key $F(1,169) = 1.04$, $p = .31$, $\eta^2_p = 0.006$ were no longer significant. There was still main effect of meaning $F(1,169) = 4.80$, $p = .030$, $\eta^2_p = 0.028$ in overall RTs. Future words ($M = 0.98$, $SD = 0.16$) were responded significantly faster than past words ($M = 1.04$, $SD = 0.18$) $t(169) = -9.79$, $p < .001$. Meaning x language group interaction was still significant $F(2, 169) = 14.30$, $p < .001$, $\eta^2_p = 0.145$. Post hoc comparisons revealed that all groups were significantly faster when the word has future meaning rather than past meaning (all ps < 0.05).

Table 3.5 *Post Hoc Comparisons - Meaning x Language Group*

Meaning	**Group**		**Meaning**	**Group**	**Mean Difference**	**SE**	**df**	**t**	**$p_{bonferroni}$**
Past	AR-TR	-	Past	TR-AR	0.08	0.03	171	2.855	0.072
		-	Past	TR-EN	0.02	0.03	171	0.549	1.000
		-	Future	AR-TR	0.10	0.01	171	9.946	< .001
Past	TR-AR	-	Past	TR-EN	-0.07	0.03	171	-2.31	0.333
		-	Future	TR-AR	0.03	0.01	171	3.488	0.009
Past	TR-EN	-	Future	TR-EN	0.04	0.01	171	3.598	0.006
Future	AR-TR	-	Future	TR-AR	0.01	0.03	171	0.55	1.000
		-	Future	TR-EN	-0.05	0.03	171	-1.85	0.998
	TR-AR	-	Future	TR-EN	-0.06	0.03	171	-2.44	0.236

Indicating a Simon type effect (Simon and Rudell, 1967), screen position x key interaction was significant $F(1,171) = 10.27$, $p = .002$, $\eta^2_p = 0.057$. Participants were faster when the screen position and correct response key position overlaps on the right side of the screen (See Table 3.6).

Table 3.6 *Post Hoc Comparisons - Position x Key*

Comparison									
position	**key**		**position**	**key**	**Mean Difference**	**SE**	**df**	**t**	**$p_{bonferroni}$**
Left	left	-	Left	right	-0.00135	0.00573	171	-0.235	1.000
		-	Right	left	0.00342	0.00544	171	0.629	1.000
		-	Right	right	0.02507	0.00566	171	4.430	< .001
	right	-	Right	left	0.00477	0.00617	171	0.774	1.000
		-	Right	right	0.02642	0.00538	171	4.912	< .001
Right	left	-	Right	right	0.02165	0.00549	171	3.942	< .001

The Meaning x Position x Language group interaction was also significant $F(2, 171) = 3.77$ $p = .025$, $\eta^2_p = 0.042$. However, post hoc comparisons revealed that reaction time for past words and future words did not differ depending on whether they were on the left or right side of the screen in any of the groups (all *p*s = 1.00). TR-EN group responded faster when the right side displays future word rather than past word $t(169) = -4.40$, $p = .001$. There were no other significant RT differences between groups in any relevant meaning position interactions (all *p*s >.05). After including Corsi scores as a covariate, 3x2x2x2 ANCOVA results revealed that Meaning x position x language group interaction was still significant.

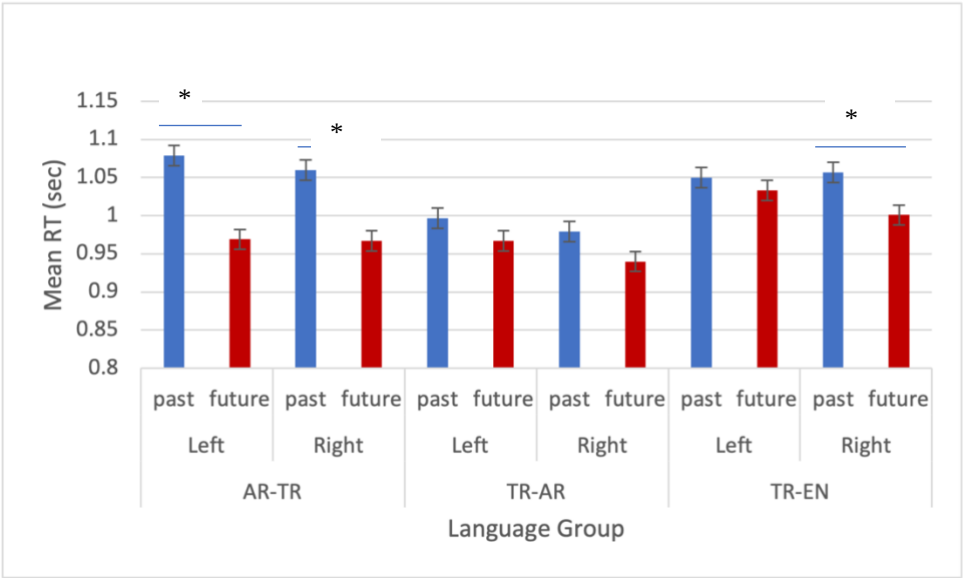


Figure 3.5 *Meaning x Position x Language group interaction*

3.4.2 Analysis of congruency

We conducted two mixed 3 x 2 ANOVAs to examine how groups differed in congruent and incongruent trials which were determined based on L1 writing direction. According to results of the first 3 x 2 ANOVA with group (TR-EN/TR-AR/AR-TR) and key congruency (congruent/incongruent) factors, there was main effect of key congruency $F(1,171) = 4.00$, $p = .047$, $\eta^2_p = 0.023$ revealing that when past and future words responded with the congruent key ($M = 0.998$, $SD = 0.16$) the reaction time was faster than when past/future words responded with the incongruent key ($M = 1.018$, $SD = 0.16$). After including Corsi scores as covariate, 3x2 ANCOVA results revealed that key congruency was no longer significant, $F(1,169) = 3.31$, $p = .072$, $\eta^2_p = 0.019$.

The results of the second 3 x 2 ANOVA with language group (TR-EN/TR-AR/AR-TR) and screen position congruency (congruent/incongruent) factors, there was main effect of screen position congruency $F(1,171) = 4.00$, $p = .047$, $\eta^2_p = 0.023$ revealing that when past and future words displayed on the congruent side of the screen ($M = 1.00$, $SD = 0.15$) the reaction time was faster than when past/future words displayed on the incongruent side ($M = 1.01$, $SD = 0.15$). When we included Corsi scores as covariate, 3x2 ANCOVA results revealed that position congruency was no longer significant $F(1,169) = 0.002$, $p = .097$, $\eta^2_p = 0.000$.

The direction of main effects was in line with our hypotheses by revealing that congruent trials were faster than incongruent trials by 20 msec with respect to response key dimension and, by 11 msec with respect to screen position dimension.

The key congruency x language group interaction $F(2, 171) = 0.63$ $p = .53$, $\eta^2_p = 0.007$ and screen position congruency x language group interaction $F(2, 171) = 1.27$ $p = .28$, $\eta^2_p = 0.015$ was not significant. There was main effect of language group on overall reaction times $F(2, 171) = 3.27$ $p = .041$, $\eta^2_p = 0.037$. Both of the analyses revealed that TR-AR group ($M = 0.97$, $SD = 0.14$) was significantly faster than TR-EN group ($M = 1.04$, $SD = 0.13$) $t(171) = -2.45$, $p = .046$ (see Figure 3.6). When Corsi scores were added as a covariate in the 3x2 ANCOVA, the effect of language group was no longer significant, $F(2, 169) = 3.27$ $p = .068$, $\eta^2_p = 0.031$.

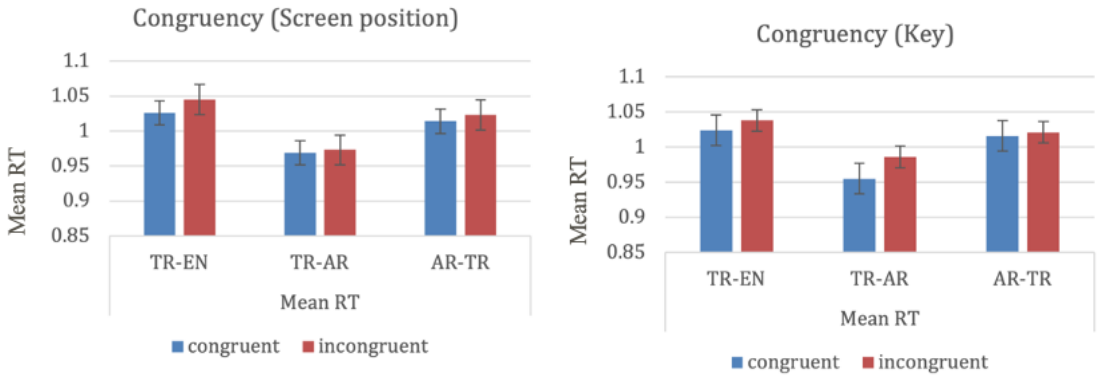


Figure 3.6 *Mean latency (RT) for congruent and incongruent trials as function of key and screen position.*

3.4.3 Analysis of accuracy

We performed an additional accuracy analysis. The analysis of 3x2x2x2 (language group x meaning x key x position) mixed ANOVA on accuracy showed that there was main effect of language group $F(2,171) = 4.53$, $p = .012$, $\eta^2_p = 0.05$. Overall accuracy of L1-Turkish – L2-Arabic was significantly higher ($M = 0.93$, $SD = 0.06$) than L1-Turkish – L2-English ($M = 0.89$, $SD = 0.07$) $t(171) = 2.87$, $p = .014$.
There was a significant effect of Position x Key interaction $F(1,171) = 15.75$, $p < .001$, $\eta^2_p = 0.084$, Position x Meaning interaction $F(1,171) = 7.34$, $p < .007$, $\eta^2_p = 0.041$, Key x Meaning interaction $F(1, 171) = 11.33$, $p < .001$, $\eta^2_p = 0.062$.

The post hoc comparisons of Position x Key interaction on accuracy revealed a Simon type effect. When the word was displayed on the left side, participants were more accurate if the respond with the left key ($M = 0.91$, $SD = 0.07$) in comparison to right key ($M = 0.90$, $SD = 0.07$) $t(171) = 3.21$, $p = .009$. Post hoc comparisons of Key x Meaning interaction revealed that participants were more accurate when the past word is responded with left key ($M = 0.91$, $SD = 0.08$) instead of right key ($M = 0.89$, $SD = 0.08$) $t(171) = 3.42$, $p = .005$. Along the line of left to right writing direction, participants evaluated future ($M = 0.91$, $SD = 0.07$) truer than past ($M = 0.89$, $SD = 0.08$) when they respond with right key $t(171) = 3.36$, $p = .006$.

There was an interaction effect of Key x Meaning x Language group $F(2, 171) = 7.99$, $p < .001$, $\eta^2_p = 0.086$. Significant within and between groups differences are listed in Table 3.7.

Table 3.7 *Post Hoc Comparisons - meaning x key x language group (accuracy)*

Meaning	Key	Group		Meaning	Key	Group	Mean Difference	SE	df	t	$p_{bonferroni}$
Past	left	AR-TR	-	past	left	TR-AR	-0.056	0.013	171	-4.147	0.004
			-	past	left	TR-EN	-0.039	0.014	171	-2.846	0.328
			-	past	right	AR-TR	-0.003	0.009	171	-0.331	1.000
			-	future	left	AR-TR	-0.045	0.011	171	-4.195	0.003
		TR-AR	-	past	left	TR-EN	0.017	0.013	171	1.259	1.000
			-	past	right	TR-AR	0.023	0.009	171	2.696	0.509
			-	future	left	TR-AR	0.015	0.010	171	1.507	1.000
		TR-EN	-	past	right	TR-EN	0.032	0.009	171	3.609	0.027
			-	future	left	TR-EN	0.058	0.011	171	5.510	< .001
	right	AR-TR	-	past	right	TR-AR	-0.030	0.016	171	-1.918	1.000
			-	past	right	TR-EN	-0.004	0.016	171	-0.246	1.000
			-	future	right	AR-TR	-0.030	0.011	171	-2.802	0.374
		TR-AR	-	past	right	TR-EN	0.026	0.015	171	1.675	1.000
			-	future	right	TR-AR	-0.016	0.010	171	-1.577	1.000
		TR-EN	-	future	right	TR-EN	-0.015	0.011	171	-1.423	1.000
Future	left	AR-TR	-	future	left	TR-AR	0.004	0.015	171	0.274	1.000
			-	future	left	TR-EN	0.064	0.015	171	4.198	0.003
			-	future	right	AR-TR	0.012	0.010	171	1.159	1.000
		TR-AR	-	future	left	TR-EN	0.060	0.015	171	4.013	0.006
			-	future	right	TR-AR	-0.008	0.010	171	-0.833	1.000
		TR-EN	-	future	right	TR-EN	-0.041	0.010	171	-4.020	0.006
	right	AR-TR	-	future	right	TR-AR	-0.016	0.012	171	-1.339	1.000
			-	future	right	TR-EN	0.011	0.012	171	0.897	1.000
		TR-AR	-	future	right	TR-EN	0.027	0.012	171	2.261	1.000

The analysis of 3x2 (language group x key congruency) analysis showed that there was main effect of key congruency $F(1,171) = 20.12$, $p < .001$, $\eta^2_p = 0.105$ revealing that participants responded more accurately when the key was congruent with their L1 ($M = 0.93$, $SD = 0.06$), than incongruent condition ($M = 0.92$, $SD = 0.08$) regardless of group. Furthermore, key congruency x language group interaction was significant $F(1,171) = 3.74$, $p < .026$, $\eta^2_p = 0.042$. Post hoc Bonferroni comparisons revealed that in conditions congruent with right to left direction, AR-TR speakers' accuracy rate ($M = 0.91$, $SD =$

0.06) was significantly higher than TR-EN (*M* = 0.88, *SD* = 0.09). The only significant within group difference was observed in TR-EN group, revealing more accurate answers when the response key is congruent with their L1 (*M* = 0.91, *SD* = 0.06) compared to incongruent condition (*M* = 0.87, *SD* = 0.09). Lastly, in incongruent trials, TR-AR group (*M* = 0.92, *SD* = 0.07) performed better than TR-EN group (*M* = 0.87, *SD* = 0.09) as depicted in Figure 3.7.

The analysis of 3x2 (language group x position congruency) analysis revealed that there was no main effect of position congruency (*p* >.05). There was main effect of group showing that overall accuracy of TR-AR (*M* = 0.93 , *SD* = 0.06) was significantly higher than TR-EN (*M* = 0.89 , *SD* = 0.07) similar to key congruency analysis *t*(171) = 2.87, *p* = .014. There was an interaction effect of position congruency x language group *F*(1,171) = 4.09, *p* = .018, η^2_p = 0.046. However Post hoc Bonferroni comparisons did not reveal a significant difference in incongruent trials between groups (all *p*s < .05).

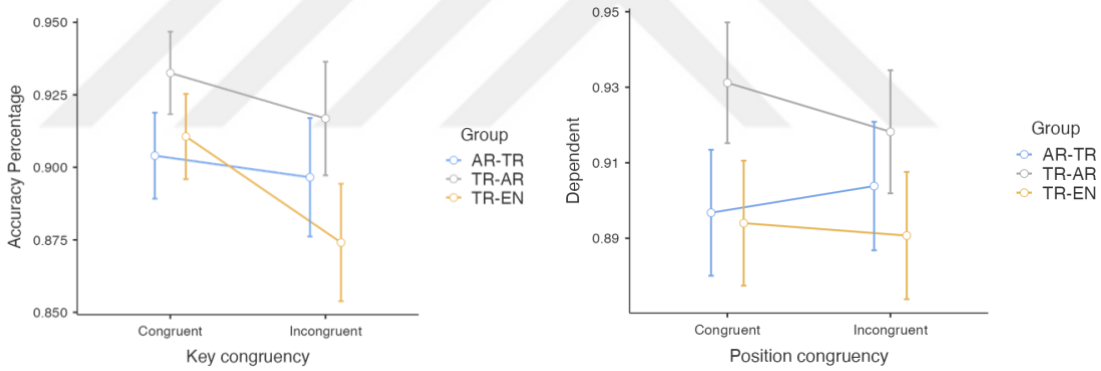


Figure 3.7 *Mean accuracy rates for congruent and incongruent trials as function of key and screen position*

4. DISCUSSION

We investigated the effect of L1 and L2 writing direction across three bilingual groups (TR-EN. TR-AR, AR-TR). For this purpose we asked 1) if the there is a bias parallel to L1 writing direction in L1-Turkish and L1-Arabic speakers, (2) if learning another language written in a different direction changes the perception of time direction, and if it does, (3) which language dominates the directional bias for participants who are familiar with writing in both directions In the third question, we sought to determine whether learning a second language for various motives would have a different implications on how one perceives time. In the spatial pointing task, we examined participants' preferences for pointing earlier and later time-points to the left or right of the reference point. In the following two tasks, we used reaction time measurements to test automatic activation of specific representations in L1 and L2 direction during temporal judgment. With this method, we aimed to distinguish and compare temporal representation biases that were congruent with L1 and L2 writing direction. While pictorial time flow task used three stages of images to examine RT differences between congruent and incongruent trials, verbal time flow task used past and future related words. These three tasks (spatial, pictorial, verbal) were chosen to see whether temporal judgments differ across domains.

Regarding our first research question, our results replicated previous studies showing that mental time-line follows writing direction. Secondly, we found that L2 had a significant effect on time perception in the first task for AR-TR group but not in the other tasks. Third, congruency results revealed that the L1 writing direction dominated the mental timeline, with congruent tasks being responded faster than incongruent trials in overall reaction times.

We had three main hypotheses and specific sub-hypotheses for each task. We mainly assumed that (1) all groups will dominantly represent time congruent with their L1, (2) language groups will differ in terms of time representation in mappings that are incongruent with their L1 (which is congruent with their L2 for TR-AR and AR-TR groups), with the AR-TR group having higher tendency to represent time in incongruent

direction compared to TR-AR and TR-EN respectively, (3) bidirectional bilinguals whose second language is the dominant (society) language (AR-TR) are expected to be influenced more by the L2 writing direction than those whose L1 is the society language and L2 is acquired for academic purposes (TR-AR).

4.1 Spatial Pointing Task

The first hypothesis predicted that, in this task, L1-Turkish groups would represent time from left to right, in accordance with their L1 writing direction. And secondly, we did not expect a difference between the TR-EN and TR-AR groups because the task explicitly requests a certain time arrangement decision, which requires a very strong L2 effect to be changed. L1 bias was expected to be reshaped only when the L2 writing direction is the society language (AR-TR). Results supported our hypothesis with TR-EN and TR-AR groups preferring to represent time left to right (86%) while AR-TR group's right to left and left to right arrangement percentages did not significantly differ (51% left to right, 49% right to left). Supporting our third hypothesis, AR-TR group's time arrangement in incongruent direction (left to right) was significantly higher than TR-EN and TR-AR groups' incongruent time arrangement (right to left). We found the same results when we included Corsi scores as a covariate in the analysis.

4.2 Pictorial Time Flow Task

According to first hypothesis, L1-Turkish groups (TR-EN, TR-AR) were expected to be faster when representing the earlier stage with the left key and later stage with the right key which is congruent with the their L1. And AR-TR group was expected to be faster in reverse mapping. And second hypothesis assumed that response time of the TR-AR participants were expected to be faster than the TR-EN bilingual participants in trials that are incongruent with their L1, but congruent with their L2 writing direction. In these trials, AR-TR bilingual participants were expected to be fastest since there is no incompatibility with their L1 writing direction. Supporting the first hypotheses, results revealed that congruent trials were responded faster than incongruent trials regardless of language group. Furthermore, when the first block represented left key as earlier AR-TR

group was faster in congruent trials than incongruent trials. And in the other block order, which firstly represented right key as earlier, TR-AR group was faster in congruent trials than incongruent trials. Secondly, TR-AR group was faster than AR-TR group in the condition congruent with Turkish writing direction. However there were no incongruent RT differences between groups. Regarding the third hypothesis assuming that AR-TR group would be faster than TR-AR group in incongruent trials, we could not find any significant difference. However, the mean difference RTs (msec) between congruent and incongruent trials revealed an expected pattern: The mean difference of between congruent and incongruent trials for TR-EN group was higher than TR-AR and AR-TR respectively. This pattern indicates to a better adaptation to the incongruent condition in bidirectional bilinguals (AR-TR and TR-AR respectively) compared to unidirectional TR-EN group.

When Corsi scores were added as a covariate in the analysis, congruency lost its main effect. Language group x block order x congruency interaction was still significant.

4.3 Verbal Time Flow Task

The first hypothesis assumed that L1-Turkish groups (TR-EN, TR-AR) would be faster when past words were displayed on the left side or responded with left key, as well as when future words were displayed on the right side or responded with right key, compared to reverse mappings. And in the reverse mappings, L1- Arabic speakers were expected to be faster than the two groups. In other words, when the condition was congruent with their L1, either in terms of key or screen position, language groups were expected to be faster. Secondly, when meaning matches with key or screen position in the congruent direction, TR-AR group was expected to be faster than TR-EN because they have no exposure to a right-to-left direction, and AR-TR group was expected to be faster in these mappings which are congruent with their L1. Thirdly, in both incongruent key mappings and incongruent position mappings, AR-TR group was expected to be faster than TR-AR. Supporting the first hypothesis, participants were faster when the words were displayed in congruent position and when they responded with congruent key, regardless of group. Also, TR-EN group was faster when future, instead of past,

was displayed on the right screen which is congruent with their L1. Second and third hypotheses was not supported since we could not find any significant post hoc comparisons between groups. However, the pattern of the mean differences between congruent and incongruent trials was in expected direction with higher difference in AR-TR in comparison to TR-EN. The comparison of mean differences between two directions could refer to our second hypothesis, which predicts that bidirectional bilinguals will be less strict in unidirectional time bias. When Corsi scores were added as a covariate in the analysis, key congruency, position congruency, and language group lost their main effects.

Although we did not have any hypothesis based on accuracy, accuracy rates in key congruency revealed that only responses of TR-EN group significantly differed depending on the key congruency. When the condition was congruent with L1 in terms of response key, they were significantly more accurate than the incongruent condition. However, the key congruency did not influence accuracy rate of bidirectional bilinguals (TR-AR, AR-TR). This result might refer to dual representation of time in bidirectional bilinguals. Furthermore, when the conditions were congruent with right to left direction, response accuracy of AR-TR was significantly higher than TR-EN, and TR-AR group performed better than TR-EN in incongruent trials, which could support the second hypothesis.

4.4 General Discussion

Overall, the results showed that L1 writing direction is an important factor in spatio - temporal representation, and individuals use space to represent time in accordance with the Conceptual Metaphor Theory (Lakoff & Johnson, 1980). L1-Turkish speakers (TR-EN and TR-AR) showed a bias to represent time from left to right in spatial pointing task. Findings regarding pictorial and verbal time flow task demonstrated that congruent trials were responded faster than incongruent trials regardless of language group in all congruency tasks. Pictorial verbal task also revealed that TR-AR group was faster than AR-TR group in the condition congruent with Turkish writing direction. Moreover, congruency analysis of pictorial task showed that TR-AR and AR-TR groups were

faster in congruent trials than incongruent trials. These findings supported our first hypothesis as well as previous findings showing that mental timeline follows L1 writing direction (e.g., Fuhrman and Boroditsky, 2010; Weger & Pratt, 2008) by confirming that people with different L1 writing directions think about time differently, which is also consistent with Whorf's linguistic relativity hypothesis (1956).

Supporting our second hypothesis regarding the L2 influence on bidirectional habits, the results of the pointing task showed that L1-Arabic speakers (AR-TR) arranged time from left to right as much as they do from right to left. This finding suggests that acquired writing habits can influence spatial representation of time in the opposite direction as it was demonstrated previously through Mandarin English speakers (e.g., Boroditsky et al., 2011; Miles et al., 2011; Fuhrman et al., 2011). In a broader sense, this would support the view that learning L2 can affect bilingual cognition (Bassetti and Cook, 2011). However, we were unable to support the view that learning a second language may reshape habitual thought in the following RT tasks, similar to recent research by Mandarin-English bilinguals which found that Mandarin-English speakers did not reconstruct their temporal cognition compared to Mandarin monolinguals (Yang et al., 2022).

Our third hypothesis was partially supported by the performance of TR-AR and AR-TR group in spatial pointing task. We assumed that the context of L2 acquisition would lead to a difference in habitual temporal thought between two groups (TR-AR, AR-TR). AR-TR group who learned L2 in society preferred to arrange time in an incongruent direction more than TR-AR bilinguals who learned L2 for academic purposes. That could be explained by the context of acquisition and frequency of habitual experience. Reading-writing is used not only in the classroom; in our daily lives, we pay attention also to graphs and signboards on the streets, which influence our tendencies. In comparison to the AR-TR group (M = 69.53 month), the TR-AR group mostly learned Arabic for academic purposes and did not spend much time in a country where Arabic is the dominant language (M = 4.53 month). Furthermore, while TR-AR speakers did not report proficiency in any other language written from right to left, 92% of AR-TR bilinguals reported that their English proficiency was higher than 1 (very weak) out of

10, indicating that they were at least exposed to English in addition to Turkish (M = 5.89, SD = 2.73). In this regard, we can say that the AR-TR group is exposed to left to right direction in many contexts, which distinguishes the AR-TR and TR-AR groups in terms of L2 influence. Although we did not manipulate the immediate language and all instructions were given in their L1, the performance of the AR-TR group may have been influenced also by the direction of computer settings (e.g., experiment link, keyboard). The influence of L2 on AR-TR and TR-AR groups did not differ significantly in the following two tasks; and this could indicate that, while AR-TR bilinguals acquired a new direction of arranging time as depicted in the spatial pointing task, this may not influence implicit reactions to the same extent.

Considering the criticisms of Bergen and Chan Lau (2012), who claim that the findings of studies revealing differences between two groups living in different cultures cannot be attributed directly to writing direction, we have recruited three groups all living in the same country and exposed to the same environment. In this way, we aimed to differentiate the effect of L2 regardless of culture. L1-Turkish groups (TR-EN, TR-AR) did not show any significant difference between each other in three tasks. This would be explained by three ways; (1) L2 writing direction did not have an influence on spatio-temporal thought, (2) it was not enough to shape cognition in the absence of cultural context or (3) participants were not proficient enough in L2 to that extend to shape their preferences.

Participants in the verbal time flow task were influenced by spatial characteristics of the task, despite the fact that it was irrelevant to their instructed goals. When a word was displayed on the right side, participants responded faster regardless of the meaning. Moreover, they responded faster when the screen position and response key position overlaps on the right side of the screen. Although this could be explained by Simon type effect (Simon and Rudell, 1967) which assumes a faster response or greater accuracy when response coordinate and stimuli are on the same side compared to opposite side, this overlap did not reach significance when they both were on the left side. This finding was in line with the Gorbunova and Falikman's (2019) finding, showing that we comprehend words on the right side faster. Similarly, there was a significant effect of

key position, indicating an independent preference for the right key (J) over the left key (F). Given that the vast majority of people are right-handed, this was an expected result. Briefly, the Simon effect, right-hand bias and visuospatial attention bias may explain why participants tended to be faster when the word is displayed on the right and responded to with the right hand as a replication to previous findings (e.g., Ouellet et al., 2010). However, when Corsi scores were added as a covariate in the analysis, key position, screen position and the interaction between them lost their effects.

Another noteworthy effect in the verbal task is the significant tendency to respond faster when the meaning refers to future rather than past. This trend was most noticeable in the AR-TR group, which could be explained by syntactic differences between the two languages. In Arabic, while the first letter indicates the future meaning, the last letter refers to the past meaning. The 48 words in the original study (Santiago et al., 2007) were in Spanish language which refers to the temporal meaning in the middle of the word. However, although Turkish words do not have a distinct setting like Arabic, future words were still responded faster than past words. This difference across three groups might be speculatively explained with the finding of Addis and Schacter (2008) revealing that individuals associate more specific details with past event representation rather than future event representation. Therefore, it might have taken time to process the past words with more details compared to future words. Therefore, it might take time to process the past words with more details compared to future words. This tendency may also be related to the Temporal Doppler effect, which causes the perception of the future being closer than the past (Caruso et al., 2013). Caruso et al. (2013) attribute this effect to a subjective experience of time movement in which the future comes towards, and past goes away. In this case, individuals in our study may have processed the future faster as a result of feeling closer.

4.5 Limitations and Future Directions

This study has several limitations. Firstly, although we only recruited university students or graduates, academic performance levels of three groups were different. Verbal time flow task revealed a main effect of language group in both reaction times

and accuracy ratings showing that TR-AR group was significantly faster and more accurate than TR-EN regardless of condition. Furthermore, TR-AR group had significantly higher scores in Corsi backward test than TR-EN group indicating a better EF performance. This could be because we reached out to TR-AR participants mostly through two institutions that teach Arabic to successful students with high academic standing. Another possible explanation is that, while the TR-AR group participated in the study in exchange for payment, the TR-EN group participated in exchange for credit.

Secondly, while all participants in the AR-TR group comprehended the formal Arabic we used, they reported that it would be preferable to have instructions in their regional dialects known as "ammiya" to make the task easier. Although we simplified the instructions following the pilot study, future studies may prefer to use specific dialects and recruit participants from specific ethnic backgrounds. Thirdly, due to Covid-19 restrictions, we conducted the study online. Although PsychoPy provides precise measurements, conducting the experiment in a lab setting would minimize distracting factors. Furthermore, due to the possibility that RTs may vary depending on the computer systems that participants used, this may pose a limitation in terms of interpreting RTs. Additionally, we did not gather data on right-handedness, which would have been more beneficial to ask and control in our study which has right and left dimensions. We may also include the general limitation of cross-cultural verbal tasks in addition to syntax differences. The 48 total past and future words in the third task were matched for word frequency and syllable count in Turkish, but there were variations between items and languages. The frequencies could not been matched in Arabic since we lacked an Arabic frequency dictionary.

Finally, we did not manipulate the immediate effect of language for bidirectional bilinguals, future research may compare reaction times in different language conditions to investigate the flexibility of dual mental time-lines. Considering that even the ethnicity of actors in stimuli shapes the direction bias of representing time (Miles et al., 2011), we expect immediate language context to activate L2 representation and help to reveal the dual representations more clearly.

5. CONCLUSION

Based on the findings, we can conclude that various aspects of linguistic and cultural context, such as visual and bidirectional experiences, and the context of L2 acquisition, can potentially influence space–time mappings. By comparing two bidirectional bilinguals living in the same country, this study highlighted the critical role of acquisition context on L2 influence. This design eliminated the limitations of cultural differences as well as language distance effect between two language groups. While we partially replicated studies showing that L1-writing direction shapes temporal representation, and the effect of L2 in the first task, our results in the second and third tasks did not support the view that L2 acquisition reconstructs habitual thought. We can conclude that, even if L2 has an effect on time representation, it may not appear independent of other factors, requiring further investigation. The role of L2 writing systems in cognition should be investigated further in different populations using various measurements.

REFERENCES

Addis, D. R., & Schacter, D. L. (2008). Effects of detail and temporal distance of past and future events on the engagement of a common neural network. Hippocampus 18, 227–237. doi: 10.1002/hipo.20405

Athanasopoulos, P. (2009). Cognitive representation of colour in bilinguals: The case of Greek blues. *Bilingualism: Language and Cognition, 12*(1), 83-95. doi:10.1017/S136672890800388X

Bassetti, B., & Cook, V. (2011). Relating language and cognition: The second language user. In *Language and Bilingual Cognition* (1st ed., pp. 143-190). Taylor & Francis.

Berch, D. B., Foley, E. J., Hill, R. J., & Ryan, P. M. (1999). "Extracting parity and magnitude from Arabic numerals: Developmental changes in number processing and mental representation", *Journal of Experimental Child Psychology*, *74*, 286–308.

Bergen, B. K., & Chan Lau, T. T. (2012). "Writing direction affects how people map space onto time". *Frontiers in psychology, 3*, 109.

Boroditsky, L. (2001). "Does language shape thought? English and Mandarin speakers' conceptions of time". *Cognitive Psychology, 43*, 1–22.

Boroditsky, L. (2011). How languages construct time. In: Dehaene, S., Brannon, E. (Eds.), Space, Time and Number in the Brain: Searching for the Foundations of Mathematical Thought. *Elsevier/Academic Press*, Burlington, MA, pp. 333–341.

Boroditsky, L., Fuhrman, O., & McCormick, K. (2011). Do English and Mandarin speakers think about time differently?. *Cognition, 118*(1), 123–129. https://doi.org/10.1016/j.cognition.2010.09.010

Bostan, I., Börütecene, A., Özcan, O., & Göksun, T. (2016).Temporal expressions in speech and gesture. In Papafragou,A., Grodner, D., Mirman, D., & Trueswell, J.C. (Eds.).*Proceedings of the 38th Annual Conference of the Cognitive Science Society* (pp. 1871–1876). Austin, TX: Cognitive Science Society.

Cai, Z. G., Connell, L., & Holler, J. (2013). Time does not flow without language: spatial distance affects temporal duration regardless of movement or direction. *Psychonomic bulletin & review, 20*(5), 973–980. https://doi.org/10.3758/s13423-013-0414-3

Caruso, E. M., Van Boven, L., Chin, M., & Ward, A. (2013). The Temporal Doppler Effect: When the Future Feels Closer Than the Past. *Psychological Science, 24*(4), 530–536

Casasanto, D., Boroditsky, L., Phillips, W., Greene, J. Goswami, S., & Bocanegra-Thiel, S. (2004). How deep are effects of language on thought? Time estimation in

speakers of English, Indonesian, Greek, and Spanish. Proc. Annual Meeting Cognitive Science Society, 26.

Casasanto, D., & Jasmin, K. (2012). The hands of time: Temporal gestures in English speakers. *Cognitive Linguistics*, *23*(4), 643–674.

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. Journal of experimental psychology. *General, 143(*2), 473–479. https://doi.org/10.1037/a0033297

Chan, T. T., & Bergen, B. K. (2005). "Proceedings of the 27th Annual Conference of the Cognitive Science Society." in *Writing Direction Influences Spatial Cognition*. eds. B. Bara, L. Barsalou, and M. Bucciarelli (Mahwah, NJ: Lawrence Erlbaum Associates), July 21-23, 2005, 412–417.

Chen, J. Y. (2007). Do Chinese and English speakers think about time differently? Failure of replicating Boroditsky (2001). *Cognition, 104*, 427–436.

Chen, J.-Y., & O'Seaghdha, P. G. (2013). Do Mandarin and English speakers think about time differently? Review of existing evidence and some new data. *Journal of Chinese Linguistics, 41*, 338–358.

Corsi, P. M. (1973). Human memory and the medial temporal region of the brain. *Dissertation Abstracts International, 34*(2-B), 891.

De la Fuente, J., Santiago, J., Román, A., Dumitrache, C., & Casasanto, D. (2014). When You Think About It, Your Past Is in Front of You: How Culture Shapes Spatial Conceptions of Time. *Psychological Science, 25*(9), 1682–1690.

Dobel, C., Diesendruck, G., & Bölte, J. (2007). How writing system and age influence spatial representations of actions: A developmental, cross-linguistic study. *Psychological Science, 18*(6), 487– 491.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Fuhrman, O., & Boroditsky, L. (2007). Mental time-lines follow writing direction: Comparing English and Hebrew speakers. In Proceedings of the 29th Annual Conference of the Cognitive Science Society.

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: evidence from an implicit nonlinguistic task. *Cognitive science, 34*(8), 1430–1451.

Fuhrman, O., McCormick, K., Chen, E., Jiang, H., Shu, D., Mao, S. and Boroditsky, L. (2011), How Linguistic and Cultural Forces Shape Conceptions of Time: English and Mandarin Time in 3D. *Cognitive Science, 35,* 1305-1328.

Gorbunova, E. S., & Falikman, M. V. (2019). Visual Search for Letters in the Right

Versus Left Visual Hemifields. *Advances in cognitive psychology*, *15*(2), 75–88. https://doi.org/10.5709/acp-0258-5

Gibbs, R. W., Costa Lima, P.L., & Francozo, E. (2004). Metaphor is grounded in embodied experience. *Journal of Pragmatics. 36*. 1189-1210.

Huang, Y., Tse, CS. (2017). Linguistic Relativity in Conceptual Metaphors. In: Ardila, A., Cieślicka, A., Heredia, R., Rosselli, M. (eds) Psychology of Bilingualism. The Bilingual Mind and Brain Book Series. Springer, Cham.

Ishihara, M., Keller, P. E., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: evidence for the STEARC effect. Cortex; a journal devoted to the study of the nervous system and behavior, 44(4), 454–461.

January, D., & Kako, E. (2007). Re-evaluating evidence for the linguistic relativity hypothesis: Response to Boroditsky (2001). Cognition, 104, 417–426.

Lakoff, G., & Johnson, M. (1980). Johnson Metaphors We Live by. *Chicago: University of Chicago Press.*

Maass, A., & Russo, A. (2003). Directional bias in the mental representation of spatial events. *Psychological Science, 14*, 296–301.

Miles, L. K., Betka, E., Pendry, L. F., & Macrae, C. N. (2010). Mapping Temporal Constructs: Actions Reveal that Time is a Place. *Quarterly Journal of Experimental Psychology, 63*(11), 2113–2119.

Miles, L. K., Tan, L., Noble, G. D., Lumsden, J., & Macrae, C. N. (2011). Can a mind have two time lines? Exploring space-time mapping in Mandarin and English speakers. *Psychonomic bulletin & review*, *18*(3), 598–604.

Núñez, R., Cooperrider, K., Doan, D., & Wassmann, J. (2012). Contours of time: Topographic construals of past, present, and future in the Yupno Valley of Papua New Guinea. *Cognition, 124*(1), 25–35.

Núñez, R. E. & Sweetser, E. (2006), With the Future Behind Them: Convergent Evidence From Aymara Language and Gesture in the Crosslinguistic Comparison of Spatial Construals of Time. *Cognitive Science, 30*, 401-450.

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2010). Thinking about the future moves attention to the right. Journal of experimental psychology. *Human perception and performance, 36*(1), 17–24.

Ouellet, M., Santiago, J., Israeli Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology*, *57*(4), 308–314.

Pavlenko, A. (2002). Emotions and the body in English and Russian. Pragmatics and *Cognition, 10* (1/2), 201-236.

Pavlenko A. (2011) *Thinking and Speaking in Two Languages*. Clevedon: Multilingual

Matters.

Pitt, B., & Casasanto, D. (2020). The correlations in experience principle: How culture shapes concepts of time and number. Journal of experimental psychology. *General, 149(*6), 1048–1070.

Roman, A., & Fathi, A. & Santiago, J. (2013). Spatial biases in understanding descriptions of static scenes: The role of reading and writing direction. *Memory & Cognition, 41.*

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. (2007). Time also flies from left to right. *Psychon. Bull. Rev. 14*, 512–516.

Simon, J. R., & Rudell, A. P. (1967). Auditory S-R compatibility: The effect of an irrelevant cue on information processing. *Journal of AppIied Psycholog*y, 51,300-304.

Tekcan, A. İ., & Göz, İ. (2005). *Türkçe kelime normları [Turkish Word norms].*İstanbul, Turkey: Boğaziçi Üniversitesi Yayınevi.

Tse, C.-S., & Altarriba, J. (2008). Evidence against linguistic relativity in Chinese and English: A case study of spatial and temporal metaphors. *Journal of Cognition and Culture, 8*(3-4), 335–357.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Crosscultural and developmental trends in graphic productions. *Cognitive Psychology, 23*, 515–557.

Weger, U. W., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin & Review, 15*(2), 426–430.

Whorf, B. L. (1956). *Language thought and reality.* Cambridge, MA: MIT Press.

Wolff, P., & Holmes, K. J. (2011). Linguistic relativity. Wiley Interdisciplinary *Reviews: Cognitive Science, 2*, 253–265.

Yang, W., Gu, Y., Fang, Y., & Sun, Y. (2022). Mental Representations of Time in English Monolinguals, Mandarin Monolinguals, and Mandarin-English Bilinguals. *Frontiers in psychology*, *13*, 791197. https://doi.org/10.3389/fpsyg.2022.791197

Zhang, L., & Ding, C. (2003). Comparative study of temporal metaphor in English and Chinese. *Foreign Languages and Their Teaching*, *174*(9), 31–34.

APPENDIX A

Questions used in Experiment 1 (Turkish)

1. Burası bugün. Dünü nerede gösterirsin? Yarını nerede gösterirsin?
2. Burası bugünler. Uzun zaman öncesini nereye koyarsın? Geleceği nereye koyarsın?
3.Burası bu hafta. Geçen haftayı nereye koyarsın? Gelecek haftayı nereye koyarsın?
4. Burası bu yaz. İlkbaharı nereye koyarsın? Sonbaharı nereye koyarsın?
5. Burası gün ortası. Sabahı nereye koyarsın? Akşamı nereye koyarsın?
6. Burası sen uyurkenki zaman. Yatağa gittiğin zamanı nereye koyarsın? Uykudan uyandığın zamanı nereye koyarsın?
7. Burası Çarşamba. Salıyı nereye koyarsın? Perşembeyi nereye koyarsın?
8. Burası şu anki yaşın. Bebekken neredeydin?
Yaşlandığında nerede olacaksın?
9. Burası bu ay. Geçen ayı nereye koyarsın? Gelecek ayı nereye koyarsın?
10. Burası bu yıl. Geçen yılı nereye koyarsın? Önümüzdeki yılı nereye koyarsın?
11. Burası öğlen. Gün doğumunu nereye koyarsın? Gün batımını nereye koyarsın?
12. Burası gece yarısı. Gün kararmasını nereye koyarsın? Gün doğmasını nereye koyarsın?

Questions used in Experiment 1 (English translation)

1. This here is today. Where would you put yesterday? Where would you put tomorrow?
2. This here is nowadays. Where would you put long ago? Where would you put the future?
3. This here is this week. Where would you put last week? Where would you put next week?
4. This here is summer (or this season). Where would you put spring (or previous season)?
Where would you put autumn (or next season)?
5. This here is midday. Where would you put morning? Where would you put evening?
6. This here is when you are sleeping. Where would you put it when you are just going to bed? Where would you put when you wake up from sleeping?
7. This here is Wednesday. Where would you put Tuesday? Where would you put Thursday?
8. This here is the age you are now. Where would you put it when you were a baby? Where would you put it when you will be very old?
9. This here is this month. Where would you put last month? Where would you put next month?
10. This here is this year. Where would you put last year? Where would you next year?
11. This here is noon. Where would you put sunrise? Where would you put sunset?
12. This here is middle of the night. Where would you put dusk? Where would you put dawn?

APPENDIX B

Example of materials used in pictorial time flow task

APPENDIX C

Verbal Time Flow Task (Translations in brackets)

Past	Future
geçmiş (past)	gelecek (future)
önce (before)	sonra (after)
öncesinde (priorly)	sonrasında (thereafter)
dün (yesterday)	yarın (tomorrow)
önceki (previous)	sonraki (next)
geçen yıl (last year)	gelecek yıl (next year)
önceden (beforehand)	sonradan (afterwards)
evvelden (afore)	bilahare (later on)
sağladılar (they provided)	sağlayacak (he/she will provide)
gelebildim (I was able to come)	vereceğim (I will give)
öğrenebilirdik (we could learn)	sürebileceğiz (we can drive)
yaşadınız (you lived)	bulacağız (we will find)
uzaklaştınız (you went away)	deneyeceksin (you will try)
istedi (he/she wanted)	çıkacak (he/she will leave)
yararlandım (I benefitted)	aşacağım (I wil overcome)
başladılar (he/she started)	başlayacak (he/she will start)
düşündünüz (you thought)	yaşayacak (He will live)
başladım (I started)	kalacağım (I will stay)
sordular (they asked)	soracak (he/she will ask)
öğrendin (you learned)	sürecek (will drive)
istedik (we wanted)	çıkacağız (we will leave)
yararlandın (you benefitted)	aşacaksın (you will overcome)
oluşturdun (you created)	inanacaksın (you will believe)
sürebildiler (they could drove)	öğrenecekler (they will learn)

Verbal Time Flow Task (Arabic version)

Past	Future
ماضي	مستقبل
قبل	بعد
قبل فاصل	بعد الفاصل
امس	غدا
قبله	بعده
سنة سابقة	سنة قادمة
سابقا	التالي
قالت	سيقول
وجدت	سأجيد
استفاد	سنستفيد
بحثتن عنه	سنبحث عنه
حاولتن	ستحاولن
ذهبت	ستذهب
حضرت	سأحضر
رأيت	سيرى
اعتقدت	سأعتقد
نظرت	سأنظر
سأل	سيسأل
شكلتن	ستشكل
أردنا	سنريد
فعلت	ستفعل
آمنت	ستؤمن
قدنا	سنقود
عاشتنا	ستعيش

APPENDIX D

Questions of L2 Background Form

(1) Lütfen bildiğiniz dilleri BİLGİ SEVİYENİZE göre, sıralı bir şekilde yazınız.
(2) Lütfen, bildiğiniz dilleri ÖĞRENME SIRASINA göre, (anadil başta olmak üzere) sıralı bir şekilde yazınız.
(3) Arapça/Türkçe/İngilizce kaçıncı diliniz?
(4) Kaç yaşında Arapça öğrenmeye başladınız?
(5) Kaç yaşında Arapça okumaya başladınız?
(6) Arapça'yı kaç yaşında akıcı olarak okumaya başladınız
(7) Toplam kaç yıldır Arapça öğreniyorsunuz?
(8) Bu dilin (Arapça) konuşulduğu ailede geçen süre (.. ay / ..yıl
(9) Arapça dilinin konuşulduğu ülkede geçen süre (...ay /...yıl)
(10) Arapça dilinin konuşulduğu okul/iş yerinde geçen süre (...ay /...yıl)
(11) Lütfen, Arapça KONUŞMA yeterliliğinizi 1'den 10'a doğru değerlendiriniz
(12) Lütfen, Arapça ANLAMA yeterliliğinizi 1'den 10'a doğru değerlendiriniz
(13) Lütfen, Arapça OKUMA yeterliliğinizi 1'den 10'a doğru değerlendiriniz
(14) Arkadaşlarla iletişimin bu dili (Arapça) öğrenirken sizi ne kadar etkilediğini 1'den 10'a doğru değerlendiriniz
(15) Okuma yazmanın bu dili (Arapça) öğrenirken sizi ne kadar etkilediğini 1'den 10'a doğru değerlendiriniz
(16) Bireysel çalışmanın bu dili (Arapça) öğrenirken sizi ne kadar etkilediğini 1'den 10'a doğru değerlendiriniz
(17) Televizyon izlemenin bu dili (Arapça) öğrenirken sizi ne kadar etkilediğini 1'den 10'a doğru değerlendiriniz
(18) Lütfen bu dili (Arapça) öğrenirken arkadaşlarla iletişimi ne derece kullandığınızı seçiniz
(19) Lütfen bu dili (Arapça) öğrenirken okuma yazmayı ne derece kullandığınızı seçiniz
(20) Lütfen bu dili (Arapça) öğrenirken kurs/bireysel çalışmayı ne derece kullandığınızı seçiniz

Questions of L2 Background Form (Arabic version)

(١) يرجى كتابة اللغات التي تتقنها بالترتيب وفقاً لمستوى إتقانك لها
(٢) يرجى كتابة اللغات التي تتقنها بالترتيب وفقاً لزمن تعلمك لها (اللغة الأم ستكون الأولى)
(٣) ما هو ترتيب معرفتك للغة التركية مقارنة باللغات الأخرى التي تعرفها؟
(٤) كم كان عمرك عندما بدأت بتعلم اللغة التركية؟
(٥) كم كان عمرك عندما بدأت الكتابة والقراءة باللغة التركية؟
(٦) كم كان عمرك عندما بدأت بتحدث وقراءة اللغة التركية بطلاقة؟
(٧) كم سنة استغرق تعلمك للغة التركية؟
(٨) كم من الوقت مكثت مع عائلة تتحدث باللغة التركية؟ (... شهر / ... سنة)
(٩) حدد الوقت الذي قضيته في التحدث باللغة التركية إن كان في الجامعة أو مكان العمل (... شهر / ... سنة)
(١٠) كم من الوقت مكثت في بلد لغته الأساسية هي التركية؟ (... شهر / ... سنة)
(١١) يرجى تقييم درجة كفاءتك في التحدث باللغة التركية (من ١ إلى ١٠)
(١٢) يرجى تقييم درجة كفاءتك في فهم اللغة التركية (من ١ إلى ١٠)
(١٣) يرجى تقييم درجة كفاءتك في القراءة باللغة التركية (من ١ إلى ١٠)
(١٤) يرجى تقييم تجربتك في مدى أهمية التواصل مع الأصدقاء أثناء تعلم اللغة التركية (من ١ إلى ١٠)
(١٥) يرجى تقييم تجربتك في مدى أهمية القراءة والكتابة أثناء تعلم اللغة التركية (من ١ إلى ١٠)
(١٦) يرجى تقييم تجربتك في مدى أهمية الدراسة الذاتية خلال تعلم اللغة التركية (من ١ إلى ١٠)
(١٧) يرجى تقييم تجربتك في مدى أهمية مشاهدة التلفاز عند تعلم اللغة التركية (من ١ إلى ١٠)
(١٨) يرجى تحديد مقدار تحدثك باللغة التركية مع أصدقاءك أثناء تعلمك لها (من ١ إلى ١٠)
(١٩) يرجى تحديد مقدار ممارستك للقراءة والكتابة أثناء تعلمك للغة التركية (من ١ إلى ١٠)
(٢٠) يرجى تحديد مقدار جهدك الفردي أو ذهابك لدورات ودروس من أجل تعلم اللغة التركية (من ١ إلى ١٠)
(٢١) اذكر أسماء المؤسسات التي تلقيت فيها دروس تعليم اللغة التركية إن وُجدت
(٢٢) كم كان عمرك عندما بدأت بتعلم اللغة الإنجليزية؟
(٢٣) كم كان عمرك عندما بدأت القراءة والكتابة باللغة الإنجليزية؟
(٢٤) كم كان عمرك عندما بدأت التحدث باللغة الإنجليزية بطلاقة؟
(٢٥) كم كان عمرك عندما أتقنت الكتابة والقراءة باللغة الإنجليزية؟
(٢٦) كم سنة استغرق تعلمك للغة الإنجليزية؟
(٢٧) كم من الوقت مكثت مع عائلة تتحدث باللغة الإنجليزية؟ (... شهر / ... سنة)
(٢٨) حدد الوقت الذي قضيته في التحدث باللغة الإنجليزية إن كان في الجامعة أو مكان العمل (... شهر / ... سنة)
(٢٩) كم من الوقت مكثت في بلد لغته الأساسية هي الإنجليزية (... شهر / ... سنة)
(٣٠) يرجى تقييم درجة كفاءتك في التحدث باللغة الإنجليزية (من ١ إلى ١٠)
(٣١) يرجى تقييم درجة كفاءتك في القراءة باللغة الإنجليزية (من ١ إلى ١٠)
(٣٢) يرجى تقييم درجة كفاءتك في الكتابة باللغة الإنجليزية (من ١ إلى ١٠)
(٣٣) يرجى تقييم درجة كفاءتك في فهم اللغة الإنجليزية (من ١ إلى ١٠)
(٣٤) كيف هو تخطيط لوحة المفاتيح لديك؟ (ما هو نوع لوحة المفاتيح الذي تستخدمه؟)

Questions of L2 Background Form (English translation)

(1) Please list the languages you know in order of proficiency level.
(2) Please list all the languages you know in order of acquisition (native language first)
(3) Arabic/Turkish/English?
(4) Age when you start learning Arabic/Turkish
(5) Age when you start reading Arabic/Turkish
(6) Age when you start reading Arabic/ Turkish fluently
(7) How many years have you been learning Arabic/Turkish in total?
(8) Time spent in the family where this language is spoken (.. month / ..year
(9) Time spent in the country where this language is spoken (...month /...year)
(10) Time spent at school/workplace where this language is spoken (...months/...years)
(11) Please rate your Arabic/Turkish speaking proficiency from 1 to 10
(12) Please rate your proficiency in comprehension of Arabic/Turkish from 1 to 10
(13) Please rate your Arabic/Turkish reading proficiency from 1 to 10
(14) Rate from 1 to 10 how much communication with friends contributed to you while learning this language
(15) Rate from 1 to 10 how much reading-writing contributed to you while learning this language
(16) Rate on a scale of 1 to 10 how self-study has contributed to you in learning this language
(17) Rate from 1 to 10 how much watching television contributed to you while learning this language
(18) Please select how much did you use communication with friends while learning this language
(19) Please select how much did you use reading-writing while learning this language
(20) Please choose how much did you use the course/individual study while learning this language

Additional questions for L1-Arabic – L2-Turkish speakers

(1) Mention the names of the institutions where you received Turkish language lessons if any.
(2) How old were you when you started learning English?
(3) How old were you when you started reading and writing in English?
(4) How old were you when you started speaking English fluently?
(5) How old were you when you mastered writing and reading in English?
(6) How many years did it take you to learn English?
(7) How long have you been with an English-speaking family? (...month/...year).
(8) Determine the time you spent speaking English if it was at the university or the workplace (...month/...year).
(9) How long have you been in a country whose primary language is English? (...month/...year).
(10) Please rate your English speaking proficiency score (from 1 to 10).
(11) Please rate your English reading proficiency score (1-10).
(12) Please rate your English writing proficiency score (from 1 to 10).
(13) Please rate your English proficiency score in general (from 1 to 10).
(14) How is your keyboard layout? (What kind of keyboard are you using?).

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