# INTERACTION OF SPATIAL CONFIGURATIONS AND LANGUAGE: AN EXPERIMENTAL INQUIRY

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submitted by **NAZ BUSE YILMAZ** in partial fulfillment of the requirements for the degree of **Master of Science in Cognitive Science, Middle East Technical University** by,

Prof. Dr. Deniz Zeyrek Bozşahin
Dean, **Graduate School of Informatics** ________________

Dr. Ceyhan Temürcü
Head of Department, **Cognitive Science** ________________

Assist. Prof. Dr. Murat Perit Çakır
Supervisor, **Cognitive Science, METU** ________________

Assoc. Prof. Dr. Cengiz Acartürk
Co-supervisor, **Cognitive Science, METU** ________________

**Examining Committee Members:**

Assoc. Prof. Dr. Barbaros Yet
Cognitive Science Department, METU ________________

Assist. Prof. Dr. Murat Perit Çakır
Cognitive Science Department, METU ________________

Assist. Prof. Dr. Murat Ulubay
Department of Management, Ankara Yıldırım Beyazıt University ________________

**Date:** ________________

**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

Name, Last Name: NAZ BUSE YILMAZ

Signature :

# ABSTRACT

INTERACTION OF SPATIAL CONFIGURATIONS AND LANGUAGE: AN EXPERIMENTAL INQUIRY

Yılmaz, Naz Buse
M.S., Department of Cognitive Science
Supervisor : Assist. Prof. Dr. Murat Perit Çakır
Co-Supervisor : Assoc. Prof. Dr. Cengiz Acartürk

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The perception and description of space are one of the most fundamental phenomena in human cognition and evolution. Knowing where we are and telling allies about it is vital information from an evolutionary perspective. There is more than one way to define spatial scenes, and we choose one of these ways without even realizing it. Literature examines the spatial linguistic systems to find out what drives and provoke these differences. Linguistic elements that define space generally examined as topological descriptions, Frame of References (FoRs) and verbs. The reason for the preference of one spatial term to another is probably related not only to the language level but also to many other cognitive faculties. Topological descriptions or FoRs are generally defined by static scenes in the literature, and attention is drawn to verbs for dynamic scenes. However, topological terms and FoRs that are experimentally studied under static scenes are often referred to as static terms, but they are also used in dynamic scene descriptions in Turkish. Due to this gap in the literature, we set out with the question of whether these terms are affected by the motion axes in dynamical scenes for Turkish spatial language. Assuming that the difference created by the movement axes at the cognitive level must have a possible equivalent in the language, we examined the situations of the egocentric reference frame or topological definition elements in the movement depending on the horizontal and vertical axes. According to the experimental results focusing on the response times, we found that the movement axes and the horizontal movement direction affect comprehension performance of observers.

Keywords: spatial language, spatial cognition, FoRs, topological descriptions, axis

# ÖZ

UZAMSAL KONFİGÜRASYONLAR VE DİL ETKİLEŞİMİ ÜZERİNE DENEYSEL BİR SORGULAMA

Yılmaz, Naz Buse
Yüksek Lisans, Bilişsel Bilimler Programı
Tez Yöneticisi : Yrd. Doç. Dr. Murat Perit Çakır
Ortak Tez Yöneticisi : Doç. Dr. Cengiz Acartürk

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Uzamsal algı ve uzamın tanımlanabilirliği, insan bilişi ve evrimindeki en temel olgulardan biridir. Nerede olduğumuzu bilmek ve bunu tanımlayabilmek, evrimsel bir bakış açısıyla hayati bir bilgidir. Uzamsal sahneleri tanımlamanın birden fazla yolu vardır ve biz bu yollardan birini farkında olmadan seçeriz. Alanyazın bu farklılıklara neyin yol açtığını bulmak için uzamsal dil sistemlerini inceler. Uzamı tanımlayan dilsel öğeler genellikle topolojik betimlemeler, referans çerçeveleri ve fiiller ile incelenir. Bir uzamsal terimin diğerine tercih edilmesinin nedeni muhtemelen sadece dil düzeyiyle değil, diğer birçok bilişsel yetiyle de ilgilidir. Topolojik tanımlamalar veya referans çerçeveleri literatürde genellikle statik sahneler ile çalışılmıştır; dinamik sahneler için ise çalışmalar fiillere yoğunlaşır. Deneysel olarak statik sahneler ile çalışılan topolojik terimler ve referans çerçeveleri, genellikle statik terimler olarak anılır ancak Türkçe'de dinamik sahne açıklamalarında da bu terimler sıklıkla kullanılır. Literatürdeki bu boşluktan yola çıkarak Türkçe uzamsal dili için bu terimlerin dinamik sahnelerdeki hareket eksenlerinden etkilenip etkilenmediğini sorduk. Hareket eksenlerinin bilişsel düzeyde oluşturduğu farklılığın dilde muhtemel karşılığının olması gerekliliğini varsayarak, yatay ve dikey eksene bağlı harekette benmerkezci referans çerçevesi veya topolojik tanımlama elemanlarının durumlarını inceledik. Tepki sürelerine odaklanan deneysel sonuçlara göre, hareket eksenlerinin ve yatay eksendeki hareket yönünün Türkçe uzamsal dilinde etkisinin olduğunu bulduk.

Anahtar Kelimeler: uzamsal dil, uzamsal biliş, referans çerçeveleri, topolojik tanımlar, eksen

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| FORS | Frame of References |
| BOWPED | Topological Relations Kit by Bowerman and Pederson |
| RT | Response Time |
| F1 | Function of zone |
| BLC | Basic Locative Construction |
| H+ | Horizontal+, Movement from left to right |
| H- | Horizontal-, Movement from right to left |

# CHAPTER 1

# INTRODUCTION

## 1.1 Objectives and Significance of the Study

The comprehension and language of space are two of the most fundamental human cognition and evolution phenomena. Knowing where we are and telling allies about is vital information from an evolutionary perspective: the direction of food found, or a warning of impending danger forces us to describe space. Searching for traces of spatial cognition in the spatial language is a relatively new field of research. While studies that start with how spatial terms are in each language continue to be exciting due to the fact that spatial terms are generally closed sets, the interaction of spatial language with spatial cognition is still a hot-debated topic.

The number of studies focusing on spatial language in Turkish has recently limited. Turkish is a verb-framed, agglutinative language and suffixes are used to construct spatial relations. While studying methods and theories are discussed in interlingual and cross-linguistic studies, structure of Turkish is noteworthy. Levinson & Wilkins offer a study method for the conceptualization of language of space studies and this method divides spatial language as statis and kinesis firstly (Levinson & Wilkins, 2006). According to this decomposition, the spatial terms are generally studied under the heading of statis; in dynamic scenes, the focus is on the verb rather than the spatial terms themselves. This parsing causes to miss some nuances arising from the verb-framed structure in spatial language studies for Turkish. For Turkish, mostly topological terms or frame of references studies consist of showing a static scene and having the spatial language produced with production tasks and measuring its frequency or diversity (Johnston & Slobin (1979); Johanson & Papafragou (2014); Atak & Uzun (2019); Ertekin (2021); see for the ‘production tasks’ (Carlson & Hill, 2007)).

The conceptual infrastructure for spatial language studies debate on the nature of static and dynamic scenes, geometry and extra-geometric features (function / context). In this context based on conceptual subdivision of spatial language studies of Levinson and Wilkins (2006), spatial language dynamical scenes studies are entirely on the verb focused in (Özyürek, 1999; Toplu, 2011; Arik, 2009, 2017) and topological or frame of reference terms study with static scenes. Studies focused on dynamic spatial relations in Turkish found that PATH information of the motion encoded more than the MANNER information of motion (see Talmy (1985b) for the verb-framed and satellite-framed languages; Arik (2017); Toplu (2011) for the PATH encoding reference).

However, the recent literature is limited concerning the focus on how Turkish encodes PATH information with the contribution of suffixed spatial terms (these are "static" topological terms -according to conceptualization of Levinson and Wilkins- like *içine, altında…* and reference frames *sağında, soluna…*) on spatial relations. Studies in which verbs and other spatial terms are examined together are a necessity for dynamic scenes in Turkish. There is also the need to study Turkish spatial language focusing on functional and dynamic relations on the axis of motion. In dynamic scenes, the subject of whether the axes of motion affect the spatial language, and if it does, how it affects it is another important subject to be investigated. Studies on axes can provide an infrastructure to make inferences about functional features of spatial language. Besides the Levinson & Wilkins (2006) categorization, other models (Talmy, 1985b; van der Zee, 1996) and studies focusing on functional features (Vandeloise, 1991; Landau, 2020) seem more suitable for studying the structure of Turkish spatial language.

In this context, it would be a logical first step to look at whether these terms are affected by the axis of motion. It will examine whether the terms topological and egocentric reference frame make a significant difference in the vertical and horizontal axes in scenes with movement, based on previous studies, approaches and models. This thesis focuses on whether the movement of the objects on the vertical or horizontal axis has an effect on the spatial terms (specific topological and egocentric frame of reference terms) of native Turkish speakers. The effect on the direction of movement on the horizontal axis was also investigated and focused on its effect on the egocentric frame of reference terms.

## 1.2 Research Questions & Hypotheses

The research questions of the current thesis is shaped around the spatial language in Turkish. In this context, the studies at the intersection of spatial language and spatial cognition were examined in detail at Chapter 2. In this section, different approaches, models for spatial language studies, experimental methods, and special studies for Turkish are investigated to form the basis of this thesis. The background of the study was created accordingly, and an experiment was designed on the response times to descriptive spatial sentences while watching dynamic scenes.

The research questions sought to be answered in this thesis are:

1. Is spatial language affected by the axes of movement?
2. How axes of motion affect Turkish spatial language: How is the use of topological descriptions and egocentric reference frame affected by the movement on the horizontal and vertical axes?
3. Does the direction of the movement (from left to right or from right to left) make a difference in the egocentric reference frame?

The hypotheses formed within the scope of research questions by examining the literature are as follows:

1. Spatial language can be affected by axes of motion and horizontal or vertical movement makes a difference in the spatial language.

In many studies spatial terms are examined with static images and static experimental setups. However, in the real world, objects are not always at this stasis, everything in nature is both in spatial relation and in motion. Object features and dynamic states are also effective along with their exact positions in the spatial relations of the objects. According to Hayward & Tarr (1995) the position of the reference object is judged better than the case of another position when the figure object is placed in vertical or horizontal alignment in both visual and linguistic results. So they argue that human cognitive system encode spatial relations as a prototypical core definition structure and this structure measures how well a positioning and alignment of the objects fits or does not fit with the specific spatial relation. At this point, we concluded that the movement itself in a certain axis should actually be effective in making inferences what the spatial relationship will be. As can be seen in the analysis and results section where the experimental results are examined in detail, we found that the motion axes affect the spatial language, and this hypothesis was supported.

2. It is essential on which axis the movement takes place also for topological descriptions, not just for reference frames.

   In the literature, topological relations have been defined as spatial relations independent of the angular relations of objects with each other and independent of perspective. Levinson and colleagues Levinson & Wilkins (2006); Bowerman & Pederson (1992); Pederson et al. (1998) examine topological relations independently of the movement. However, when describing the spatial relations of objects in motion, we use these terms with verbs while expressing dynamical situations in Turkish. Therefore, the axis of motion must be important in our topological inference of what the current spatial relationship will lead to. It's probably more likely that one object will fall into another while moving vertically from top to bottom than the probability of falling into another when moving from left to right, and we know this involuntarily. This hypothesis has been confirmed.

3. While the figure moves on the horizontal axis, the response time given to the "topological descriptions" should be shorter than the "egocentric reference frame".

   At this point, while constructing the hypothesis, we set out from the data in the literature that people have difficulty in defining spatial relations in the horizontal axis. We deduced that the peculiarity of left and right may lead to an shorter response times of topological relations. However, the results of the experiment turned out to be exactly the opposite of this hypothesis. The response times given to the topological relations when there was movement in the horizontal axis were higher than the response times given to the egocentric reference frames. The possible reason here was the integration and involvement of the object-recognition system in this spatial interpretation, which Landau emphasized while defining topological relationships Landau (2003).

4. Direction matters in horizontal axes based on egocentric reference frame sentences, and from left to right should have less response time than from right to left.

   Landau (2003) provides evidence in experiments that participants were more successful in the right direction in both linguistic and non-linguistic tasks. In our study, the response times were shorter in videos and sentences containing "from left to right" movement than in "from right to left"; participants are faster at perceiving the left to right direction or processing it spatially or linguistically interpreting it. So the hypothesis is supported. There may be many reasons for this, and the reason is open to speculation: perhaps the direction of reading in Turkish is one of them, or it may be related to the dominant hand, this area is open to questions, new research questions and new studies.

In summary, the research questions and experiments aim to measure whether the movements of geometric shapes on vertical or horizontal axes affect their response times and, therefore, their spatial language when native Turkish speakers are observers. In addition, it has been investigated whether the direction of movement on the horizontal axis has an effect.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Spatial Language and Spatial Cognition

Spatial cognition is an inevitably vital phenomenon, and spatial language is another important topic that has been studied in different contexts for centuries naturally. One of the debates among researchers is whether humanity used spatial language is rooted in spatial cognition or is the relationship between spatial cognition and spatial language too weak to be mentioned? Is the arrow of the relationship between spatial language and spatial thought unidirectional or bidirectional?

Language of space, i.e., language for describing spatial relations, has been used for studying spatial cognition. It is appropriate in this thesis to begin with the conceptual subdivisions of spatial language. In this section, starting from the physicists' approach to space, the studies of Piaget & Inhelder (1948), who fed the linguistics studies in the field of developmental psychology; afterwards, the models created by Talmy (1985b) and Levinson & Wilkins (2006) while examining spatial language and the category-based model of Landau & Jackendoff (1993) will be mentioned.

While examining the spatial language, different models based on geometry and functioncontext have been formed. Spatial language in static and dynamic scenes, as well as extra-geometric features that affect spatial language is investigated and have been tried to create a conceptual infrastructure.

There is more than one way to define spatial scenes and speakers choose one of these ways naturally and without even realizing it. The systems that define the space are examined according to whether there is movement in the scene, but there are also different classifications for understanding the spatial language. While topological definitions and frame of references are generally sought in static scenes in the studied literature, the focus is on verbs in spatial terms containing motion. In this thesis, the cases of Turkish spatial terms will be examined in this order and then discussed. Linguistic elements that define space independently of perspective are called *topological descriptions*, on the other hand, linguistic elements that contain a perspective based on the speakers themselves, the relationship of objects to each other, or environmental landmarks are called *frame of references (FoR)*. Most languages have more than one frame of reference (FoR) however the speakers use one certain FoR for a certain situation. The reason for the preference of one frame of reference to another is probably related not only to the language level but also to many other cognitive faculties. The topic of motion is very important because the issue of force-dynamics in language is still a topic of much current debate and its place in models has the potential to change as cross-linguistic studies are conducted.

How cross-linguistic studies are done, experimental setups, methods, and protocols are examined in a separate section. Studies carried out for Turkish and the spatial language structure of Turkish are examined in a separate section.

In sum, the studies related to the subject in the literature have been examined and the conceptual basis of this thesis has been established. Turkish is a verb-framed and agglutinative language and numerous suffixes are used to describe spatial relations; it will be investigated whether the terms topological and reference frame make a significant difference in the vertical and horizontal axis in scenes with dynamic movement, based on the studies, approaches and models mentioned below.

### 2.1.1 Conceptual Subdivisions of Spatial Language

The mapping of how perceived space is perceived can be traced through spatial language. Jackendoff (1996b). Spatial language encompasses all the answers and the questions that resonate with "where" questions in the simplest sense Levinson (2003).

Certainly, spatial concepts are not only the subject of cognitive science or linguistics; mathematics, physics, and philosophy discuss space and spatial concepts long before them. It would be beyond the limits of this thesis to dig deep dive into what space is in those fields, but it became necessary to give a background in order to understand what space we are also talking about. Absoluteness and relativeness of space have been the main topics of discussion. The space approach of Newton is absolute, so it is independent of the motion or existence of the objects it covers; however, Leibniz's approach defines the space composition of the relationships between objects. (Arthur, 1994). Space is relational from the viewpoint of Leibniz and spatial language is also relational; speakers describe scenes, motion or location of things with respect to others and according to relationships.

Developmental studies also explore the relationship, but the relationship between the experiencer (infants) and the experiencee (space). Piaget and Inhelder examine space under three main subdivisions: Topological Space, Projective Space, and Euclidian Space from a developmental perspective in their study focused on children's conception of space (Piaget & Inhelder, 1948). Firstly, in the development of topological space, the following steps are followed in order: Perceptual Space, (Haptic Perception of the Space), Representational Space, and Pictorial Space. Secondly, The Projective Space stage mostly focused on perspective taking and conceptualizing the changing viewpoint that causes changes in objects. Finally, Euclidian Space sets up distance and length as meaningful and the size or the shape of the object becomes meaningful with its position. In this study, Piaget examines the child's developmental stages of spatial concepts through the child's relationship with space and names the forms of these relationships in the light of the principles of the Gestalt school. (separation, proximity, order, enclosure, continuity, etc.). Forty years later, Talmy applies the same methodology to linguistics as Piaget did in developmental psychology. He introduces the concepts of "figure" and "ground" into the spatial language (Talmy, 1985a).

Talmy's method of describing spatial language is based on figure and ground relations. Talmy sums it up as follows: *"The state of an object or mass in the location function is analyzed by its* *relation with another object or mass"* (site, path & orientation). This primary object is named "figure" and the secondary object is named "ground" (Talmy, 2000). Talmy's work begins by describing the components of spatial language and accepting spatial language, initially prepositions, as a schematic relationship. In these schemes, other qualities of space, such as color or shape remain outside. When using a preposition, for example, "between" has nothing to do with the color of the objects in the spatial relation.

According to Talmy (2000), the linguistic schematic organization of space consists of two subsystems: The function of the first subsystem is containment and localization which covers the concepts of region and location in a static manner and path and placement in a dynamic manner. It refers to a classification of relationships between objects according to their kinetic.

The function of the second subsystem is the presence of geometrically bounded objects that are distributed without geometrical bounds. This system refers to a representative structure more than a classification, and spatial categories do not have strict boundaries. A spatial preposition defines an approximate encoding of the relation. Talmy suggests that this schematization is the nature of spatial prepositions. Talmy describes a basic motion event with six components: Figure, Ground, Path, Motion; Manner, and Cause. According to Path component's nature, he divides languages into *satellite-frame* and *verb-frame* (Talmy, 2000).

In the following years, it is seen that the two basic components are also defined by the following names: Figure (also described as the theme, trajector, referant) located relatively Ground (also described as landmark, place, relatum, reference), (Levinson & Wilkins, 2006). After the concepts come the categorization of the forms of spatial relationships. Spatial concepts do not match with specific parts of a spatial language universally, i.e. adpositions or finding every three types of FoRs in each language; however, Levinson & Wilkins (2006) suggest that the distinctions and patterns in spatial languages are enough to suggest a diagram (see Figure: 2.1) to investigate spatial relationships in different languages. For this reason, while examining the spatial aspect and spatial variety of languages, Levinson & Wilkins (2006) firstly investigates scenes as statis or kinesis; then look at three subdomains: topological relations, frames of references, and motion (verbs).

Besides the de facto geometric relationship between two objects (called referent and relatum by Levinson (2003)) summarises his conceptual approach as spatial language ensures universal structures for the space conceptualization however also provides a colorful cultural variety and culture-based unique perspectives. He also states that semantics and conceptual structures are the two true places to look for cognitive traces of space, however cultural divergences do not provide the reflection of spatial cognition (Levinson & Wilkins, 2006). According to Levinson's categorization of spatial terms, the spatial terms like left, right, behind... (frame of references) are generally investigated under the category of static/locative spatial expressions; also, the topological descriptions like: in, on, etc. are examined under the category of static/locative spatial expressions; dynamical relations are generally investigated with motion verbs. Yet, Talmy characterizes motion events as the continuation of stationary location (Talmy, 1985b). Jackendoff proposed that the conceptualization of space consists of several structures: Spatial, Conceptual, and Linguistic, (Jackendoff, 1996a). The conceptual structure combines all spatial information. Spatial structure is about the perceptual capacity and Linguistic structure is about the lexicon and grammar of space. Jackendoff's hypothesis is that conceptual structure is universal and similar in all languages however syntax or semantics can change, when a message about spatial relations is being translated from one language to another, it will not be lost because the same/similar concept is found in that language. Spatial

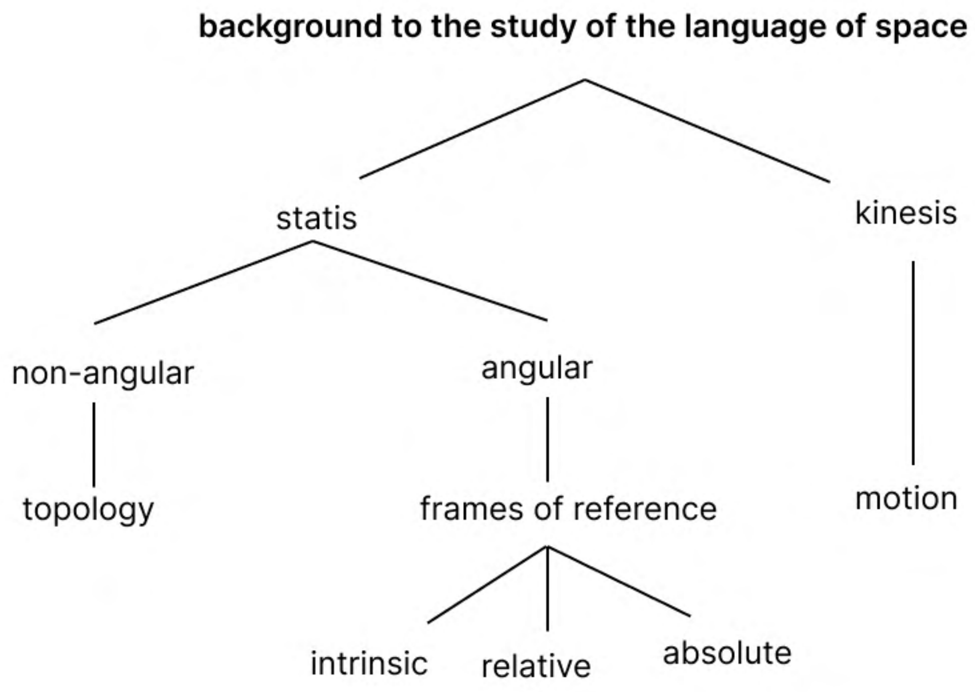



Figure 2.1: The conceptual subdivisions of the language of space by Levinson & Wilkins (2006)

categories such as in, on, above, right, etc. are part of a closed class of ±80 prepositions in most languages (Landau & Jackendoff, 1993).

They studied the systematics of English prepositions and categorized this closed group as in Figure 2.2 features of spatial relations by (Landau & Jackendoff, 1993). When we look at the models proposed for "categorization" by scientists contemporary to Talmy, we see two wings: *Feature-based models* and *prototype-based models* (Hayward & Tarr, 1995). Feature-based models explain a category membership with particular features: a member should carry all features of the category. On the contrary, prototype-based models offer a fitness/mapping scale for the category membership. The more parts of a member that fit with the prototype, the more they belong to that category; the less similarity with the prototype means less belonging to the category (Hayward & Tarr, 1995). According to Hayward & Tarr (1995), what Talmy does is applying prototype modeling to the spatial language domain.

(Hayward & Tarr, 1995) draw attention to the significant congruences between spatial perception and spatial language. In their study, which includes a series of linguistic and visual experiments, three findings are remarkable. Firstly, the position of the reference object is judged better than the case of another position when the figure object is placed in vertical or horizontal alignment in both visual and linguistic results. Secondly, they argue that human cognitive system encode spatial relations as a prototypical core definition structure so this structure measures how well a positioning and alignment of the objects fits or does not fit (and how much fit) with the specific spatial relation. Thirdly, the response patterns suggest that visual and linguistic systems overlap for spatial relationships in a non-random way. Hayward and Tarr speculated both ways: perhaps the spatial perception organized itself according to spatial terms, or the spatial language adapted itself according to the spatial structural properties of the vision. Although it is not yet known which speculation is correct, the first two findings of this study formed a basis for studies focusing on vertical and horizontal axes in the studies that followed.

Like Hayward & Tarr (1995), Landau & Jackendoff (1993) claims a one-to-one mapping between spatial cognition and spatial language and spatial terms (Slack & Van Der Zee, 2003). There are lexical or morphological categories in Turkish that correspond to the category prepositions in English: spatial nominals and case markers (dative case -A , locative case –DE, ablative case –DAn) therefore it is slightly different from the category groupings above. Details for Turkish are discussed later in the thesis.

Landau & Jackendoff (1993)'s proposals based on the assumption that spatial language has its roots in non-linguistic spatial representations (Landau, 2003). Starting from the closed and constrained set that defines "where", Landau & Jackendoff (1993) proposed a two-way "what" and "where" pathway whose traces we see in the neural system based on study of Mishkin et al. (1983) (as cited in (Landau & Jackendoff, 1993)). What pathway *(ventral)* features of the object, all the object names, adjectives, etc. Where pathway *(dorsal)* is activated by spatial terms, and these spatial terms have little relevance to the geometry of the objects themselves. In the following years, Landau "where" system deepened her studies on spatial terms and grouped this group into two as geometric and functional (force-dynamic) (Landau, 2017, 2020) she continue to examine and group topological terms according to the mechanical relations between objects and according to force-dynamics. Force-dynamic and functional relationship terms such as in and on; these relations are highly variable however geometry-based relations are tightly organized (Johannes et al., 2016). Another important point in the work of the Landau & Jackendoff (1993) is that they examine and group spatial terms categorically, not metrically specified combinations of direction and distance (such as O'Keefe & Burgess (1996)). Two other researchers who noted the effect of extra-geometric effects on deciding spatial terms were Talmy (1988) and Vandeloise (1991). Talmy studied force-dynamics to motion (verbs), however other researchers extented the work to more comprehensively.

Extra-geometric factors like force-dynamic relations analyzed under two groups: object-specific functional information and potential dynamics / interaction (K. Coventry & Garrod, 2005). Claude Vandeloise (1991) argued that definitions of the spatial terms (specifically topological / prepositions / containment relations) are deficient in the spatial language literature because they are just based on geometric relations. Until the work of Vandeloise, the preposition "in" has been defined in terms of static properties such as topological inclusion or geometric concavity. On the contrary, she presents envelopment and concavity as the results of the containment *function* in her works that emphasize *kinetic* and *dynamic properties*. Supporting the findings of this study, a remarkable point in her study is that preverbal children are *aware of the static and kinetic properties of containment* (in). Later, she argues, precise knowledge of the containment concept develops as children manipulate objects around them and become *aware of the dynamic aspects and function*. Vandeloise investigates spatial relationships with a focus on force-dynamics. Not-dynamic relations are the relations depends on shape and the characteristics of the objects (topological), however dynamic relations are both static and kinetic conditions that force (and also movement/affordances) play a role (Vandeloise, 1991). (see: Figure 2.3 for Vandeloise's set of oppositions)

In this case, it is clear that grouping some spatial terms as Levinson (2003) and Levinson

**Features of spatial relations by Jackendoff and Landau (1993)**

### Reference object geometry

**Volumes, surfaces, and lines:** in, on, near, at, inside
**Single axis:**
**Vertical:** on top of
**Horizontal:** in front of, in back of, beside, along, across
**Quantity:** between, among, amidst

### Figure object geometry

**Single axis:** along, across, around
**Distributed figure (medium or aggregate):** all over, throughout, all along, all around, all, across

### Relation of region to figure object

**Relative distance**
**Interior:** in, inside, throughout; out of
**Contact:** on, all over; off of
**Proximal:** near, all around; far

**Direction**
**Vertical**: over, above, under, below, beneath

**Horizontal**
**Side-to-side:** beside, by, alongside, next to
**Front-to-back:** in front of, ahead of, in back of, beyond

**Choice of axis system**
**Inherent:** on (the) top of, in front of, ahead of, behind
**Contextual:** on top of, in front of, behind, beyond

**Visibility and occlusion:** on top of, underneath

### Paths (trajectories)

**Earth-oriented:** up, down, east, west, north, south
**Figure object and axis-oriented:** forward, ahead, backward, sideways, left, right

**Operators on regions**
**Via:** through (= via inside), along (= via along)
**To:** to, into (= to in), onto (= to on)
**Toward:** toward
**From:** from, from under, from inside
**Away from:** away, away from

Figure 2.2: Redrawn for this thesis of the categorization and features of spatial Relations by Landau & Jackendoff (1993)

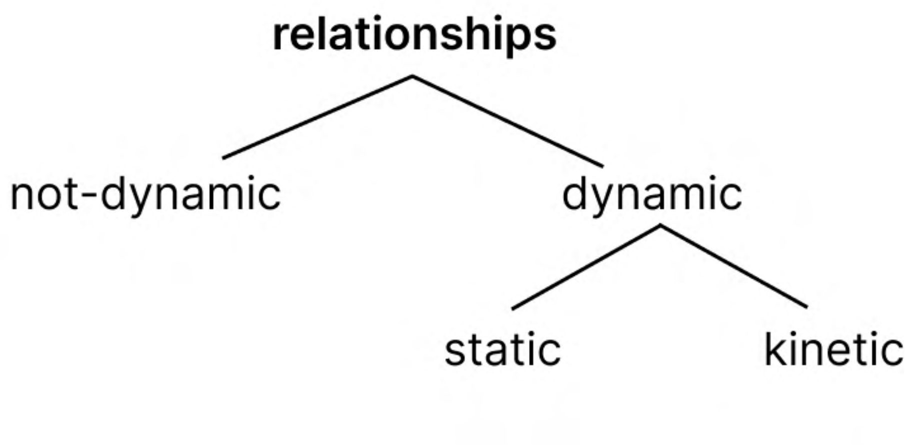



Figure 2.3: Vandeloise's set of oppositions (Vandeloise, 1991).

& Wilkins (2006) suggest would be incomplete because they both motivate geometrical and independent from context/function. Dividing spatial terms into statis and kinetic states and covering the kinetic situations just with motion verbs is to a certain extent for Germanic languages however it is not a suitable categorization strategy for languages such as Turkish: agglutinative, verb-framed and has a range of spatial terms enriched by the use of suffixes.

Finally, van der Zee & Eshuis (2003) listed the factors that determine which reference system to choose or which category of spatial term to use, beyond geometric relations, in defining the relations of figure and ground in space: (van der Zee & Eshuis, 2003) (See 2.4van der Zee & Eshuis (2003)'s spatial feature categorization model)

van der Zee (1996) has studied the axis system for Dutch spatial terms then propose a reference system model. (see Figure 2.5) This model inspires Nikanne (2003) study for Finnish postpositions and Nikanne argue that, unlike same hierarchical level of p,q,r axes as in van der Zee (1996) model, Finnish spatial semantic offer a different hiearchial structure for the axes as r>p>q: bottom&top-vertical > front&back-horizontal1 > left&right-horizontal2 (Nikanne, 2003). Accordingly, in this current study, it has been questioned whether spatial terms make a difference in response times in horizontal axis movement and vertical axis movement in Turkish and whether direction makes any difference in the horizontal axis.

In summary, this chapter examines the conceptual subdivisions of spatial language and how they change chronologically. Spatial language is used effortlessly by combining geometric and extra-geometric constraints, weighting the information available in the dynamic or static scene. How a language weights information in this spatial scene is affected both by the lexical elements of that language and by the spatial constraints associated with these terms, such as the axis in question (i.e., the syntactic and morphological structure of the language). Although none of the differences in spatial terms between languages express differences in cognitive terms, each one provides a small answer to the question of how and according to what we define space and its possible unified model.

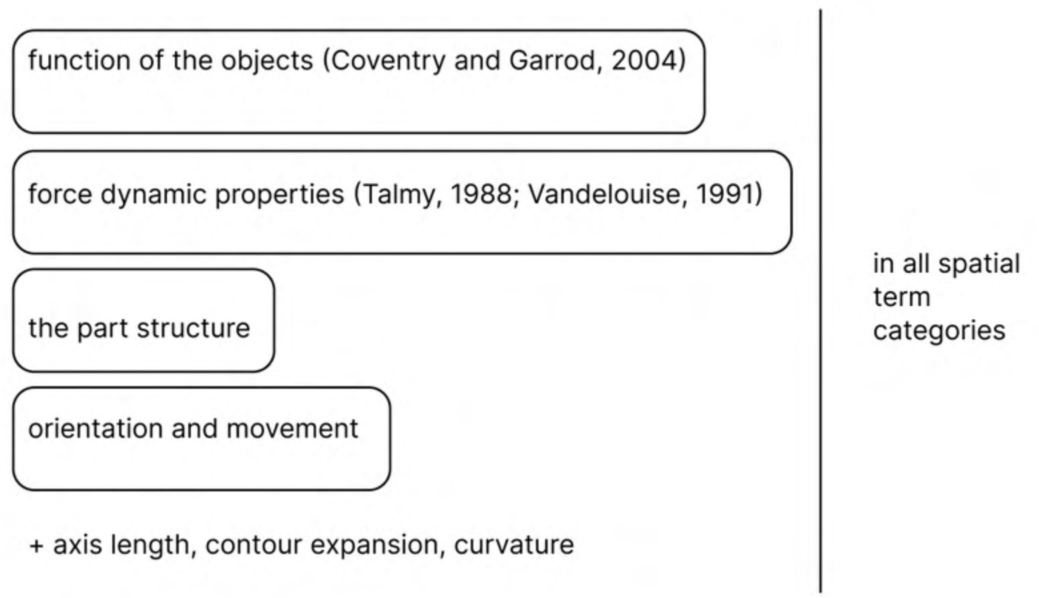



Figure 2.4: Van der Zee and Eshius' (2003) spatial feature categorization model (van der Zee & Eshuis, 2003)

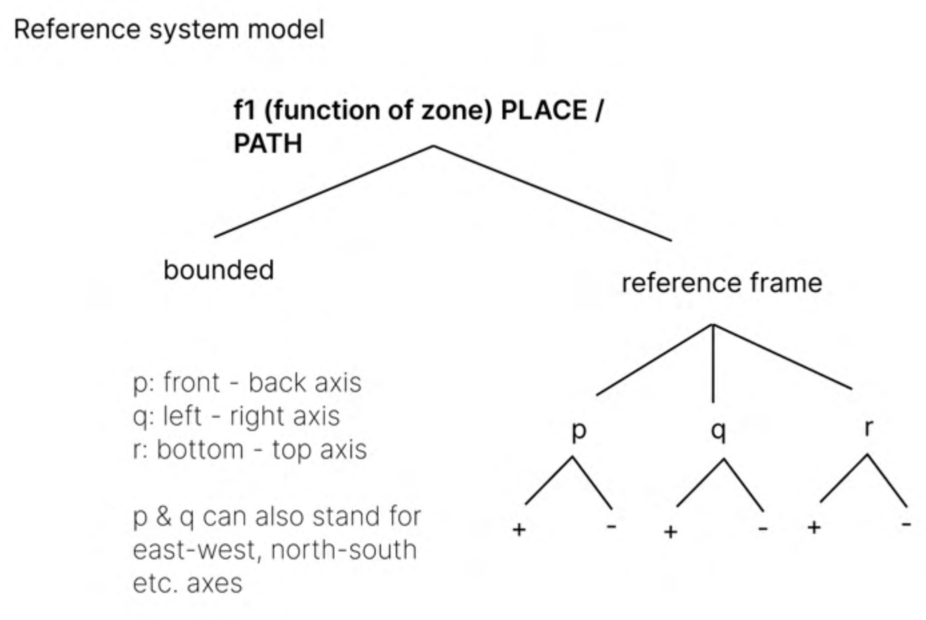



Figure 2.5: Van der Zee's axis system, redrawn model for reference systems (van der Zee, 1996)

#### 2.1.1.1 Topological Descriptions

The main function of spatial language is communicating about spatial relationship between objects. Figure and Ground are the main components. Topological descriptions are the simplest spatial relationships that appear are those that describe the relationships between Figure and Ground. in, on, near etc. are the examples of topological descriptions from English, they are prepositions in this case. They can describe a *closeness, contact or containment* situation and these are all topological relations (Bowerman & Pederson, 1992). “At”, “on”, and “in” are the prepositions of English that describe a relationship between figures and grounds and hold states of closeness, contact, or containment with their existence.

In order to answer the question of whether there are package words that hold these topological relations in every language, experimental setups were prepared and cross-linguistic studies were carried out. (See Experiment Methods and Protocols section for details)

To categorize topological relationships and compare situations across languages, Bowerman & Pederson (1992)’s “Topological Relation Picture Series” consists of 71 line drawings of the figures, grounds, and their relationships. These main relationship types are as listed in Figure 2.6:

+/− horizontal support
+/− vertical support (hanging)
+/− adhesion
+/− liquid/mastic adhesion
+/− marks on surface
+/− living creature on non-horizontal surface
+/− attachment of projecting figure to ground
+/− attachment by cord
+/− encirclement
+/− envelopment
+/− clothing/adornment
+/− complete containment
+/− partial containment
+/− containment in liquid or mass
+/− containment in encircling boundary
+/− attachment by piercing
+/− negative spaces (holes, cracks)
+/− vertical non-contact (above)
+/− behind
+/− in front of
+/− under
+/− next to

Figure 2.6: Main Topological Relationships (Bowerman & Pederson, 1992)

In the set, which has been created to investigate topological relations and variations in many languages, the figure object is shown with an arrow or with a different color, and the question "where is x" is directed to the native speakers of that language (see: Figure 2.7)

The similarities and differences that we have seen in the studies conducted in different natural languages from the time the topological relations set were first created in the 90s to the present are striking. Levinson & Wilkins (2006) define this closed group as adpositions that answer the where question. The hypothesis of how the basic locative construction is set up can be examined from the Figure 2.8:

However, in Levinson & Wilkins (2006)’s categorization, these relations are used to describe static situations. In recent studies, it has been revealed that some relational situations are valid for some dynamic scenes and the basic locative construction hierarchy, which excludes dynamic configurations, is being retested. (Support-From-Below case; (Landau, 2020)).

Struiksma & Postma (2017) state that topological relations are short function words that ac-

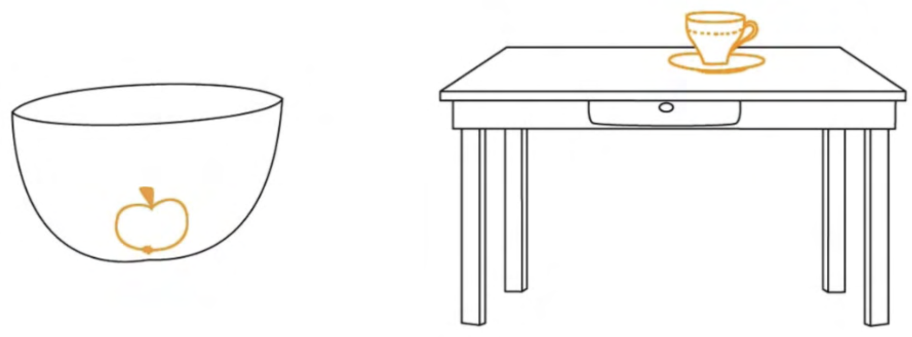


Figure 2.7: Figures from BowPed - Topological Relations Kit (Bowerman & Pederson, 1992)

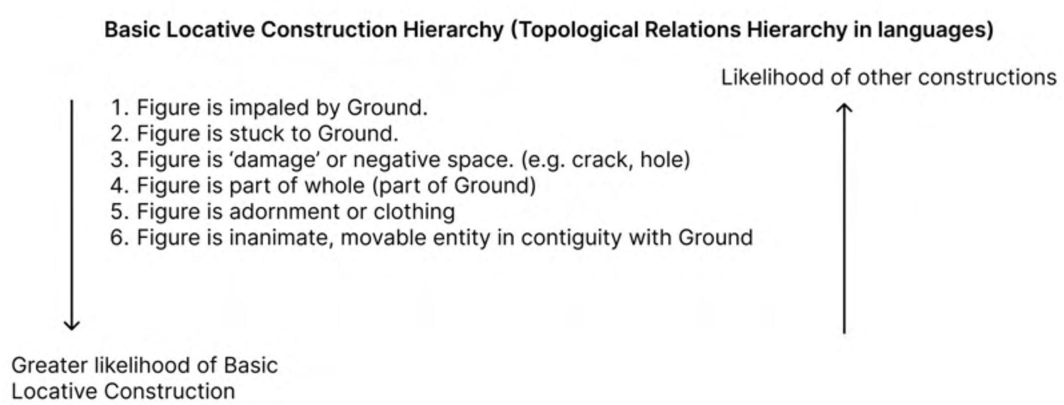



Figure 2.8: Basic Locative Construction Hierarchy (Topological Relations Hierarchy in languages) (Levinson & Wilkins, 2006)

quired relatively early ages compared to Frame of References (projective relational spatial terms). Jackendoff states that topological relations (in, on etc.) are universal in languages conceptually (Jackendoff, 1990). However the way of the language refer a spatial relation can change according to context or interaction so do not depend on geometrical features or geometrical relations only. (Vandeloise, 1991; K. Coventry & Garrod, 2005).

In summary, all languages contain topological relations, but the variations in naming the relations in different languages with cross-linguistic or similar structures indicate that we are still far from a generally accepted spatial model, including topological relations. In the sections, we have examined the models and conceptualizations created while studying spatial relations. In this section, we have examined the approaches to topological relations; in the next section, frames of references will be discussed.

#### 2.1.1.2 Frame of References

When the *Figure* and the *Ground* come to the positions where the topological relations with each other lose their meaning, spatial language begins to go beyond the topological expressions and a new form is needed. Levinson and Wilkins summarize this situation as follows: *"It is inevitable that angles and coordinate systems come into play where the divergence of figure and ground begins in space."* (Levinson & Wilkins, 2006). Although these spatial expression forms, where angularity comes into prominence, are called Frame of Reference (for short, FoR) in the literature, it is a subject that has been and continues to be discussed intensively in both spatial language and spatial cognition. Spatial reference frames include an *anchor*, besides the *figure* and *ground*. An anchor is an entity or event that introduces a spatial asymmetry in which the axes of the coordinate system are projected (O'Meara & Báez, 2011).

Similar to the naming of "topological relations" on the spatial linguistic system, which includes angular relations, are also called reference frames, following Piaget and Inhelder's studies, since they depend on perspective, coordinates, and a "*projection*" of axes (Piaget & Inhelder, 1948). Talmy (1985a) divides the structure, which is based on the schematization of Figure and Ground's relations with each other, into 3 subtitles: ground-based, field-based, and speaker-based, and indicates that the speaker chooses one schematization. The choice of this scheme differs according to language. Cross-linguistic and cross-cultural studies in the 1990s focused heavily on the variety and differences in the use of frames of reference in different languages (Levinson & Brown, 1994). In early studies, the pattern of axes of the reference frames generally focused on "left" and "right" or "front" and "back" on the horizontal axis, anchoring the human body. However, further studies with non-European languages found patterns where the speaker's body coordinates were not the dominant reference frame (Levinson, 1996; Senft, 1997). Levinson questioned the underlying mechanism of the different coordinate systems operating for different languages (Levinson, 1996).

Frame of references was categorized as three-way: intrinsic, relative, and absolute FoRs, (Levinson, 1996, 2003; Levinson & Wilkins, 2006), and this classification is be named '*Nijmegen classification*' by (O'Meara & Báez, 2011).

Other nomenclatures and classifications in the literature are as follows: object-centered, direct, landmark-based, and geomorphic. The speakers encode the location of objects using three spatial frames of reference according to Levinson and Pederson and "Man and Tree Task" is used to study for the research of FoRs (Pederson et al., 1998) (see Figure: 2.17).

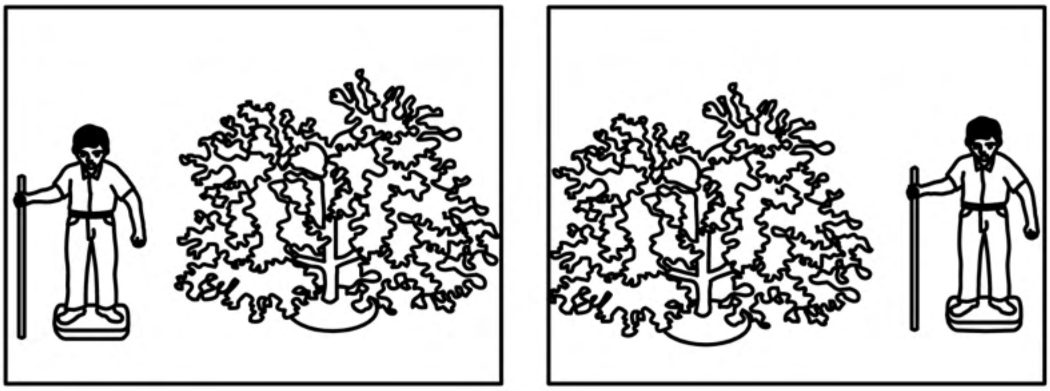


Figure 2.9: Man and Tree Task, from the Semantic Typology and Spatial Conceptualization study Pederson et al. (1998).

When asked to describe the objects in Figure, English speakers (also similar in Turkish), if these objects are located in front of them, firstly describe “The man is on the left and the tree is on the right.” This description is *egocentric FoR* because the perspective here depends on the observer and the axes of the observer’s body projected onto the ground. (also *relative FoR*, (Pederson et al., 1998). Alternatively when the observer describes the scene as “the tree is on the man’s left.”, also correct and now this is *intrinsic FoR*. The observer describes independent from their perspective but according to man, the anchor is changed from the observer’s body to figurine man’s spatial features. Third FoR, *the absolute FoR*, depends on environmental anchors like a mountain, sun, etc. If the observer describes the scene as “The tree is on the north.” this is a cardinal direction and independent from the observer’s perspective and also independent from the relation between the figurine man and the tree. Absolute and Relative FoRs are called *allocentric FoRs*, so both are independent of the perspective of the observer, unlike *egocentric FoR*.

In the experimental psychology literature, the FoR classifications are grouped as *Egocentric*, *Intrinsic*, and *Geocentric* with similar but slight differences (Wassmann & Dasen, 1998; Li & Gleitman, 2002). In more recent studies, the groups are as follows: *Relative, Direct, Object-Centered, Geomorphic, Landmark-Based, Absolute* (Danziger, 2010; O’Meara & Báez, 2011). In the table below, you can examine the equivalents of these different groupings and terminology in the literature. (See Figure 2.10).

Some languages lack some FoRs or one or two FoRs in the spoken language are more dominant than others. The reason why one frame of reference is dominant over the others in native speakers of a language or the differentiating FoRs between different languages has been examined by both linguistic and non-linguistic cognitive studies. (Levinson, 1996, 2003; Pederson et al., 1998; Majid et al., 2004; Wassmann & Dasen, 1998). Cross-linguistics aspects of spatial reference frames usage on a small-spatial scale are redrawn based on Majid et. al’s work, and Turkish has been added according to the work of Atak and Uzun (Majid et al., 2004; Atak & Uzun, 2019) (see Figure: 2.11)

A vivid discussion focus on whether FoRs are cultural or innate and form two camps in this context. Li & Gleitman (2002) argue that the use of a preferred spatial frame of reference is sourced from culture-specific reasons like different levels of literacy and geography so FoRs

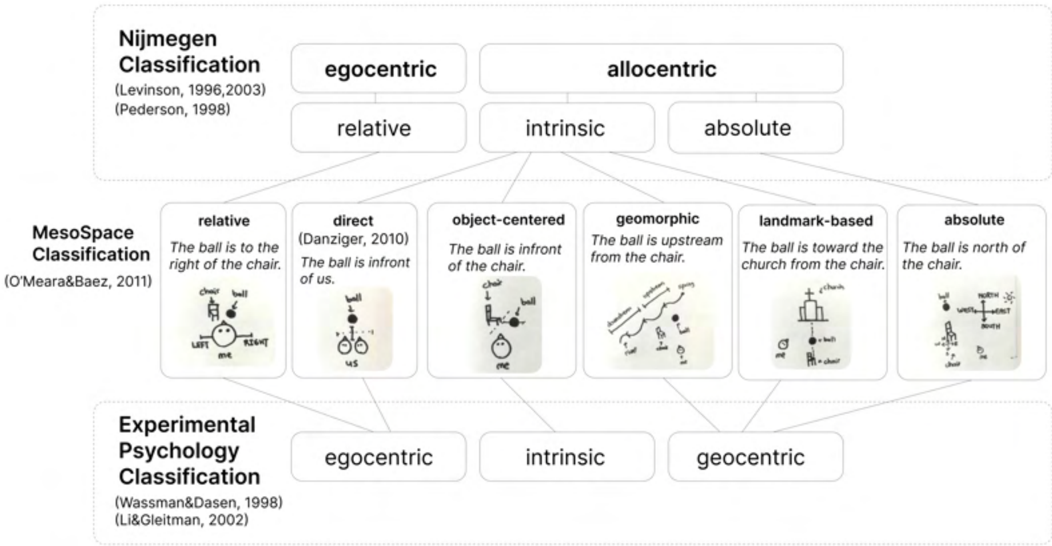



Figure 2.10: Figure with all classifications has been redrawn by the author based on the work of (O'Meara & Báez, 2011)

are not innate they are *context-dependent*, also populations adapt any kind of FoRs and it is not an indicator of their cognitive preferences. Other camp agree with the Li & Gleitman (2002) argument of acquiring any kind of FoRs by populations, however, they argue that the native language's preferred FoR can affect the mastering another kind of FoRs, also linguistic preferences for FoRs have a reflection on non-linguistics tasks. (Pederson et al. (1998); argue that the relation between spatial language and spatial thinking is just correlational, the link between them still unexplained.) Levinson et al. (2002) argues FoRs are context-free. The pursuit of linguistic FoR prioritization in non-linguistic tasks has also led to the debate as to whether the *Linguistic Relativity Hypothesis* is supported. This topic will be detailed in the spatial cognition section.

To sum up, researchers continue their long-standing debate over the use of different spatial FoRs in different languages, the reasons and the mechanisms for preferring one FoR over others, and the link between spatial language and spatial thinking. In this thesis, the use of the Egocentric - Relative reference frame, which is common to all three Nijmegen, MesoSpace, and Experimental Psychology literature classifications, is examined in native Turkish speakers on a small spatial scale. In the pre-experiment part of this study, it was observed that Turkish native speakers frequently used egocentric-relative FoR in the small-scale space in which they explained the positions of geometric objects relative to each other, and it was decided to compare behavioral data of this FoR preference with the frequently used topological spatial terms on vertical and horizontal movement axes. Finally, the reference on what the dominant FoR is in Turkish is based on the pre-experiment for this study and the work of Atak & Uzun (2019). However, Arik (2003) states that Turkish speakers use the intrinsic reference frame more than relative in his experiments. This is a solid example of context-dependency in FoRs studies. The following section will focus on how motion is studied in spatial relations.

| Language | Country | Family | Linguistic Frame of Reference: intrinsic | relative | absolute |
|---|---|---|---|---|---|
| Arrernte | Avusturalia | Pama Nyungan | ◌ | | ● |
| Balinese | Indonesia | Austronesian | ◌ | ◌ | ● |
| Belhare | Nepal | Tibeto-Burman | ◌ | ◌ | ● |
| Dutch | Netherlands | Indo-European | ◌ | ● | ○ |
| English | UK, USA,etc. | Indo-European | ◌ | ● | ○ |
| Ewe | Ghana | Niger-Congo | ● | ● | ● |
| Guugu Yimithirr | Australia | Pama Nyungan | | | ● |
| Hai//om | Namibia | Khoisan | ◌ | ○ | ● |
| Jaminjung | Australia | Jaminjungan | ● | ○ | ○ |
| Japanese | Japan | Isolate | ◌ | ● | ○ |
| Kgalagadi | Botswana | Bantu | ● | ● | ● |
| Kilivila | Papua New Guinea | Austronesian | ● | ● | ● |
| Longgu | Solomons | Austronesian | ◌ | ○ | ● |
| Mopan | Belize | Mayan | ● | | ◌ |
| Tamil | India | Dravidian | ◌ | ● | ● |
| Tiriyó | Brazil | Cariban | ● | ● | ● |
| Totonac | Mexico | Totonacan | ● | | ○ |
| Tzeltal | Mexico | Mayan | ◌ | | ● |
| Warwa | Australia | Nyulnyulan | ◌ | | ● |
| Yukatek | Mexico | Mayan | ● | ● | ◌ |
| **Turkish* | *Turkey, Balkans etc.* | *Altaic* | ◌ | ● | ○ |

● indicates the preferred FoR describing for spatial relations between small-scale, manipulative objects

◌ indicates that used by a language

○ indicates that only used in restricted circumstances NOT in table-top space

Figure 2.11: Frame of References according to different languages and language families redrawn based on (Majid et al., 2004)'s work, (See: (Johnston & Slobin, 1979) to Turkish Linguistic Family reference and See: (Atak & Uzun, 2019) for Turkish FoRs dominance)

#### 2.1.1.3 Motion

Motion is the change of an object's position relative to a point against time. Its philosophical definition and conceptual structure have been discussed in almost every age by ancient philosophers, medieval thinkers, mathematicians and physicists. After its rules were defined by Newton in physics, continued to be examined by different researchers in the fields of psychology and linguistics. It is not easy to separate motion from space when it comes to human cognition.

Expressions that carry spatial information in language are motion and location (Jackendoff, 1985). In linguistics studies, the concept of motion is mainly examined through verbs. The systematic study of motion from a linguistics perspective begins with Talmy's pioneer work and he characterizes motion events as the continuation of stationary location (Talmy, 1985b).

While coding space information, there are two situations as described by Levinson & Wilkins (2006): location and motion (statis or kinetis situations). Let's take a look at the example in Turkish:

(1) Pembe daire sağda duruyor.

*The pink circle stands on the right.*

(2) Pembe daire sağda hareket ediyor.

*The pink circle is moving at the right.*

(3) Pembe daire soldan sağa doğru gidiyor.

*The pink circle goes from left to right.*

The example (1) describes a static event. (2) and (3) describe a kinetic event. (1) and (2) include locative information however (3) describe a change in location rather than just locative information. Talmy states the motion and location within the framework of motion together; he defined the motion event as a state involving displacement and a form of stability that persists at a particular location. The basic structure of a motion event is abstractly shown as the displacement of the figure. Among these examples, the example of displacement of the figure and the PATH where the source (from left) and goal (to right) are clear in example (3). In this thesis, it is investigated whether the axis of motion affects the spatial expressions (frame of reference and topological terms) that support the path in kinetic conditions similar to those in example (3) and the example (2). In addition, it is questioned whether the direction of movement in the horizontal axis has an effect on response times, (similar to the one in (3)) for the displacement of the figure.

Talmy (1985b) describes a basic motion event with six components: Figure, Ground, Path, Motion; Manner, and Cause. The meaning components which are defined in the simplest way as the movement or positioning of an entity relative to another, are divided into two groups: These are the internal components, that is, the components that make up the core event (Figure, Ground, Path, Motion), and the external components, that is, the components that make up the co-event (Manner, Cause).

MOTION: Motion is the presence of motion or location

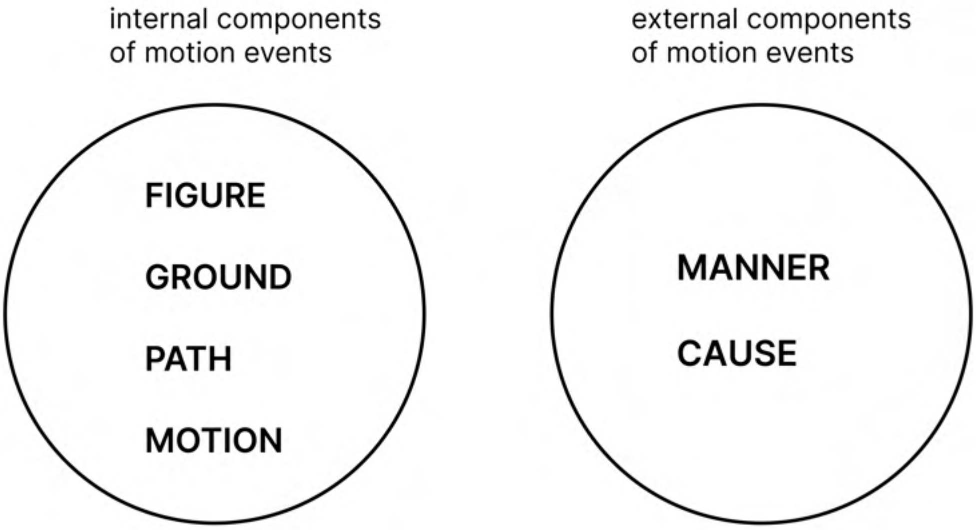



Figure 2.12: Talmy (1985b) describes basic motion event's components as four internal elements and two external elements

FIGURE: Figure is a thing that moving or located with respect to another object.

GROUND: The motion or location of the Figure is determined according to Ground, it is the spatial reference point of Figure.

PATH: Path is the trajectory followed by the figure during its motion. Path includes two main components: source and goal. Source is the starting point and the goal is the endpoint, the trajectory between them creates the path.

MANNER: Manner is the component of how the movement or location is done, the way of the motion or location. This is defined by Talmy (1985b) as an external element because it is a linguistically separate event that supports the motion event.

CAUSE: Cause is the second external element that refers to the reason for a motion event.

The PATH is the component most likely to be encoded into the motion event. The way of a language can encode the path component into the event is seen as a criterion that reveals the differentiation between languages (Talmy, 1991). While Talmy describes the motion event, he takes the PATH information as the core element of the motion. PATH, so, trajectory followed by the figure is the principal element of Talmyan Typology. This is why he divides languages into 2 groups according to where the path of motion is framed and encoded: Verb-framed Languages and Satellite-Frame Languages.

**Verb-framed Languages:** PATH component is framed in the main verb of a clause or sentence.

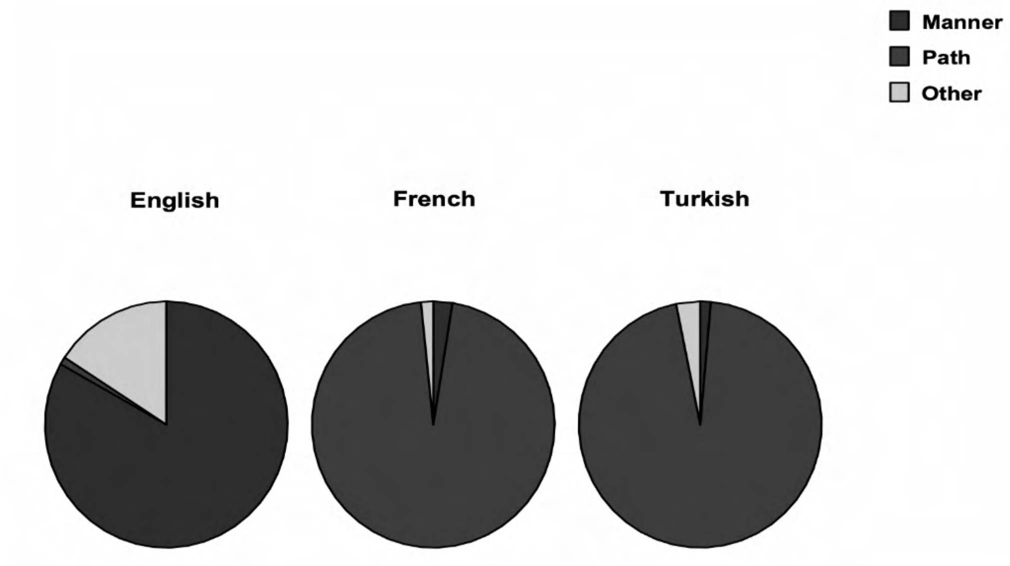



Figure 2.13: Distribution of the verbal descriptions for three languages according to the Toplu (2011)'s study

**Satellite-framed Languages:** PATH component is framed in a peripheral element called a satellite rather than verb.

Talmy (1991) grouped languages according to the PATH component's encoding, however never claimed that languages have just one style to expressing motion events. Instead of, he refers to a language characteristic shaped by situations such as frequency of use.

Turkish is a verb-framed language and PATH is typically encoded in the main verb and MANNER is expressed by a gerund or an adverbial form (Toplu, 2011). But not all the verbs in Turkish does not encapsulate PATH information in the main verb. It also contains actions that encode only MANNER and MANNER+PATH in the form. Arik's study for the Turkish supports that in dynamic spatial scenes, the motion PATH is encoded more than the motion MANNER (Arik, 2017).

In Toplu's crosslinguistic study for Turkish, which looked at the distribution of verbal descriptions of motion events in sentences produced after watching a dynamical scene, it was found that Turkish speakers formed PATH sentences at a very high rate (95.4%) according to English (1%) . Distribution of the verbal descriptions between Turkish and French was similar, they are both Verb-framed Languages according to Talmyan Typology and frequently describes scenes with PATH sentences, but English speakers describes with MANNER sentences more (83.2%) (Toplu, 2011). (See Figure 2.13 Distribution of the verbal descriptions for three languages according to the Toplu (2011)'s study.)

According to Levinson & Wilkins (2006)'s categorization of spatial terms, the spatial terms like left, right, behind etc. (frame of references) are generally investigated under the category of static/locative spatial expressions. Also, the topological descriptions like: in, on, etc. are examined under the category of static/locative spatial expressions in a grueling amount of study. However, at this point, there are hypotheses that argue when using spatial terms, more than geometric components are involved such as function and context (Vandeloise, 1991). Although it is a fact that spatial terms are used with reference to the human body or environmental references, it is difficult to predict which terms are used in what conditions because they are motivated by extra-geometric factors K. Coventry & Garrod (2005) identify extra-geometric factors into two categories: object-specific functional information and actual or potential dynamics (interaction). What will happen over time provides the basic judgment about the appropriateness of a set of (spatial) terms (((Carlson-Radvansky et al., 1999; K. Coventry & Garrod, 2005). Movement in a specific axis and the direction of movement is one of these contextual situations (potential dynamics  interaction).

In conceptual semantics Figure and Ground components can have different terminologies like theme for the Figure; PLACE, reference object for the Ground. As seen in Levinson & Wilkins (2006) categorization, in English spatial semantics Ground / PLACE has a stationary state. (Nikanne argues that the same situation is probably valid for other Germanic languages; (Nikanne, 2003)). However, in some languages like Turkish, it is possible to express spatial relations with the same adpositions in dynamic relations as well with the support of locative cases without a motion verb, unlike English. Although the direction of movement does not differ much in terms of English spatial terms specifically in prepositions, is it the same for other languages? The effect of intensive MANNER coding instead of PATH coding in dynamic events in English, which is the first language on which researchers work intensively while categorizing spatial terms, is another subject worth discussing, but it goes beyond the scope of this thesis. There are two studies focus on this subject in the frame of Finnish: effect of the movement, allignment and orientation to the comprehension of spatial adpositions is investigated (Nikanne, 2003; K. R. Coventry & Frias-Lindqvist, 2005). Finnish has more adpositions than English prepositions to describe spatial relations and situations for the "in front of" (edellä and edessä) and "behind" (jäljessä and perassä). These are the terms examined under statis according to categorization of Levinson & Wilkins (2006), however the adposition edellä use in the case of motion with the support of locative cases. Nikanne's determination for spatial terms in a language with locative case is noteworthy because he states that locative cases creates finer semantically distinctive spatial relations. "In English (and in Norwegian, for example), spatial prepositions such as 'behind' and 'in front of ' cannot be governed by spatial prepositions referring to the goal-direction (to, toward), and therefore the meaning must rely more on the governing verb." (Nikanne, 2003). K. R. Coventry & Frias-Lindqvist (2005) investigate an empirical study (rating the appropriateness of sentences containing in front of and behind terms to describe pictures of cars at various positions) to see whether in front of and behind usages are different from English in dynamical scenes and they found that results show similarities in both languages while Finnish speakers distinguished 'behind' terms when the objects are in motion Also, movement affected the acceptability of terms when there were frame of reference conflicts in both Finnish and English scenes. In such cases, how the languages define spatial relations using what kind of hierarchy is another subject worth investigating.

To sum up, Turkish is a verb-framed and agglutinative language and lots of suffixes are used to construct spatial relations as well. Verb-framed structure has been studied comparatively with other languages and how PATH componant is coded in Turkish has been revealed, but there is no study that focuses directly on PATH supporting terms, that is, non-verb or the strategy or hieararcy of spatial term usage that supports PATH for Turkish. Moreover, the fact that frame of references and topological terms in research made for Turkish are mainly examined with conceptual infrastructures that are examined on Levinsonian statis / kinesis plane, however the structure of Turkish (similar to Finnish - locative cases) reveals that the spatial terms that are characterized as static do not remain only in the static plane and that only verbs should not be investigated at for motion, mixed methodologies and conceptual categorizations need also to be looked at. In order to be the first step towards such a hierarchy study, the effect of motion in horizontal and vertical axes on spatial terms was investigated in this thesis for the Turkish.

### 2.1.2 Spatial Cognition

This section examines the spatial cognition in a relation between spatial language. Since spatial cognition is a base of many of the other mental and behavioral capabilities, its research naturally consisted of an interdisciplinary approach. Attention, perception, memory, categorization, decision making, problem solving and language based processes will inevitably be a part of this research. How do our concepts of space map (in a non-linguistic way) into spatial language, that is the question. There are two camps here, those who argue that spatial thought (arguably representations) has a direct roots in language and those who do not or have weak links between them. Advocates of the spatial language has roots in cognition are also divided into two camps, those who argue that spatial language modifies and influences thought and that differences in spatial languages lead to differences in thought (Relativists: linguistic determinism and linguistic relativity) and those who do not (Universalists). For instance Bowerman's hypothesis is that spatial language (specifically the prepositions) does not directly project the world of spatial thoughts. (Bowerman & Pederson, 1992) - She states that language just makes selections for specific spatial options. However, Landau & Jackendoff (1993) argue that spatial language has its roots in non-linguistic spatial *"representations"* (Landau, 2003).

For the *spatial representation* issue, the concept of "representation" used in the studies of the late 90s is a bit ambiguous. In the study of Landau & Jackendoff (1993), the concept of spatial representation is translatable mental "representation" that comprehends the geometric properties of objects, and spatial relations between objects. Jackendoff proposed that the conceptualization of space consists of several structures: Spatial Representations, Conceptual Representations, and Linguistic Representations, (Jackendoff, 1996b). That study links spatial terms to the dorsal and ventral where and what pathways of Mishkin et al. (1983), therefore, we can roughly evaluate the terms defined as representations in their period as neural traces. Jackendoff's hypothesis is that conceptual structure is universal and so spatial information is translatable crosslinguistically. According to O'Keeffe's argument supporting some linguists' spatial representational base of spatial language and the metaphorical extension of spatial language, human hippocampal representations of the left side of the brain evolved to process linguistic and episodic information rather than spatial information (O'Keefe, 2001).

In O'Keefe and Burgees' study, in which we have seen the neural traces of spatial perception: they described major categories of spatial cells: place cells, head direction cells, grid cells and boundary cells in their animal studies in the neuroscience of spatial cognition. These cell types have a characteristic firing pattern that encodes spatial parameters relating to current position and orientation (O'Keefe & Burgess, 1996). Also they found theta oscillation in that cell's activity means functional role in the representation and processing of spatial information. For the spatial information, O'Keefe (2001) propose Vector Systems: a spatial system

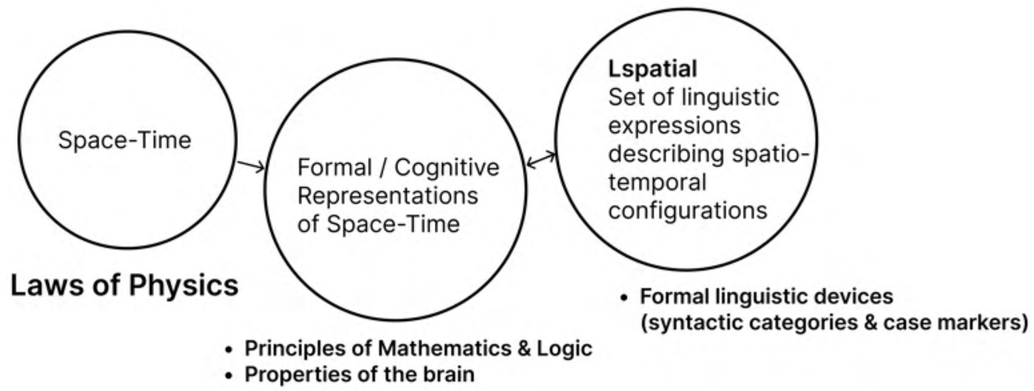



Figure 2.14: Based on van der Zee & Eshuis (2003) framework for the relations shows the mappings (or interfaces) while studying at this zone (mappings are many-to-many)

based on geometric properties; metrically specified combinations of direction and distance and Vector Grammar adress that different spatial relations are encoded within a vector-based represantation in the brain. Based on van der Zee & Eshuis (2003) framework for the relations shows the mappings (or interfaces) while studying at this zone, (mappings are many-to-many) see Figure 2.14

If we examine the two-way arrow in depth here, encountered a distinction between relativism and universalism. In the classical approach the arrow was one way from cognition to language and language was a passive system for just expression of spatial thoughts and spatial communication. Sapir and Whorf challenged this classical approach with argued language's itself shape the thoughts (Sapir & Whorf, 1956). Would language really influence thought, and if so, how? Here are the thoughts of the two groups within the scope of this question:

**Relativism**: They have two camps: strong version (linguistic determinism or Sapir-Whorf Hypothesis) and weak version (linguistic relativity). Linguistic determinism or Sapir-Whorf Hypothesis support that language structures directly effect thought patterns of its speakers; one of its current advocates is (Levinson, 1997). Weak version states that language has an influence and partial effect on thought. Slobin tried to answer the question of what such situations are and when they occur, with the *"thinking-for-speaking"* hypothesis and mentioned that these differences may arise while trying to communicate (Slobin, 1996).

**Universalism**: According to this view, which is the opposite of relativism, differences between languages do not lead to differences in thought and cognition. Researchers of this view mention that experimental setups are not suitable for empirical approaches that test the language thought relationship Landau (2003). Two researchers known for Universalist view are Chomsky and Jackendoff.

The subject is still being discussed. Researchers trying to experimentally prove the linguistic differences between spatial language and thought (Brown & Levinson, 1978; Pederson, 2002) with both linguistic and non-linguistic tasks, their studies could not be verified when re-replicated by updating environmental conditions by (Li & Gleitman, 2002). Li & Gleitman (2002) argue that the use of a preferred spatial frame of references in that studies is sourced from culture-specific reasons like different levels of literacy or geography not from a cognitive / thought pattern difference. In empirical studies such as spatial term categorization studies or spatial memory studies should be set to eliminate task dependency as much as possible, in crosslinguistic research.

The definitions of spatial terms in languages are intertwined and a general hierarchy has not yet been established on how these spatial terms are used (altough there are many model suggestions such as for the semantic of spatial terms: topological relations dependent on geometry and/or function, Frame of references dependent on geometry and/or function , Spatial Feature Categorization Model, Attentional Vector Sum Model, Boundary Vector Cell Model etc.). From another domain, artificial intelligence, Spatial Semantic Hierarchy, created by Kuipers (2000), for larger space rather than table-top space, is a large-scale spatial knowledge model consisting of interactive multiple representations, both qualitatively and quantitatively. It was inspired by the features of the human cognitive map when it was created, and it is intended to be used both as a model of space in the human cognitive map and as a method of robot exploration and map creation.

In this model (see Figure 2.15) the causal and topological definitions differ from Talmy (1985b) and Levinson (2003) definitions for spatial language topological or CAUSE terms. However, it has been added to this section as it is a model that can serve as an example of how a semantic hierarchy can be formed at the point where the spatial concepts in the cognition of the human being, who is also a dynamic agent, are expressed.

In summary, the relation between space interface, spatial cognition interface and spatial language interface continues to be researched and modeled. In this framework, discussions continue mostly on the arrow of the relationship between spatial language and cognition. Since this study is itself an experimental study and measures response times, it is close to the view that spatial language originates from spatial cognition, but it is insufficient to present an argument about how language affects thought or whether it affects thought; before reaching such a conclusion it should be tried cross-linguistically and interlinguistically. This thesis aims to measure whether some perceptual or cognitive differences are reflected in language by looking at whether a hierarchy (of van der Zee (1996), reference system model) in spatial terms for Turkish for the movement on vertical and horizontal axes movement.

## 2.2 Empirical Methods and Protocols for Studying Spatial Language and Spatial Cognition

Numerious empirical methods have been developed to examine spatial language and spatial thinking in cross-linguistic studies. The distinction between experimental setups begins with whether the stimuli set is static or kinetic.

Experiment sets in which topological or frame of reference relations are examined by mainly showing static scenes (or toys) are as follows: Topological Relations Picture Series is for topological relations (see Figure 2.16, the Men  Tree Task 1 is focused on FoRs (Danziger, 1992), the Men  Tree Task 2 also focused on FoRs (Pederson et al., 1998), Talking Animals (Bohnemeyer, 2012) (Talking Animals has a similar design and protocol of the Men  Tree Task), Ball  Chair (also similar design and protocol of Men  Tree Task) (Bohnemeyer & Báez, 2008).

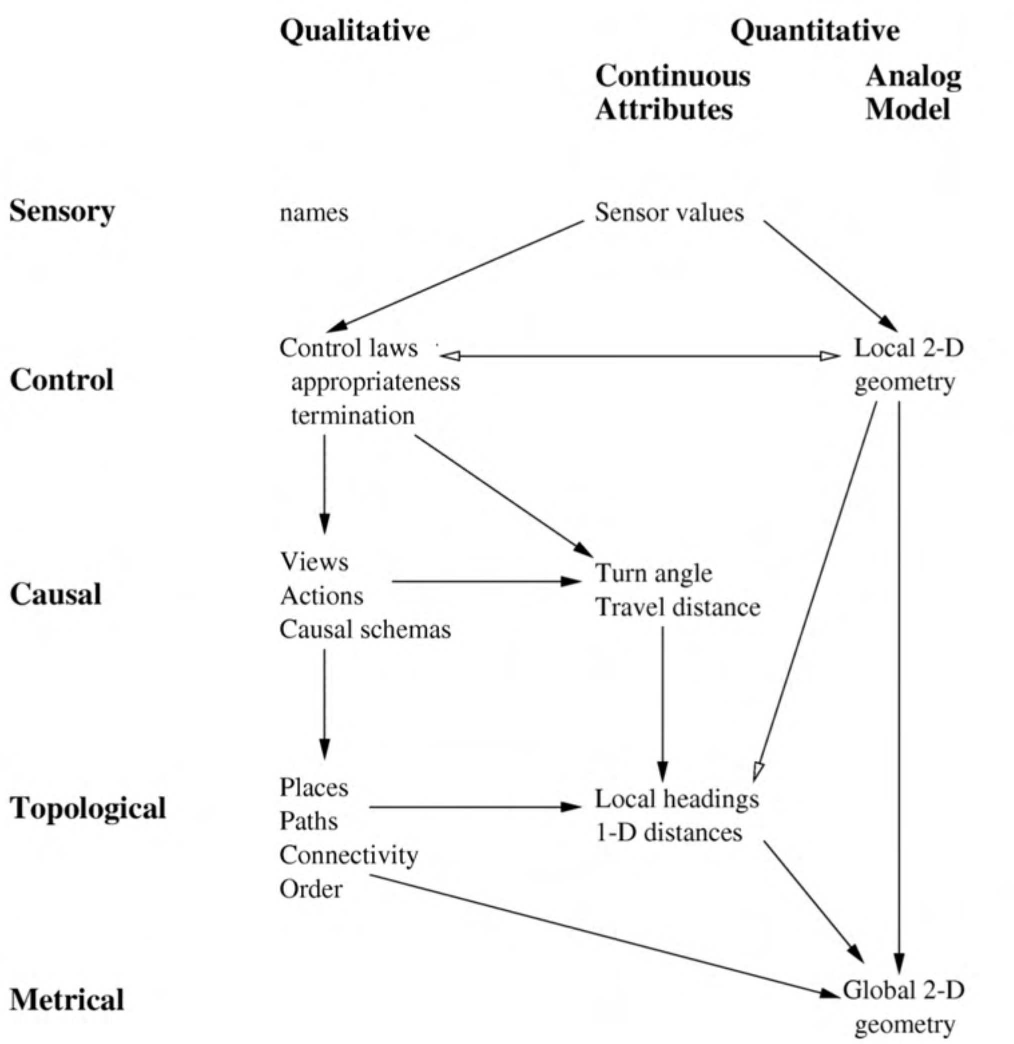



Figure 2.15: The Spatial Semantic Hierarchy from (Kuipers, 2000) (Closed-headed arrows: dependencies; open-headed arrows: potential information flow without dependency)

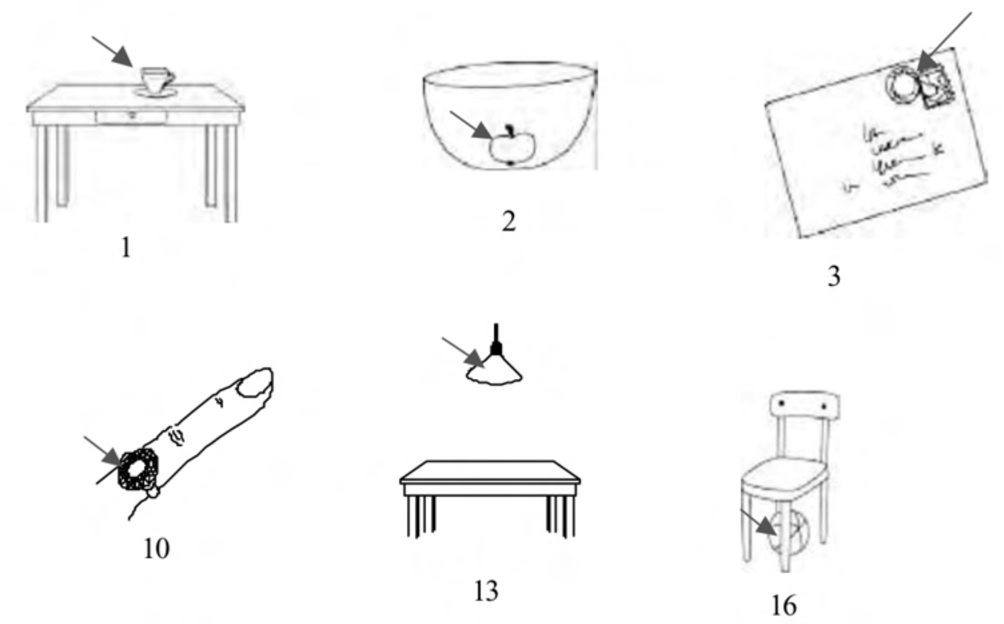



Figure 2.16: Topological Relations Picture Series (Original work: Bowerman & Pederson (1992) this figure is taken from the edited 1993 version from Max Planck Institute for Psycholinguistics)

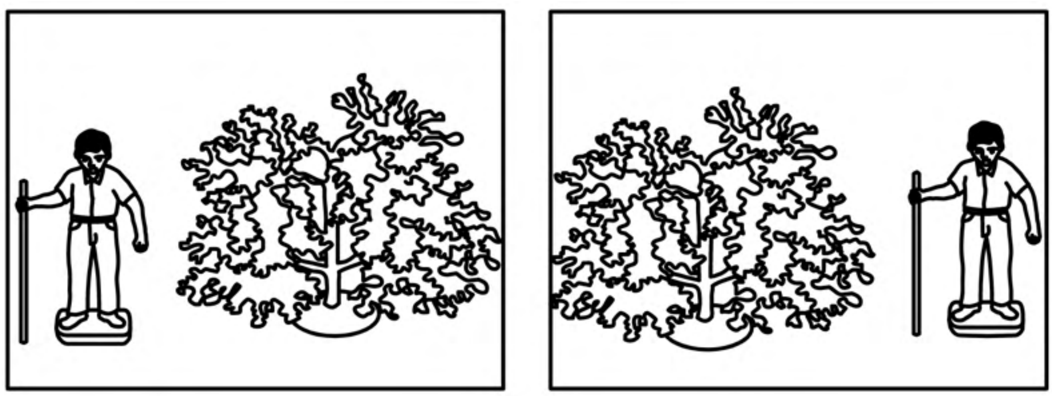


Figure 2.17: Man and Tree Task, from the Semantic Typology and Spatial Conceptualization study Pederson et al. (1998)

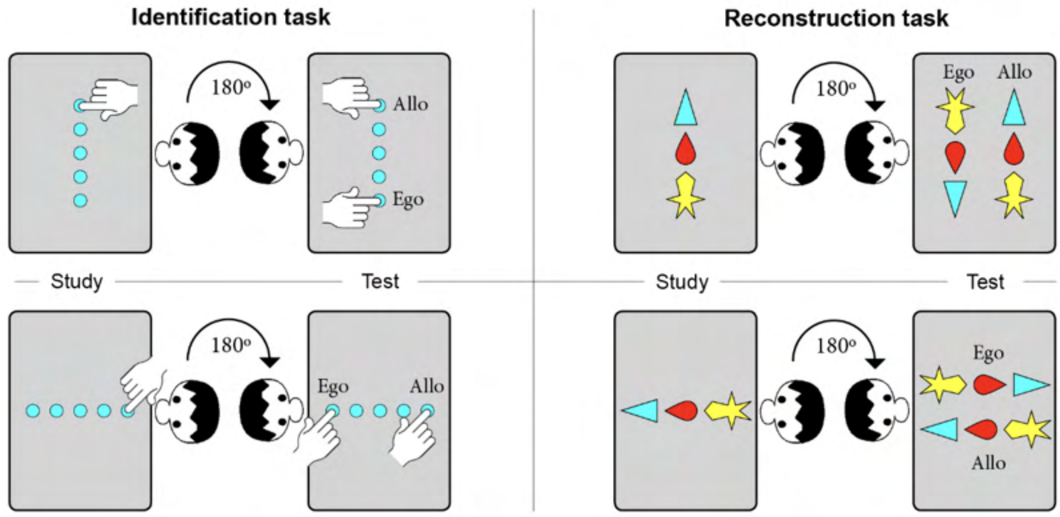



Figure 2.18: Edited version by Pitt et al. (2021) of original Chips Task Levinson (2003)

These are the linguistics tasks. Researchers created non-verbal tasks to test for spatial FoRs focused on spatial arrangement and these are identification tasks and reconstruction tasks: In the identification task or "chips task" participants see five objects on the table on different axes, in each trial researcher touch a specific object and participants turn 180 degrees and show the "same" position in the first arrangement (Levinson & Wilkins, 2006). In the reconstruction task, participants see objects in an arrangement on different axes and after turning 180 degrees reconstruct the "same" first array they saw (Pederson et al., 1998).

Frog Story (Mayer et al., 1969) is a wordless children's picture-book is used for measuring the narrative skills of Western children then used for motion-related spatial cross-linguistic studies to measure manner and path expressions (Levinson & Wilkins, 2006; Wilkins, 1997). However, the images measuring motion-related spatial relationships consist of 4 static drawings in the Frog Story setup.

There are also two designs focusing on verbs to measure motion semantics in languages: "Come  Go Questionnaire" (Wilkins & Hill, 1995)) and "EnterExit film" designed by Kita to measure the change of state vs. motion can be distinguished from each other. (Kita, 1999) (see Figure 2.20).

Non-linguistic tasks, which mainly focus on the relationship between spatial cognitive styles and spatial language, are predominantly on the axis of memory and recall. The majority of these tasks were prepared or adapted by Max Plank Institute researchers and tested in cross-linguistic studies. These tasks are *Animals in a Row* (Recall Memory), *Red and Blue Chips* (Recognition Memory), *Eric's Maze* (Motion to path transformation, recognition), *Steve's Maze* (Path Completion and Recognition), *Transitivity* (Memory) (Levinson, 2003).

Besides the empirical methods, Carlson and Hill classify the methods used in spatial language and spatial thinking studies into five main headings according to the method and what they measure: *Acceptability Rating, Speeded Verification, Placement Tasks, Parsing the Space Tasks,* and *Production Tasks* (Carlson & Hill, 2007). In *acceptability rating* tasks, participants

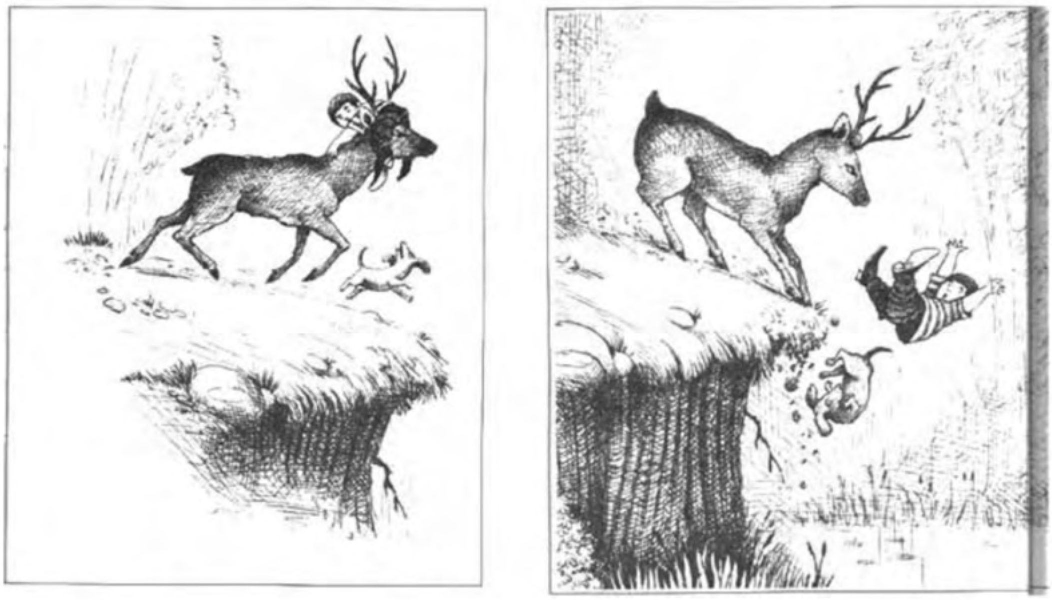


Figure 2.19: Edited version by Levinson & Wilkins (2006) of original Frog Story (Berman & Slobin, 2013)

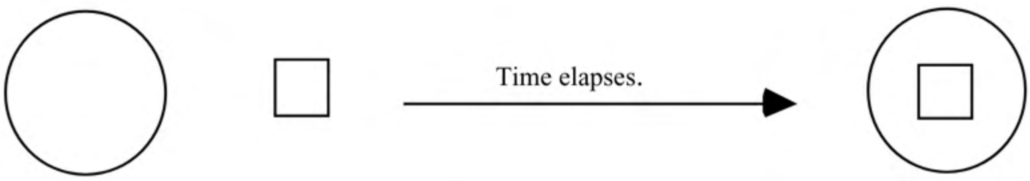



Figure 2.20: Enter&Exit Task by Kita (1999) from Levinson & Wilkins (2006)

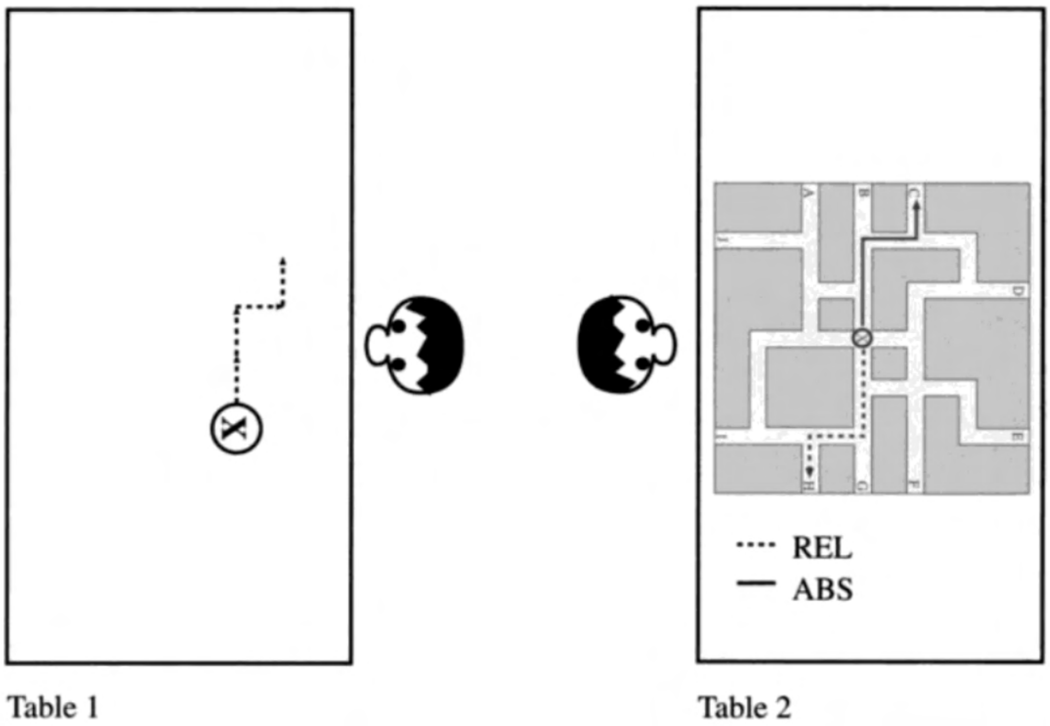



Figure 2.21: Maze Recognition Task for identifying “absolute” vs. “relative” FoRs in testing language (Levinson, 2003)

see objects arranged in a specific spatial configuration along with related sentences and score the congruence of these sentences with the arranged objects on a scale. (i.e. Hayward & Tarr (1995)) In *speeded verification* tasks participants see objects arranged in a specific spatial configuration along with related sentences again but this time they are expected to respond quickly, whether sentences are right or wrong, response time and accuracy are measured. In *placement* tasks, participants are given spatial instructions regarding the objects or pictures and are expected to position the objects or pictures according to the spatial instruction. In *parsing the space* tasks, participants are expected to zone the space around a target object and define spatial boundaries. In *production* tasks, participants are shown object arrangements and are expected to produce spatial descriptions accordingly. They can be expected to choose from a predetermined set of spatial terms or define entirely freely. (Carlson & Hill, 2007). In this thesis, the *production* task and the *speed verification* task are used as methods to understand whether the movement of the objects on the vertical or horizontal axis has an effect on the spatial language use of native Turkish speakers focused on *paths* without focusing on directly verbs.

## 2.3 Studies on Turkish

Recently, studies within the scope of spatial language in Turkish are limited. A developmental examination of spatial concepts in Turkish, crosslinguistic studies, studies on static spatial terms, and studies on dynamic spatial terms are the studies in the last fifty years. Spatial concepts were mainly examined in gestures and Turkish sign language studies in the past twenty years.

The first studies in which spatial concepts in Turkish are examined as crosslinguistic are those with children. Turkish is a verb-framed language and adpositions are postpositions, Turkish is an agglutinative language and lots of suffixes are used to construct spatial relations as well. Spatial expressions are roughly divided into two according to static spatial relationships and dynamic spatial relationships (Levinson, 2003; Levinson & Wilkins, 2006).

The static spatial relationships in Turkish can be broadly classified into two major types:

**First type:** applied with spatial nominals following the noun referring to the ground object

tabure-nin üst-ün-de

*stool-GEN top-POSS.3SG-LOC*

on the stool

**Second type:** with a locative case suffix (-de) on the noun referring to the ground object

tabure-de

*stool-LOC*

on the stool (a slightly weaker "on" spatial relationship than the first)

An early study in the field was Johnston & Slobin (1979) comparing the developmental order of locative expressions in English, Italian, Serbo-Croatian and Turkish with children aged 2.0 and 4.8. In this study, Johnston and Slobin argue that spatial terms are acquired developmentally as follows: The first group: in, on, under, beside; second group: between, back, front (for featured objects); third group: back, front (non-featured objects). Slobin argues that it makes a difference whether the language has a prepositional or postpositional from the comparison of developmental spatial terms and argues that since Turkish is a language with a postpositional structure, spatial concepts are easier to acquire than the other three languages (Johnston & Slobin, 1979). Accordingly, the acquisition order of spatial terms for Turkish is similar to other languages and is as follows: 1. içinde (in), 2. üstünde (on), 3. altında (under), 4. yanında (beside), 5. arkasında (back), 6. önünde (front), 7. arasında (between), 8. arkasında-relative (back) 9. önünde-relative (back). It has been reported that spatial concept diversity is less in Turkish than in other languages. "yanında" is the only term while English has beside, next to, near, and close to for the same locative situation (Johnston & Slobin, 1979). In this first study, Turkish was compared and analyzed due to its postpositional structure. Another feature of Turkish is that it has a verb-frame structure; therefore, in another study, including satellite-frame other languages, it was found that containment-related spatial terms are used in scenes occlusion and cover relations, as they are used in other languages Johanson & Papafragou (2014). Both of these studies focused on static spatial terms (topological relations) and used frequency as a measure. Ertekin's study in Turkish shows how static scenes are diversified in topological terms with the production task and eye-tracking experiment, and there is also Atak and Uzun's study shows how the use of FoRs is distributed with production task and frequency analysis (Ertekin, 2021; Atak & Uzun, 2019).

The dynamic spatial relationships in Turkish:

*PATH is typically encoded in the main verb and MANNER is expressed by a gerund or an adverbial form (example taken from (Toplu, 2011)):*

Adam **koşarak** merdivenlerden **indi.**

*manner adv. V motion+path*

*The man descended from the stairs (by) running.*

However, the verbs in Turkish may not encapsulate PATH information as in the example above. It also contains actions that encode only Manner, and Manner+Path in the form of binary phrases. For dynamic spatial scenes, the motion PATH is encoded more than the motion MANNER in Turkish Arik (2017).

Motion verb examples from Arik:

(1) MANNER encoded Motion Verbs: yürü- (walking), tırman- (climbing)

(2) PATH encoded Motion Verbs: çık- (exit), yaklaş- (coming closer)

(3) MANNER + PATH: yuvarlanarak düş- (falling by rolling) (Arik, 2017)

Arik observed that the participants, who looked at the photographs of stationary objects, described the scenes in Turkish with dynamic spatial terms (Arik, 2009, 2017). One of the most striking results for Turkish is that the words indicating trajectory direction are used rather than static localization terms while participants are explaining static spatial scenes (Arik, 2017). It has been found that Turkish speakers encode the PATH of objects rather than their static / location in the coding of static and dynamic events or in single macro-actions containing only MANNER according to the data consisting of a total of 680 narrations from 20 participants, Arik argues that this differentiation in Turkish is probably context-based, not cognitive-based (Arik, 2017).

Due to the Verb-framed structure of Turkish, MANNER and PATH have been compared with English in Ozyurek Kita's study; whether there are differences in speech, gesture, and conceptualization has been examined. Turkish and English speakers narrated a one-motion event animation and their gestures are recorded. Gesture analysis shows that typologically different languages have a tendency to show different gestures while describing dynamical events (Özyürek, 1999).

In another study on dynamic events and spatial concepts in Turkish, Verb-framed Turkish-French and Satellite-Frame English were compared in both linguistic and non-linguistic tasks, and they found that all three languages were in common in terms of conceptual event pattern, and Toplu found a result supporting the universal approach to the concept of linguistic relativity (Toplu, 2011).

In both Arik's and Toplu's spatial dynamic studies, participants described the scenes with the usage of the dative case marker (-A) with spatial terms (sol-a / sağ-a) or the usage of the phrase (-a doğru) with spatial terms (aşağıya doğru / sola doğru) is a subject that is mentioned but not detailed with its contribution to PATH information (Arik, 2017; Toplu, 2011).

Other spatial studies for Turkish focus on spatial terms in Turkish Sign Language: Previous studies reported that deaf children acquire spatial expressions much later than hearing children; however, Sümer et al. (2016)'s analysis that focuses on the static spatial terms of in, on, and under say the opposite; there is no difference in children's acquisition of spatial expressions using Turkish sign language and children speaking Turkish at the same age (Sümer et al., 2016). The study also reported that the usage of the locative case suffix (-da) on the noun referring to the ground object did not occur at all compared to spatial nominals following the noun referring to the ground object. Another important point mentioned in this study is to draw attention to the fact that spatial relations are expressed in different ways in static picture descriptions and video/picture narrations containing motion (Sümer et al., 2016). In Allen et al. (2007)'s crosslinguistic study, at very young age (mean 3,8) child speakers of Turkish (Verb-Frame), English (Satellite-Frame) and Japanese (Verb-Frame) watched the motion of animated tomoto like creature and generate motion-verb sentences. Study shows that children display language-spacific patterns and also some universal patterns together (Allen et al., 2007).

To sum up, Turkish is an agglutinative, verb-frame language and has a range of spatial terms enriched by the use of suffixes (Toplu, 2011). According to the developmental crosslinguistic studies examining spatial concepts in Turkish, the order of acquisition of spatial terms is the same as in other languages (Johnston & Slobin, 1979). Studies mainly focused on static spatial terms and the studies on dynamic spatial terms mainly focused on the verb-frame nature of Turkish (Arik, 2017; Toplu, 2011; Özyürek, 1999). Spatial terms were mainly examined in gestures and Turkish sign language studies to whether a difference between acquisition with the spoken language (Sümer et al., 2016). Studies focused on dynamic spatial relations in Turkish found that PATH information of the motion encoded more than the MANNER information of motion (Arik, 2017; Toplu, 2011). However, there is no study in the literature focusing on precisely how Turkish encodes PATH information with the contribution of suffixed spatial terms on spatial relations. This thesis focused on whether the movement of the objects on the vertical or horizontal axis has an effect on the spatial terms (specific topological and egocentric frame of reference terms) of native Turkish speakers. The effect on the direction of movement on the horizontal axis was also investigated and focused on its effect on the egocentric frame of reference terms in Turkish.

## 2.4 Summary

Spatial language studies scrutinize directly spatial cognition or the whether there is a relationship between the two. In the first part of Chapter 2, conceptual subdivisions and study methods are investigated in order to examine the relationship between spatial language and spatial cognition. Different researchers' approaches and definitions of spatial terms, "topological terms," and "frame of references", which are common to most studies, are examined. A separate chapter has been devoted to motion since the Turkish spatial language's path-framed structure and since this thesis examines the effect of motion axes on spatial language. A separate section is devoted to experimental methods and protocols created to study the spatial language, satial language studies for Turkish are also examined.

When the subject is the motion in space, there are studies on verb-focused and lexical structures of verbs. There is no study in the literature focusing on precisely how Turkish encodes PATH information with the contribution of suffixed spatial terms (these are "static" in Levinson & Wilkins (2006), topological terms like içine, altında etc. and reference frames sağında, soluna etc.) on spatial relations. However, for Turkish, it is very clear that spatial relations in dynamic scenes are not established only with verbs. How these terms are used and how they are used is worth studying. There is also no study for Turkish focusing on functional and dynamic relations on the axis of motion. It has not been studied before whether the axis of motion reveal any significant situation in Turkish spatial language.

This thesis focuses on whether the movement of the objects on the vertical or horizontal axis has an effect on the spatial terms (topological and egocentric frame of reference terms). The effect on the direction of movement on the horizontal axis was also investigated and focused on its effect on the egocentric frame of reference terms. In the next section, experiments and results based on research questions, hypotheses, and literature will be shared in detail.

# CHAPTER 3

# METHODOLOGY

## 3.1 Experiment

The aim of this experiment is to measure whether the movement of the objects on the vertical or horizontal axis has an effect on the spatial language use of native Turkish speakers when they are stationary observers. Secondly, it was investigated whether the direction of movement in the horizontal axis has an effect. Although the idea of the experiment was originally designed in a laboratory environment, it was decided that it would be safer to conduct the experiment online due to the logistical problems caused by the difficult Covid19 pandemic conditions. For this, three online experiment tools were examined, and finally, the online experiment was built using Gorilla Experiment Designer.

Participants attended the experiment with their own desktop or laptop computers. The videos, consisting of 3 seconds segments, were centered by the test tool according to the dimensions of the individual screens. After the design of the experiment was completed, the intended 51 participants were reached within 3 weeks. In the experiment, the response times (RT) of the participants to the true and false sentences shown with the relevant dynamic scenes and the accuracy of their answers were measured. Accuracy and response times were recorded, and raw data was created and analyzed in the following process.

A pre-experiment was prepared with four completely different participants than the main experiment. The language task method, one of the tasks in Hayward & Tarr (1995) study in which spatial terms in English were measured with two linguistic and non-linguistic experiments, was applied by changing. In the original method, Hayward & Tarr (1995) showed a static image with the figure and reference and questioned where the figure was in relation to the reference with the sentences "fill in the blank." The same method was used in both instant and memory tasks (Hayward & Tarr, 1995). In our pre-experiment, the participants were asked to describe the scenes by watching the stimulus to be used in the main experiment verbally, not in writing. And they were also expected to narrate simultaneously while watching, not as a memory task. Their voices were recorded. Patterns that are common in their descriptions of the scenes have been identified. These descriptions were arranged, and the opposite meanings and incorrect versions of the correct sentences were also created. 24 sentences were determined to be used in the main experiment as correct and incorrect sentences according to scenes.

The distribution of sentences is as follows: six sentences in egocentric reference frames and correct sentences, six sentences are topological descriptions and correct sentences; six sentences are in egocentric reference frames and incorrect sentences, six sentences are topological descriptions and incorrect sentences according to the movement of the two-dimensional geometrical shapes in the stimuli. (See Figure 6.2 For the example sentences from experiment)

In the main experiment, sections of three seconds of a classical video drawn and animated by Heider and Simmel in the 1940s as stop-motion were used as stimuli (Heider & Simmel, 1944). However, the video used as a stimulant was not used in its original form, black and white, but with the Shu et. al version, because the colored shapes made it easier for the participants to refer to which shape (Shu et al., 2018). At the same time, the movement trajectories of geometric shapes were also examined in the aforementioned study, based on the data here, the stimuli were prepared by cutting the parts where the movements in the x (horizontal) and y (vertical) axes are clear.

With the same experiment setup, the effect of the direction of motion on horizontal axes is also investigated. In the experiment, the occurrence of the movement in the horizontal or vertical axis, whether the frame of reference sentence or the topological sentence is shown together with the video, whether the sentence is a correct or incorrect, and if the movement is in the horizontal axis, whether there is a movement from left to right or right to left was defined. The response time was recorded in the light of these groupings. Experiment details will be examined in the next section.

## 3.2 Participants and Experiment Design

Fifty-one adult native Turkish speakers participated in the experiment. The vast majority of the experiment participants were reached through the mail group of the METU Informatics Institute. The experiment follows a repeated measures (within-subjects) design, so the same subject participates in all the conditions.

After obtaining the permission of the METU Human Subjects Ethics Committee, the consent form was obtained from the participants while starting the online experiment. Firstly the aim of the experiment is explained briefly then the participants see the instructions page. (See Appendix: 6.1).

Participants were expected to quickly respond by pressing the True or False assigned keys on their keyboard to the correct or incorrectness of the Turkish sentences that came simultaneously with the short videos playing on the screen. 2 participants contacted via e-mail and reported that their experiments were stuck due to a network-related problem. During the analysis phase, outliers were detected in the data of these participants, and those dirty data were not included in the analysis.

### 3.2.1 Demographic Information of Participants

Fifty-one adult native Turkish speakers participated in the experiment. The demographic data collected anonymously from the participants at the beginning of the experiment with a questionnaire were analyzed:

The age distribution is as follows: 21 is the minimum age and 61 is the maximum age, ($M$ =

29.39, *SD* = 6.33).

The gender distribution is as follows: 23 females, 25 males, two “do not want to specify”, and one "other".

When the participants were asked about languages other than their native (Turkish), they answered 100% (N=51) as English as their second language. English was followed by Japanese (N=5), German (N=4), French (N=3), and Russian (N=3), respectively. As third languages, Italian, Spanish, Arabic, and Bulgarian responses were given once. All participants answered their native language as Turkish and all of them answered their “learned” second language as English, there is no bi-linguality case.

Response times analysis was not required according to the gender and age information of the participants. The demographic survey was included to check for bilingualism in the participants and if there was a significant accumulation by age or gender. The numbers were balanced and since there was no bilingual participant, the analysis was continued in a natural flow.

## 3.3 Experiment Design

The experiment was designed to observe the effect of vertical and horizontal axial movement on the spatial language and to find out whether the direction in the horizontal axial movement makes a significant difference in the perception time cloud base research platform “Gorilla Experiment Builder” is used and behavioral data (Response Times) are measured.

Participants watch short videos in which geometric shapes move. Under the videos, correct and incorrect egocentric frame of reference and topological sentences about the movements of the figures are shown. If the sentence that is read is correct, expected to press the L key, and if D is incorrect. It has been reported that the expectation from participants is to respond as quickly as possible. There are 24 sentences and five short videos in total.

Sentences by spatial language groups are in four:

Topological True, Topological False

Egocentric Frame of Reference True, Egocentric Frame of Reference False

Sentences by motion axes groups are in two:

The vertical axis of motion of geometric shapes in the video

The horizontal axis of motion of geometric shapes in the video

At the beginning of the experiment, the first static “fixation cross” in the middle of the screen is shown in 400 milliseconds, and there is a waiting period of 100 milliseconds before and after. Then the screen, followed by a two-three second video, comes with the sentence that is expected to be marked as true or false. After the participant indicates true or false with the keys assigned on the keyboard, the simple static fixation point again a “+”, appears for 250 milliseconds, and there is a blank screen wait of 100 milliseconds in front of and behind the plus. The purpose of the fixation point is to provide the right area of view on the screen and

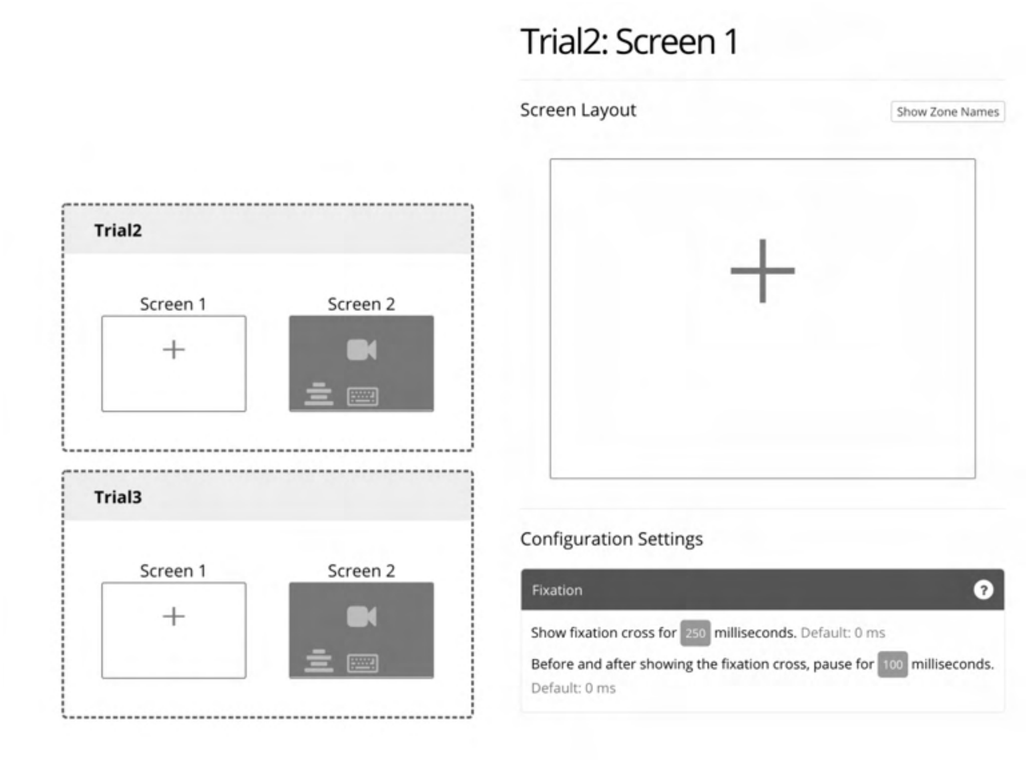



Figure 3.1: Screen1 stable fixation point

to ensure that the participants' concentration continues.

Screens with fixation points and then videos in the tasks were designed one after the other for each trial.

The design of the experiment consists of a start and final information screen, a screen with instructions and permissions, a single page survey where demographic information is collected, a fixation point screen as explained in detail above, and then the relevant spatial sentence written under the geometric shapes videos in total five tasks and 24 trials.

## 3.4 Analysis Procedure

Hayward & Tarr (1995) follows a two steps experiment design, first: generate the spatial language, and second rate the applicability of spatial terms to the spatial relations of objects. The same method was followed with modification. Production and speeded verification tasks are used as methods (Carlson & Hill, 2007).

First: Generating Spatial Language / Production Task

In this short experiment, audio recordings collected from four participants, in which they describe the movement of geometric shapes in videos, were listened to. The focus was on repetitive sentences for the 5 video segments. It was determined that they used natural and predominantly egocentric reference frames and topological sentences. This is the equivalent

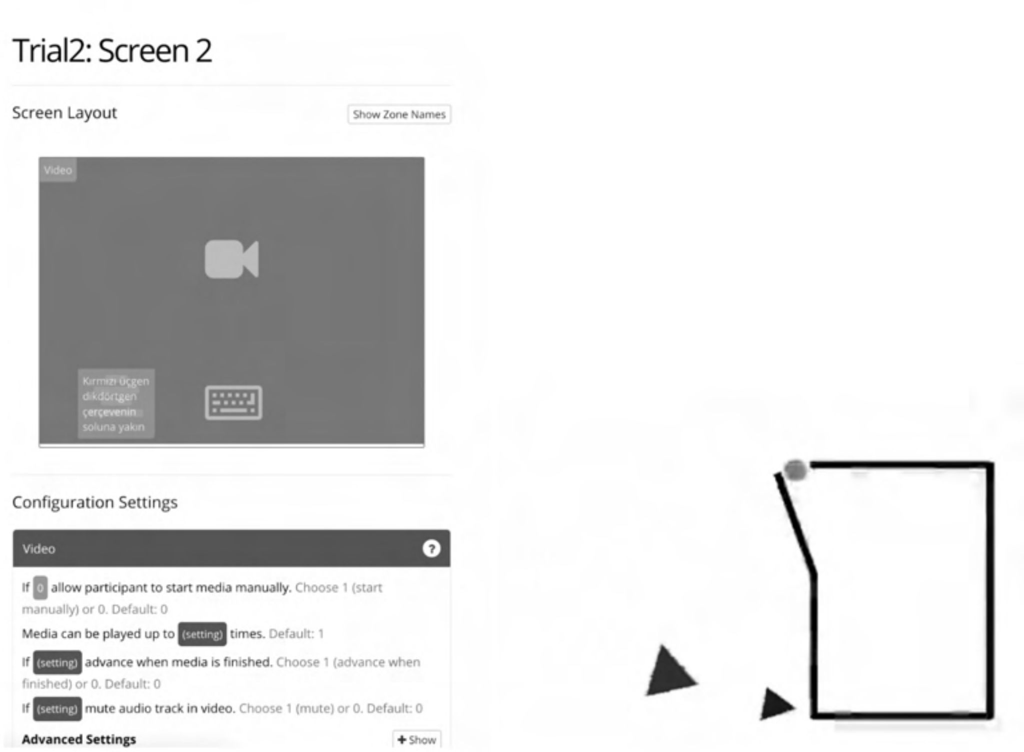



Figure 3.2: Screen2 sample screenshot from the video used in the experiment

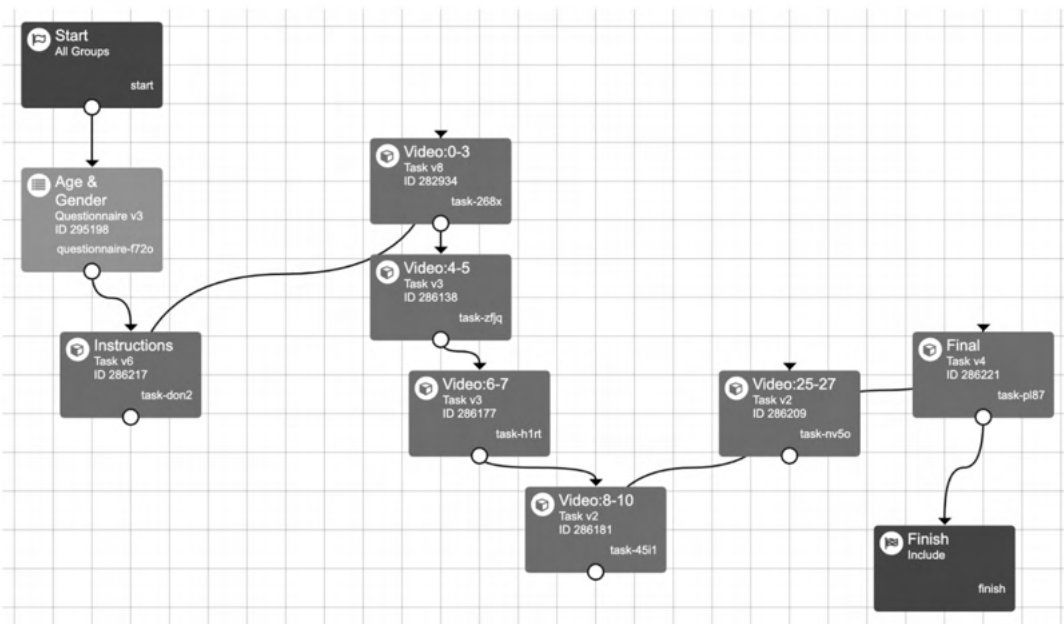



Figure 3.3: Schematic representation of the experiment design

in the literature, and the noticed point is compatible with the literature. (Egocentric reference frame usage is also mostly frequent in Turkish according to Atak & Uzun (2019)'s study. Already, two types of spatial language (perspective base / angular: frame of reference and non-perspective base / not-angular: topological) were wanted to be compared. Since the dominant use is egocentric reference frame and topological uses, it was decided to compare these two types.

Experiment data is labeled according to whether it contains a frame or topological sentence, movement on the vertical axis, or movement on the horizontal axis. The data were grouped by taking the averages for the video groups in which each sentence and movement was watched. Data were classified into four groups (FrameHorizontal, FrameVertical, TopologicalHorizontal, TopologicalVertical) for each participant. Two participants were contacted via email and reported that they were stuck in the experiment due to the online test tool and network-related problems. When the data of these participants were evaluated with all other participants, it was determined as outliers in two groups and the analysis was continued by clearing these three data points.

Data is labeled according to whether it contains a movement on the vertical axis or movement on the horizontal axis, also labeled for the direction of the movement. "Horizontal+" represents a movement from left to right, and "Horizontal-" represents a movement from right to left, "HorizontalMixed" represents the movement of the geometric objects opposing from left to right and from right to left. Data were classified into four groups as (FrameVerticalLeft, FrameHorizontal+, FrameHorizontal-, FrameHorizontalMixed) for each participant. Non-accurate answers that incorrectly marked the sentence that should be true or vice versa, were eliminated, and only the results that marked correct sentences as true and incorrect sentences as false were evaluated. The network and experiment tool-related problematic data of two participants who were marked as outliers in the first analysis were excluded because they were observed as outliers in this analysis as well.

# CHAPTER 4

# ANALYSIS AND RESULTS

To answer the question "Does vertical and horizontal axial movement affect spatial language in particular topological sentences and egocentric frame of reference sentences, and how does it?" an experiment was designed in which 51 native Turkish speaker subjects participated, which they quickly answered as true or false to the correct and incorrect sentences in the predefined categories, and their response times were recorded and analyzed.

A repeated-measures ANOVA was conducted to determine whether there were statistically significant differences in response times (RT) between perspective (egocentric frame of reference) and non-perspective (topological) spatial language with the horizontal (x) and vertical (y) axes-based movement in dynamic scenes. Four groups were compared: egocentric reference frame sentences when motion on the x-axis, egocentric reference frame sentences when motion on the y-axis, topological sentences when motion on the x-axis, and topological sentences when motion on the y-axis. There were three outliers and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test (ps = .097, .318, .357, .749), respectively. The assumption of sphericity was violated, as assessed by Mauchly's Test of Sphericity, $p < .001$. Therefore, a Greenhouse-Geisser correction was applied ( = 0.671).

The effect of motion axes on spatial language sentences response times was found to be statistically significant, $F(2.01, 94.56) = 8.12$, $p < .001$, 2 = .147, with the longest response time for when the movement on the horizontal axis (x) while using topological sentences (M = 4971.80 ms, SD = 1349.21 ms ) and the shortest response time for when the movement on the horizontal axis (x) while using the egocentric frame of reference sentences (M = 4049.46 ms, SD = 1130.36 ms). On the vertical axis movement, the response times are respectively, (M = 4290.24 ms, SD = 950.36 ms) for the topological sentences, and (M = 4495.71 ms, SD = 982.61 ms) for the egocentric reference frame sentences.

Post-hoc analysis with a Bonferroni adjustment revealed that when the movement on horizontal axis response times for the topological sentences and egocentric frame of reference sentences statistically significantly differs (M = 922.33 ms, $p < .001$, d = 0.82), and response times for the topological sentences statistically differs for the movement of horizontal and vertical axes (M = 681.56 ms, $p < .005$, d = 1.87) but there is no statistically difference between the frame horizontal vs. frame vertical case (M = 446.24 ms, $p > .005$, d = 0.40), frame horizontal vs. topological vertical case (M = 240.77 ms, $p > .005$, d = 0.21), frame vertical vs. topological horizontal case (M = 476.09 ms, $p > .005$, d = 0.43), and frame vertical vs. topological vertical case (M = 205.47 ms, $p > .005$, d = 0.18).

The results show that there is a statistically significant difference between spatial language

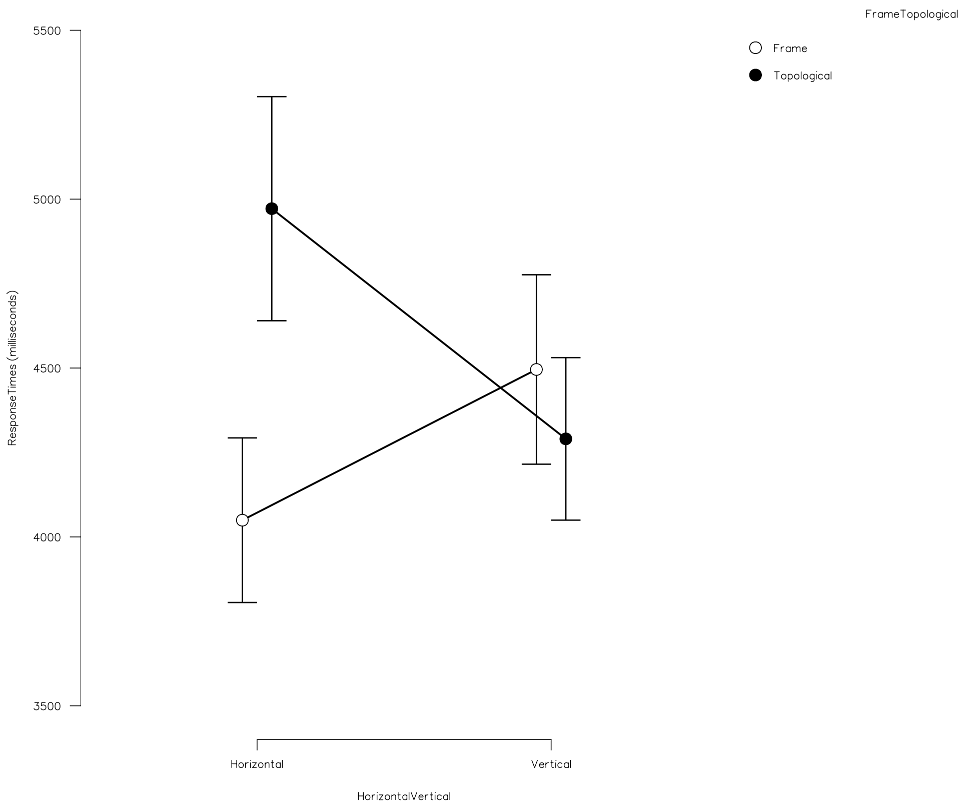



Figure 4.1: Interaction Effect

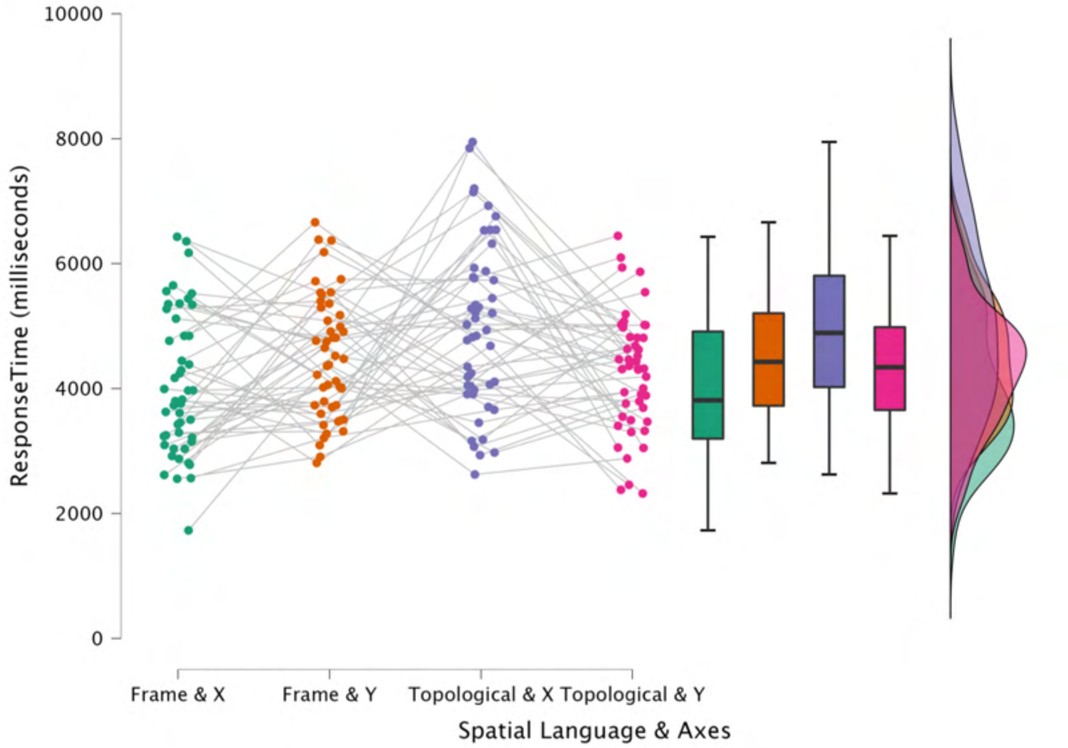



Figure 4.2: Spatial Language and Axes Relationship

categories (topological and frame of reference) and the motion axes (horizontal and vertical). Specifically, when the motion on the horizontal axis (x), response time statistically significantly differs between the egocentric frame of reference sentences and the topological sentences. While watching a movement on the horizontal axis, the response time the participants gave to an egocentric reference frame sentence is shorter than the response time given to a topological sentence. No significant difference is observed in the movement in the vertical axis in two different spatial language sentence categories.

However, in the topological language category, surprisingly, the horizontal or vertical movement made a statistical difference in the response time given to the sentences. While the response time is shorter in the vertical axis movement, the response time is longer in the horizontal axis movement. However, the movement in the horizontal or vertical axis in the egocentric reference frame sentences did not cause a significant response time difference.

When evaluated overall, the response time given to topological sentences is higher than the response time given to egocentric reference frame sentences. Moreover, the response time of sentences when the movement on the horizontal axis is longer, while the response time of sentences when the movement on the vertical axis is shorter based on the means above. Chapter 5, Discussions will discuss possible reasons for these results in detail.

## 4.1 The Role of Direction: From Left to Right vs. From Right to Left

The following question was also investigated with the same experimental design and the data: Can a significant difference be observed in the response times given to the true and false Turkish egocentric frame of reference sentences when a movement from left to right (horizontal+) or right to left (horizontal-)?

A repeated-measures ANOVA was conducted to determine whether there were statistically significant differences in response times (RT) between the direction of the movement. Four groups were compared: egocentric reference frame sentences when motion on the y-axis and at the left side of the screen, egocentric reference frame sentences when motion on the x-axis and from left to right (horizontal+), egocentric reference frame sentences when motion on the x-axis and from right to left (horizontal-), egocentric reference frame sentences when motion on the x-axis and the motion direction of the geometrical shapes in a combination, one triangle moves from left to right and the other moves from right to left at the same time. There were four outliers, and the data was normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test (*p*s = .166, .525, .066, .485), respectively. Variances of the differences between all combinations of related groups are equal, as assessed by Mauchly's Test of Sphericity, $p = .082$.

The effect of the direction of movement on the specifically horizontal axis for the egocentric frame of reference sentences response times was found to be statistically significant, $F(3, 93) = 5.88$, $p = .001$, $2 = .159$, with the longest response time for when motion on the x-axis and from right to left (horizontal-) (M = 4785.08 ms, SD = 2205.18 ms ) and the shortest response time for when motion on the x-axis and from left to right (horizontal+) (M = 2925.31 ms, SD = 1002.53 ms). When motion on the y-axis and at the left side of the screen (M = 3915.84 ms, SD = 1986.16 ms), and (M = 4229.55 ms, SD = 1744.68 ms) for the egocentric reference frame sentences.

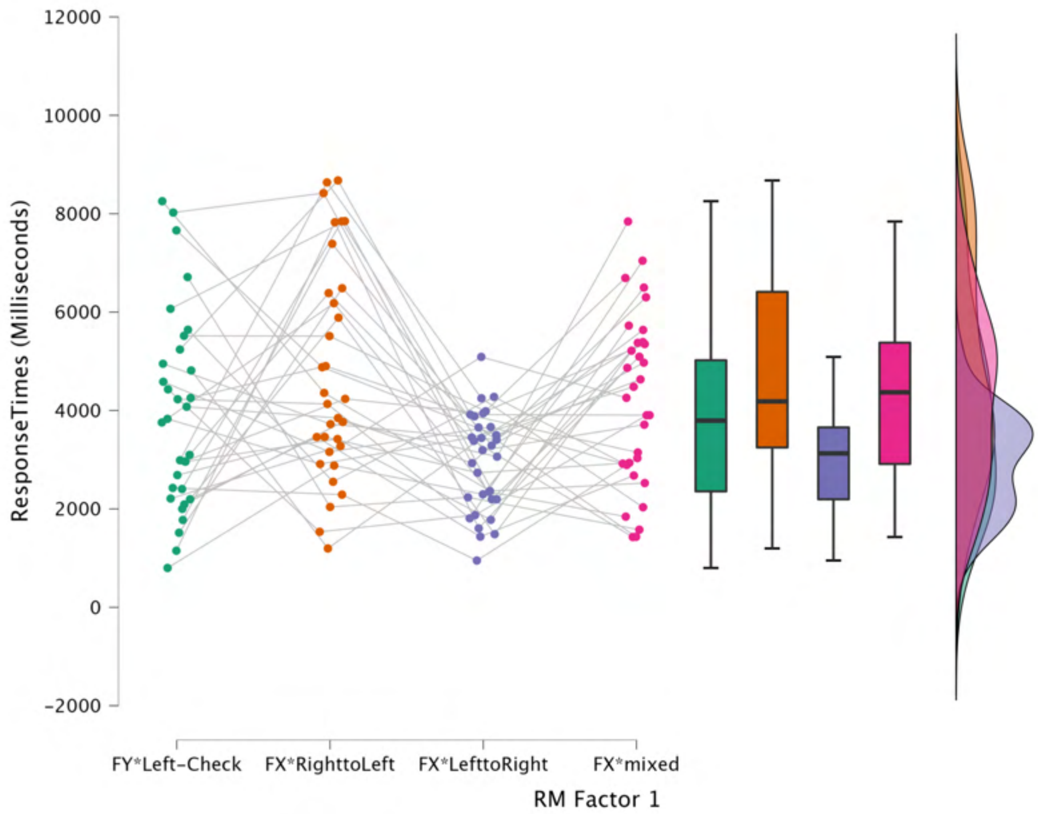



Figure 4.3: When the movement direction of geometrical objects is from left to right, response times are the shortest

*Post-hoc* analysis with a Bonferroni adjustment revealed that the direction of movement matters, so response times for frame of reference sentences when the direction is from left to right or from right to left statistically significantly differ ($M$ = 1859.77 ms, $p < .001$, $d$ = 1.04), and response times for the mixed direction and from left to right also statistically differ ($M$ = 1304.24 ms, $p < .005$, $d$ = 0.74) but there is no statistically difference between when motion on the y-axis and at the left side of the screen vs. direction of the motion from right to left ($M$ = 869.24 ms, $p > .005$, $d$ = 0.48), when motion on the y-axis and at the left side of the screen vs. direction of the motion from left to right ($M$ = 990.53 ms, $p > .005$, $d$ = 0.55), when motion on the y-axis and at the left side of the screen vs. direction of the motion is mixed ($M$ = 313.71 ms, $p > .005$, $d$ = 0.17), and direction of the motion is from right to left vs. direction is mixed case ($M$ = 555.53 ms, $p > .005$, $d$ = 0.31).

In summary, first experiment shows that there was a significant difference between the two types of spatial language sentences and the motion axes: specifically when motion is on the horizontal axis (x). The second research question investigates the role of the direction of horizontal motion in egocentric FoR sentences, and analysis shows that the direction also creates a statistically significant difference in RTs. When the movement direction of geometrical objects is from left to right, response times are the shortest, and from right to left are the longest. Possible reasons for these results will interpret in the next discussion chapter.

# CHAPTER 5

# DISCUSSION & CONCLUSION

This chapter provides conclusions and further discussions based on experimental findings. This thesis focuses on the spatial language and axis relationship in Turkish with the aim of finding out how the layout of the space/dynamic scene affects language in order to understand how the underlying mechanism works while choosing a spatial concept. There are three main research questions:

1. Do axes of motion affect spatial language?
2. How do axes of motion affect Turkish spatial language? (topological terms and egocentric frame of references with motion on horizontal and vertical axes)
3. Does the direction of the movement (from left to right or from right to left) make a difference for the egocentric reference frame sentences?

By examining the literature within the framework of these questions, hypotheses were formed as follows:

- Spatial language can be affected by axes of motion.

This hypothesis is based on the studies of Hayward & Tarr (1995) and Landau (2017). Although these studies are carried out with static scenes, they are the studies that show horizontal and vertical axes have priority in spatial language compared to other axes. At this point, Levinson & Wilkins (2006) static and kinesis division in the spatial language as a study method in literature remains narrow for examining languages, because it focuses verb structure for the kinesis situations and examine angular (frame of references) and non-angular (topological) spatial relations just in static cases (Levinson & Wilkins, 2006). It is clear that more comprehensive studies and models are needed to examine spatial language in both static and dynamic scenes.

- Horizontal or vertical movement makes a difference in the spatial language.

Examining the topological and reference frame spatial terms, which have always been studied as "static" terms, in the context of dynamic scenes with axes can set up an interesting discussion ground since it is still a mystery in the literature on how exactly the geometric and extra-geometric (functional - dynamic) spatial term classifications will be separated. The results of the experiment shows that there is a statistically significant difference between spatial language categories (topological and frame of reference) and the motion axes (horizontal and vertical). Response time statistically significantly differs between the egocentric frame of reference sentences and the topological sentences when the motion on the horizontal axis (x). The response time of participants gave to an egocentric reference frame sentence is shorter than the response time given to a topological sentence when the movement on the horizontal axis. No significant difference is observed in the movement on the vertical axis in two different spatial language sentence categories for Turkish.

- It is essential on which axis the movement takes place also for topological descriptions, not just for reference frames.

In many studies pioneered by Levinson, topological terms are defined as terms whose boundaries are determined by geometric concepts (such as concavity and convexity or the boundaries of objects), independent of the angle of the figure and ground or the perspective of the speaker. This pre-definition actually caused such terms to be examined firstly by experiments independent of "movement" and then independent of axes. When it comes to axes, frame of references based on angle and perspective have been studied mainly. This is the geometric approach to spatial language. However a spatial relation can change according to context or interaction so do not depend on geometrical features or geometrical relations only. (Vandeloise, 1991; K. Coventry & Garrod, 2005; Landau, 2020). At this point, it is expected that the axes will have an effect on topological terms, because they are important for interaction and also provide a context.

According to experiment results, the horizontal or vertical movement made a statistical difference in the response time given to the sentences in the topological language category. While the response time is shorter in the vertical axis movement, the response time is longer in the horizontal axis movement. In this case, we actually perceive the word "in" faster when it's the result of a top-down / vertical movement than when it is the result of a horizontal movement. However, the movement in the horizontal or vertical axis in the egocentric reference frame sentences did not cause a significant response time difference.

- While the figure moves on the horizontal axis, the response time given to the "topological descriptions" should be shorter than the "egocentric reference frame". (refuted - in the opposite way)

This hypothesis is inspired by the peculiar nature of “left-right” (Pitt et al., 2021). In their study, Pitt argues that people are really bad at distinguishing left and right linguistically and perceptually. The possible reasons are listed as follows: bilateral symmetry of the brain Corballis (2018) and symmetrical-only nature across the horizontal axis of the human body (Clark, 1973). While this was the case, we expected the response time given to egocentric reference frame sentences containing left and right describing a movement on the horizontal axis to be longer than sentences containing topological terms. However, on the contrary, the response time to these sentences were shorter than topological sentences. This situation actually makes us think that the response time may have been prolonged due to the involvement of the object recognition system in the spatial interpretation of topological terms Landau (2003).

This argument also leads us to stay closer to the studies on the extra-geometric properties of spatial terms, interaction with objects, function and context (Vandeloise, 1991; K. Coventry & Garrod, 2005; Landau, 2020).

- Direction matters in horizontal axes based on egocentric reference frame sentences, and from left to right should have less response time than from right to left.

Axis and direction are the two key parameters of location. In her study, Landau (2003), argued that direction is represented separately from the axes, called the right direction: horizontal+ and provides evidence in experiments that participants were more successful in the right (relative to horizontal- / left) in both linguistic and non-linguistic tasks. In our study, the response times were shorter in videos and sentences containing "left-to-right" movement than in "right-to-left"; participants are faster at perceiving the left-to-right direction or processing it spatially or linguistically interpreting it. There may be many reasons for this, and the reason is open to speculation: perhaps the direction of reading in Turkish is one of them.

As another important point, it is suggested to include the number of words in the sentences in the analysis and add the covariance analysis. When compared by taking the averages of word-count of the sentences written for the experiment: FrameHorizontal = 7.2 words; FrameVertical = 6.0 words; TopologicalHorizontal = 7.5 words and TopologicalVertical = 6.5 words. The number of words in the sentences is distributed as balanced as possible. So, the variance in covariance (word-count) is equal to 0 after grouping on independent variables.

In summary, spatial language and axis relationship in Turkish with the aim of finding out how the vertical or horizontal motion axes affects language studied in detail with response times. Three research questions and five hypotheses were examined in detail. However, as in every scientific study, there are limitations in this scientific study and these limitations are guiding future studies. These limitations will be discussed in the next section.

## 5.1 Limitations and Future Work

Research activity at intersection between language and space focus on spatial arrangements and their linguistic mapping (Carlson & Hill, 2007). This study is a behavioral based experimental study and production and speeded sentence verification tasks are used as methods. These methods have advantages as well as disadvantages.

The critical design issue of experiment design of speeded sentence verification tasks is deciding to where to show sentences, simultaneously or sequentially. Because this is a situation that will directly affect the response time, in the design of this experiment, it was deemed appropriate to give the sentences with the video simultaneously from the beginning to the end.

Another point to be careful about in such experiments is the interpretation of the differences in response times. Carlson & Hill (2007) point out that changes in reaction time can also be caused by extraneous factors and provide examples such as difficulty in identifying objects, reading sentences, and lack of attention. For this reason, the movements of the simplest geometric objects in two dimensions were chosen for this experiment, and the data seen as outliers were cleaned. Sentence lengths and word count of the sentences have been tried to be almost the same after the production task, there is no serious difference between video lengths. For each test case, enough and very repetitive question-answer flows were prepared. For this reason, the within-subjects design method was preferred.

The most challenging and limiting point after this experiment is of course the point of generalization of findings. Although a detailed review of the literature has attempted to understand alternative reasons for providing or not providing hypotheses, if this thesis were being rewritten (and in a Covid-free world), it would be recommended as a combination of other experimental methods. The use of these test methods in combination with other indirect methods such as eye-tracking or ERP will provide more precise answers to understand what the underlying processes are during the understanding of a spatial sentence. In the initial idea stage of this thesis, it was planned to perform these experiments with an eye-tracker. Afterwards, the experimental method was rearranged due to the limitations. Another important point is the experimental setup. Although it seems like sentence verification at first, the scenes in the experiment come simultaneously with the sentences to avoid the memory effect. The results could be compared by working separately as sentence verification and picture verification versions.

This study supports the argument that differences between languages may be due to context or task rather than spatial cognition differences (Li & Gleitman, 2002). However, while measuring the effect of axes of motion on the spatial language in other languages, the suffixes that Turkish uses extensively when describing spatial situations and its path-framed and agglutinative nature should not be overlooked.If there is a difference in other languages, it will still be challenging to understand why this is because, as far as the literature shows, a unified model of how the interlingual spatial language issue should be studied has still not been established.

This means that there are many gaps open to study in this area where even the accepted spatial term naming is still not formed (most researchers explain exactly what they mean when they say frame of reference, whether they are axis, angle, direction, or vector) and shows the possibility of an exciting discovery point.

# CHAPTER 6

# APPENDIX

# Katılım Sonrası Bilgi Formu

Bu araştırma ODTÜ Bilişsel Bilimler Bölümü'nde yürütülen bir yüksek lisans tezi kapsamında, Türkçe'de uzamsal terimleri kullanma eğiliminin yatay ve düşey geometrik akslardaki hareketlerden etkilenip etkilenmediğini araştırmak üzere kurgulanmıştır. İzlemiş olduğunuz videolardaki geometrik şekiller bu akslarda hareket etmektedir ve doğru ya da yanlış olarak kurgulanan cümlelere verdiğiniz cevap süresi ile cevapların doğruluk değeri ölçülmektedir. Bu çalışmadan alınacak ilk verilerin Kasım 2021'de elde edilmesi amaçlanmaktadır. Elde edilen bilgiler sadece bilimsel araştırma ve yazılarda kullanılacaktır. Çalışmanın sağlıklı ilerleyebilmesi ve bulguların güvenilir olması için çalışmaya katılacağını bildiğiniz diğer kişilerle çalışma ile ilgili detaylı bilgi paylaşımında bulunmamanızı dileriz. Bu araştırmaya katıldığınız için tekrar çok teşekkür ederiz.

Araştırmanın sonuçlarını öğrenmek ya da daha fazla bilgi almak için:

Bilişsel Bilimler Yüksek Lisans Öğrencisi: Naz Yılmaz

eposta: e245966@metu.edu.tr

Çalışmaya katkıda bulunan bir gönüllü olarak katılımcı haklarınızla ilgili veya etik ilkelerle ilgi soru veya görüşlerinizi ODTÜ Uygulamalı Etik Araştırma Merkezi'ne iletebilirsiniz.

eposta: ueam@metu.edu.tr

Figure 6.1: Participation Information Form

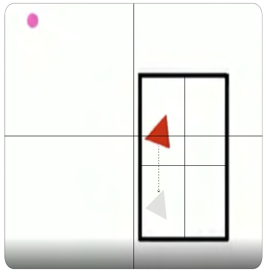
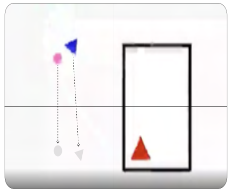
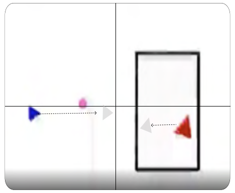
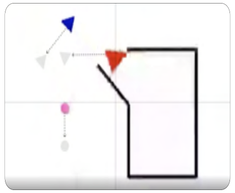
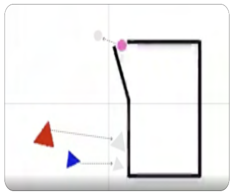
| Video (Motion Trajectory) | TRUE / FALSE | SENTENCE | FRAME / TOPOLOGICAL | AXES (X / Y) |
|---|---|---|---|---|
|  | True | Kırmızı üçgen dikdörtgenin içinde. | Topological | Y, Vertical |
| | True | Kırmızı üçgen dikdörtgen çerçevenin soluna yakın. | Frame | Y, Vertical |
| | False | Kırmızı üçgen dikdörtgen çerçevenin sağına yakın. | Frame | Y, Vertical |
| | False | Kırmızı üçgen dikdörtgenin dışında. | Topological | Y, Vertical |
| | False | Kırmızı üçgenin son hareketi dikdörtgenin üstüne doğruydu. | Topological | Y, Vertical |
| | False | Pembe daire sağda. | Frame | Y, Vertical |
| | True | Kırmızı üçgenin son hareketi dikdörtgenin altına doğruydu. | Topological | Y, Vertical |
| | True | Pembe daire solda. | Frame | Y, Vertical |
|  | False | Pembe daire ve mavi üçgen sağ tarafta hareket ediyor. | Frame | Y, Vertical |
| | True | Pembe daire ve mavi üçgen yukarıdan aşağıya iniyor. | Topological | Y, Vertical |
| | True | Pembe daire ve mavi üçgen sol tarafta hareket ediyor. | Frame | Y, Vertical |
| | False | Pembe daire ve mavi üçgen aşağıdan yukarıya çıkıyor. | Topological | Y, Vertical |
|  | False | Kırmızı üçgen dikdörtgenin dışında mavi üçgen içinde hareket ediyor. | Topological | X, Horizontal |
| | True | Kırmızı üçgen dikdörtgenin içinde mavi üçgen dışında hareket ediyor. | Topological | X, Horizontal |
| | True | Mavi üçgen sağa kırmızı üçgen sola doğru gidiyor. | Frame | X, Horizontal |
| | False | Mavi üçgen sola kırmızı üçgen sağa doğru gidiyor. | Frame | X, Horizontal |
|  | True | Mavi üçgen solda kırmızı üçgen sağda. | Frame | Y, Vertical |
| | True | Pembe daire mavi ve kırmızı üçgenlerin altında. | Topological | Y, Vertical |
| | False | Mavi üçgen sağda kırmızı üçgen solda. | Frame | Y, Vertical |
| | False | Pembe daire mavi ve kırmızı üçgenlerin üstünde. | Topological | Y, Vertical |
|  | False | Kırmızı ve mavi üçgenler sola doğru gidiyor. | Frame | X, Horizontal |
| | False | Kırmızı ve mavi üçgenler dikdörtgenin içinde. | Topological | X, Horizontal |
| | True | Kırmızı ve mavi üçgenler sağa doğru gidiyor. | Frame | X, Horizontal |
| | True | Kırmızı ve mavi üçgenler dikdörtgenin dışında. | Topological | X, Horizontal |

Figure 6.2: Experiment Schematic Infographic

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