ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

BODILY EXPERIENCE AND SPATIAL THINKING IN ARCHITECTURAL DESIGN PROCESS

Ph.D. THESIS

Sema ALAÇAM

Department of Informatics

Architectural Design Computing Graduate Program

OCTOBER 2014

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

MİMARİ TASARIM SÜRECİNDE BEDENSEL DENEYİM VE UZAMSAL DÜŞÜNME

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Sema Alaçam, **a Ph.D.** student of ITU **Graduate School of Science Engineering and Technology** student ID 523082005, successfully defended the **dissertation** entitled "**BODILY EXPERIENCE AND SPATIAL THINKING IN ARCHITECTURAL DESIGN PROCESS**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my family,

FOREWORD

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(M.Sc. Architect)

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ABBREVATIONS

AI	: Artificial Intelligence
App	: Appendix
CAD	: Computer Aided Design
CAAD	: Computer Aided Architectural Design
CAM	: Computer Aided Manifacturing
CMD	: Computer Mediated Design
ETH	: Eidgenössische Technische Hochschule
GUI	: Graphical User Interface
HCI	: Human Computer Interaction
ICKT	: Information Communication and Knowledge Technologies
ITU	: Istanbul Technical University
PMA	: Perceptual Meaning Analysis
TUI	: Tangible User Interface
2D	: Two-dimensional
3D	: Three-dimensional

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BODILY EXPERIENCE AND SPATIAL THINKING IN ARCHITECTURAL DESIGN PROCESS

SUMMARY

The transition from craft to mechanic production over the first half of the twentieth century led to an aesthetic crisis, in Herbert Marcuse's words, the division of "thought and action", "conception and execution", "hand and mind", in several disciplines, including the field of architecture (Marcuse, 1964/2002). Architectural discourse, theory and practice today have to additionally deal with a new crisis arising from the encounter with digital media. I aim to unfold the discussions on architects' way of interacting with digital media through phenomenological approach which have common foundations in philosophy, human-computer interaction and cognitive science. This study can be considered as an attempt to seek qualitative clues for the theories of embodiment through empirical observations. Most of the theories and concepts, which are discussed in this dissertation, have been available since ancient times, however they are not among the mainstream theories. This dissertation is also an attempt to understand the nature and aesthetic dimensions of bodily experience acquired and expressed through hand gestures and to explore the role of this bodily experience in the way architects develop spatial ideas.

In the Chapter 1.1, I explain crucial focal points and changes in the way of making in architecture and their relations with "body" from a historical perspective. Although, I mention four focal points of empirical, rational, mechanic and digital approaches, which bring important insights for today's transformation, I particularly focus on the changes within the 20th century. In the Chapter 1.2, I unfold the discussions in the philosophy of Sartre, Merleau-Ponty and others who investigated ontological dimensions of body. Later in the Chapter 1.3, I examine the epistemological perspectives of sensory experience.

In Chapter 2, the theories of embodiment in architecture, cognitive science and human-computer interaction are discussed. Johnson and Lakoff's arguments on embodied experience is a backbone for investigating the related embodiment theories (Lakoff and Johnson, 1999; Lakoff and Johnson, 2008; Johnson, 1987; Johnson, 2008).

In Chapter 3, whose title is "Nonverbal and Nonvisual Foundations of Thought", I overviewed the findings in the fields of development psychology, neuropsychology, anthropology and other empirical studies in relation to the tacit, spatial and unconscious dimensions of conscious experience.

Chapter 4 is focused on how bodily experience is examined in the protocol studies, which analyses the behaviour of the designers.

Chapter 5 consists of two case studies within the scope of dissertation. The first case study is a structured digital modeling exercise and the second one is an empirical observation of the fourth-year architecture students' jury presentation in the 2013-2014 spring semester. The case studies were recorded, and the verbal content transcribed. The body schemas of Johnson and Lakoff (2008) and the gesture categories of McNeill (1992) are used for analysing the data. Later the verbal transcripts and the gestural transcripts are analysed. I analyse the way in which gestural interaction and the vocabulary of verbal description is affected when the designers

communicate increasingly complex and abstract spatial relations or metaphoric concepts. The outcomes and the findings of the case study is explained in this chapter.

Chapter 6 is about the concluding remarks of the dissertation and the discussions on the future of digital design environments.

MİMARİ TASARIM SÜRECİNDE BEDENSEL DENEYİM VE UZAMSAL DÜŞÜNME

ÖZET

20. yy'ın ilk yarısında el ile üretimden makina ile üretime, zanaatten endüstrileşmeye geçiş, mimarlık da dahil olmak üzere pek çok disiplinde Herbert Marcuse'un ifadesiyle "düşünce ve eylemin", "kavram ve yürütmenin", "el ile zihnin" ayrışması krizine neden olmuştu (Marcuse, 2002). 20. yy'ın ikinci yarısından itibaren, temelleri kartezyen dünya tasavvuruna dayanan, bilginin deneyimden ayrı olarak (disembodied) idealist bir biçimde temsil geleneği ile bilgi ve iletişim teknolojilerinin bu ayrık gelenek üzerine inşaası ise, mimarlığın "sayısal"la karşılaşmasında yeni bir krize yol açmıştır. Günümüzde, mimarlık kuram, söylem ve uygulamalarında, tasarım düşüncesi ile tasarımcı bedeni ayrı iki özne olarak belirmektedir. Sayısal çağın krizinde parçalara ayrılan el ve zihnin ötesinde, duyusal algı bütünlüğü olmaktadır. Bir yandan görsel duyu kutsanırken, öte yandan dokunma duyusu ve bedenin uzam ile süreç içinde kurduğu iletişim biçimleri giderek silikleşmektedir.

Tez kapsamında mimarların sayısal ortam ile kurdukları diyaloğa ilişkin tartışmaların; mimarlık, bilişsel çalışmalar ve insan-bilgisayar etkileşimi alanlarından yararlanarak açılması ve derinleştirilmesi amaçlanmıştır. Bedenin ortadan kaybolmasının krizini tek bir yöntem ya da yaklaşım ile açıklamak olanaksız olduğundan, olabildiğince deneyimleyen özne tarafında kalmaya ve bütüncül yaklaşılmaya çalışılmıştır. Bu çalışma, cisimleşme (embodiment) kuramına, ampirik gözlemler aracığıyla niteliksel destekler arama çabası gütmektedir. Aynı zamanda bu çalışma kapsamında, mevcut (geleneksel) tasarım süreçlerinde, tasarımcıların tasarım temsilleri ve çevreleri ile kurdukları bedensel deneyimin doğal ve estetik niteliklerinin irdelenmesi ve tasarımcıların uzama dair düşünce geliştirirken bedensel deneyimin rolüne ilişkin içgörü kazanılması amaçlanmıştır.

Birinci bölüm üç temel alt başlıktan oluşmaktadır. Birinci alt başlıkta, tarihsel perspektif içerisinde mimarlıkta yapma biçimlerindeki değişim ve dönüşüm eşikleri ve bu eşiklerin "beden" ile kurduğu ilişki biçimleri tartışılmaktadır. Herhangi bir temsile ihtiyaç duymadan bedeni ve elleri aracılığıyla duvar ören ustadan, günümüzde bilgisayar destekli tasarım yapan mimara değin, mimarlık pratiği, kuramı ve söyleminde "beden" ve "bedensel deneyim"in geçtiği kırılma noktaları ele alınmıştır. Antik Dönem, Rönesans, Endüstri ve Sayısal Çağları olarak dört ana kırılma noktasına göz atılmakla birlikte, günümüzdeki sayısal düşüncenin dinamiklerini anlamak üzere 20. yy başlarında makinalaşma dönemine odaklanılmıştır.

Birinci bölümün ikinci alt başlığında, Sartre, Merleau-Ponty ve bedenin ontolojik boyutlarını sorgulayan diğer düşünürlerin tartışmaları açılmaktadır. Birinci bölümün son alt başlığında ise, duyusal deneyimin epistemolojik perspektifleri irdelenmektedir. Sartre bedeni hem "kendi-için-varlık", hem de "başkası-için-varlık" olarak iki ontolojik düzlemde ele almaktadır (Sartre, 2009). Merleau-Ponty, Sartre'ın bu iki ontolojik düzlemini algı ve deneyim; Kant'ın "aşkın estetik" kavramını ise "bedensel deneyim" olarak yorumlamıştır (Rawes, 2008). Merleau-Ponty aynı zamanda, Husserl ve Heidegger'deki aşkınlık kavramının yerine bedeni koymak olmuştur. Merleau-Ponty'nin bilinci somutlaşan bir deneyim olarak (insan ve insan olmayan diğerleri arasındaki karşılaşmada dokunsal bir varolma biçiminde) beden üzerinden kuramsallaştırmasının devrimci bir adım olduğunu ifade edilmektedir (Young, 2005).

Merleau-Ponty Descartes'in mekanik algı anlayışını, mekanik psikolojiyi ve klasik psikolojiyi indirgemeci oldukları iddiasıyla eleştirir. Deneyimin somutlaşan (embodied) boyutu ile dokunmak ve dokunulmanın aynı anda duyumsanmasının algıda bir muğlaklığa neden olduğunun altını çizer (Merleau-Ponty, 2012). Merleau-Ponty'ye (2012) göre, bedenimiz dünya içerisindeki tekil bir nesneden öte; yaşayan, nefes alan ve deneyimleyen bir varlıktır. Bu nedenle Merleau-Ponty, bedenle ilgili her kuramın "algılanan dünya" kuramını dikkate almak durumunda olduğunu öne sürer.

İkinci bölümde ete kemiğe bürünme, somutlaşma, cisimleşme olarak Türkçe'ye çevirebileceğimiz "embodiment" kuramları tartışılmaktadır. Mimarlık, bilişsel bilim ve insan-bilgisayar etkileşimi alanlarındaki, "deneyimin somutlaşmasına" ilişkin kuramlar irdelenirken, Johnson and Lakoff'un konu ile ilgili savları esas alınmıştır (Lakoff and Johnson, 1999; Lakoff and Johnson, 2008; Johnson, 1987; Johnson, 2008). Kökenlerini özellikle bir kıta Avrupası felsefecisi olan Merleau-Ponty'nin düşüncelerinden devralan "somutlaşma" (embodiment) kuramı, felsefe, psikoloji, biliş, dil bilim, yapay zeka, gibi pek çok farklı alandaki tartışmaları etkilemiştir. Nöroloji alanındaki gelişmelerden beslenerek giderek önem kazanmaktadır. Bu yaklaşım, beden ve zihni bütünsel bir şekilde ele almaktadır. Bu anlamda düşünme sürecinde bedenin önemli bir rolü olduğu varsayılır. Zihnin çalışmasını bilgi işlem kuramında açıklayan girdi – işlem – çıktı süreci biçiminde değildir. Fiziksel çevre ile kurulan ilişki önemlidir, ancak bu ilişki kişinin çevreye adaptasyonunu da gerektiren süreklilik içerisinde ve beden aracılığıyla yapılmaktadır.

Deneyimin somutlaşması yaklaşımının, "beden", "dış dünya" ve "beden ve dış dünya arasında süregiden etkileşim" biçiminde üç ana unsurundan söz edilebilir. Deneyimin somutlaşması yaklaşımı ile ilişkili olan diğer kavramlar beden-imaj, beden-şeması ve imaj-şemasıdır. Beden-imaj kavramına mimarlık alanında ilk olarak Bloomer ve Moore, 1977 tarihli "Body, Memory, Architecture" kitaplarında yer vermişlerdir. Bloomer ve Moore, beden-imaj teriminin daha geniş anlamda klasik "imgelem" kavramını, beden-algı ve beden-şeması gibi kavramları içerisinde barındırdığından söz ederler (Bloomer ve Moore, 1977). Bloomer ve Moore ise kullandıkları beden-imaj kavramını, kişinin uzamsal yönelimleri (intentions), değerleri, kişisel bilgisi ve deneyimleyen bedeni ile edinilen bütünsel bir duygu ya da üç boyutlu "Gestalt" duygusu olarak tanımlamaktadırlar ve "bilinçaltı seviyesinde farkında olmadan bedenlerimizi üç boyutlu bir sınıra yerleştiririz" demektedirler. Beden-imaj şemaları olarak "aşağı/yukarı", "ileri/geri", sağ/sol" ve "burada ve içeride" gibi şemaları sıralarlar (Bloomer ve Moore, 1977). Lakoff ve Johnson'un imaj şemaları, tasarım ve modelleme sürecinde tasarımcıların tasarım temsilleri ile kurdukları iletişimin örtük boyutlarını anlamamız açısından önemli bir kavrayış sağlamaktadır. Beşinci bölümdeki uygulamaların çözümlenmesi sırasında kullanılmış olan "kutulama" şeması, "kaynak-iz-amaç" şeması, ikinci bölüm içerisinde açıklanmaktadır.

"Düşüncenin Sözel ve Görsel Olmayan Temelleri" başlıklı üçüncü bölümde, bilinçli düşüncenin örtük, uzamsal ve bilinçaltı temelleri ile ilgili olarak, gelişim psikolojisi, nöropsikoloji, antropoloji ve ampirik çalışma yapılan diğer alanlardaki literatür incelenmiştir. Bu kaynaklardan, el jestlerinin mimari tasarım ve modelleme süreçlerindeki rolüne ilişkin ipucu sağlayabilecek olanlara yer verilmiştir. İncelenen çalışmalarda "hareket" algısına ve "dokunma" duyusuna çok sayıda referans verildiği görülmektedir. Bu bağlamda bölüm üç alt başlık biçiminde kurgulanmıştır. Bunlardan ilki "çocukluk dönemindeki dokunma deneyimi"dir. Gerek dokunmanın gerekse hareketin, erken çocukluk döneminde dünyanın algılanmasında önemli bir yeri bulunmaktadır. Çocukluk döneminden itibaren bu deneyim, sinir sisteminde çeşitli izler ve örüntüler biçiminde imaj şemalarının temellerini oluşturmaktadır (Johnson, 2008). Tez kapsamında bu alt başlığın önemi, durum çalışmasına katılan kişilerin dijital ortam ile çocukluk dönemlerinde benzer bir iletişim biçimi kurmalarıdır. Çocukluk döneminden itibaren dijital ortam ile farklı iletişim ve etkileşim biçimi kurmuş olan gelecekteki katılımcılar için, tezde ulaşılan bulgu ve sonuçlar farklılık gösterebilir. Bir başka alt başlıkta el jestlerinin kinestetik nitelikleri tartışılmaktadır.. Kinestetik duyumsama hareket ile algılanan deneyimi içermektedir. Diğer yandan dokunma duyusu ile bütünlüklü çalışan, yer yer örtüşen bir yanı da vardır. Yakınlık-uzaklık ilişkisini anlamamıza örtük bir şekilde destek olmakta olan kinestetik duyumsama, özellikle erken çocukluk döneminde kaynak-iz-amaç imaj şemasının ilk şekillenme sürecinde önemli bir rol oynamaktadır (Mandler, 2012). Bu bölümün son alt başlığında "el"in kavramsal düşünme süreçleri üzerindeki etkisi incelenmiştir.

Dördüncü bölümde genel olarak tasarımcı davranışının, özel olarak bedene ilişkin analizlerin, tasarımda protokol çalışmalarında nasıl ele alındığı konusuna odaklanılmaktadır. Psikoloji alanında protokol çalışmaları mimari tasarım alanından çok daha önce başlamıştır. Günümüzde, protokol çalışmaları alanında pek çok farklı yöntem ve yaklaşım geliştirildiği görülmektedir. Tez kapsamında ise, mimari tasarım sürecinde "bedensel deneyim"in ele alındığı ve bunun yanısıra "uzamsal kodlamalar" içeren çalışmalara yer verilmiştir.

Beşinci bölümde, tez kapsamında yapılan iki farklı durum çalışması sunulmaktadır. Durum çalışmalarından ilki, yüksek lisans düzeyinde iki mimarlık öğrencisinin katılımı ile gerçekleştirilen, kurgulanmış bir modelleme deneyidir. Bu deney ortalama 30 dakika sürmekte olup, 4 adet fiziksel maketin bilgisayar ortamında modellenmesinden oluşmaktadır. Deney, birisi İstanbul Teknik Üniversitesi ve diğeri ETH Zürih'te olmak üzere toplamda 4 katılımcı ile 2 kez tekrarlanmıştır. İkinci durum çalışması ise İstanbul Teknik Üniversitesi, Mimarlık Fakültesi son sınıf öğrencilerinin 2013-2014 bahar yarıyıllarından bitirme jurilerindeki sunuşlarının ampirik olarak gözlenmesi biçimindedir. Öğrencilerin el jestlerini doğal bir şekilde kullanmaları amacıyla, gözlem öncesinde deneyin içeriği ile ilgili bilgilendirme yapılmamıştır. Her iki durum çalışması da video ile kaydedilmiştir. İlk durum çalışmasındaki sözel içeriğin tamamının çözümlemesi yapılmıştır (Ek A.1 ve Ek B.1). İkinci durum çalışmasından ise, 2013-2014 bahar yarıyılında bitirme projesi almış ve dönem boyunca üç kez juri sunuşuna çıkmış olan öğrencilerden seçilen ikisinin sözel çözümlemesi yapılmıştır (Ek C). Analiz yöntemi olarak, Johnson ve Lakoff'un (2008) beden şemaları, McNeil'in (1992) jest kategorilerinden yararlanılmıştır. El jestlerinin McNeill'in (1992) kategorilerine göre dağılımı, el jestleri ile sözel içeriğin ilişkisi, el jestleri ile maketin anlatıldığı ortamın ilişkisi ve son olarak da Lakoff (1987) ve Johnson'ın (1987) imaj şemaları ile el jestlerinin ilişkisi irdelenmiştir. Tasarımcıların uzamsal, soyut kavramları ya da metaforik kavramları açıklarken kullandıkları el jestlerinin bütünleyici rolü irdelenmiştir. Deneyin çıktı ve bulguları yine aynı bölümde açıklanmıştır.

Altıncı bölümde ise, gelecekteki sayısal tasarım ortamlarının değerlendirilmesi amacıyla görüş, tartışma ve öneriler aktarılmıştır.

1. INTRODUCTION

The evolution of technology and human beings are at asymmetric speed. Because of the pace of the evolution, human beings lags behind the speed of the changes in technology, there is a constant gap between these two processes. Concerning the relation between human beings and technology, the perceptual and the biological limitations of human beings have not been taken into consideration; instead, the focus has been on the speed of technology and its limitations. Within the process of technological progress, the experiential dimensions of the "body" have been neglected. This neglectance occurs at both the literal and the theoretical/conceptual levels. As a result of approaching the human body and the mind, the experience and the thought, the making and the thinking; as two different entities and the reflection of this approach in scientific studies; in the areas of the researches of architectural design, cognitive sciences and the human-computer interaction (HCI) from a methodological and ontological perspective, reductionism occurs to a certain extent.

In a broader sense, these reductionist and disembodied approaches have become insufficient to understand the contemporary dynamics and the essence of digital transformation. Moreover, any singular methodology or point of view would not suffice to gain a comprehensive insight. However, I should still underline the need for holistic ways of approaching the mind-body and thought-experience interrelations instead of dualistic ones. It is not easy to say whether this transformation will be a Kuhnian-revolutionary or a Popperian-evolutionary one. In other words, within the context of architectural design, it is difficult to claim which one will prevail in the future. Either there will be a radical departure from traditional way of making or there will be a gradual transformation of it. I claim that, the role of human "body" will play a crucial role in the digital age, which is independent from the direction and the trajectories of the transformation in the way of making in architecture. Moreover, I argue that the aesthetic dimensions of bodily experience is one of the key concepts in the effort to get a deeper understanding of today's crisis and gain insight about future directions of digital design environments.

Since the first year of my bachelor education, I have been witness to these changes with relatively novel digital tools. I started to learn the principles of technical drawing by using sketch papers and rapidos in the first year of my bachelor education in 2000, at ITU, Faculty of Architecture. Since then, I have been personally experiencing how digital tools and methods are embedded in design pedagogy. We started to use various digital tools and medium for architectural design such as the 2D drawing softwares, the 3D modelling softwares, parametric and algorithmic design environments. On the other hand, sketching and physical modelling have always been important during my education. When I was an undergraduate student of architecture, I expected a radical departure from the traditional design environments. However, neither I, nor the students that I have observed in the last 9 years could actualize this departure. I always began developing my initial design ideas on physical papers by sketching, writing notes or making physical models during my architectural design processes. First, I had concrete ideas in the physical environment, and then I was working with computers or in a broader sense with the digital medium. Since then, I have been curious about the underlying reasons of this dependency.

I encountered two exceptional students throughout my 7 years of experience as a teaching assistant. One of them had been playing computer games intensely since his childhood. The other student had a degree both in architecture and in civil engineering. His insights from the civil engineering education enabled him to handle more abstract diagrams and parametric design models in digital environment without any need for paper. What is more, I have not met, in Palfrey and Gasser's (2013) words, "digital natives" yet (Palfrey and Gasser, 2013). Therefore, I ought to underline that the reflection of the technological change on "digital natives" might be different from the assumptions of this dissertation, which are mainly derived from my personal experience and observations.

To mention another experience of mine, I have been more comfortable in handwriting instead of typewriting, not only in architectural design processes but also in general. For example, I was always able to remember the notes of the courses in which I took handwritten notes. Was it because of the quality of the representation or my hand itself? Handwriting, like sketching, involves a symbolic codification of the letters/verbal data. Moreover, it involves a visual codification. It matters whether the length of the letters is shorter or longer; the lines are transparent or bold; the turns are smooth or not. Thus, the writing itself is capable of involving both the verbal and the visual/diagrammatic modes of information. At the same time, the reason I can easily remember my notes might be related to the movement of my hand or the haptic and tactile feedback from the material, or the kinesthetic feedback from my muscles, or the relationship with/in the space consisting of different modes of tacit information. In his book "Why Architects Still Draw", Paolo Belardi gives priority to sketching as a recursive exploration process (Belardi, 2014). "In addition, because successive 'explorations'-i.e., sensations of the same subject in different times and contexts-are never the same, each category is determined and then reclassified as an infinite number of times" says Belardi (Belardi, 2014). In reference to Rudolf Pophal, Belardi (2014) emphasizes the inseparability of writing and sketching and he claims that the sketching will still be important in the digital age. In my case, I cannot assume that either sketching or model making will still be important in the future in architectural education. However, I can claim that unless the digital media support the main body schemas of the designers as physical dimensions of the designing activity, these representations will probably exist. In other words, what is important is the inseparability of the whole, the body and the mind including the unconscious perceptual circuits and the intentional conscious thought. Therefore, the design environment which will allow designers to experience multisensory perception, in particular tactile, haptic, kinesthetic dialogue with the design medium and the design environments which provide flexibility in the shifts between different body schemas will be luckier in comparison with the reduced visual screens. Thence, we need to revisit the aesthetic qualities of making in parallel to the attempts in the earlier 20^{th} century, in particular the curricula of Bauhaus in the broader researches.

In my master thesis under the supervision of Prof. Dr. Gülen Çağdaş, whose title is "An Interface Proposal for Architectural Design Collaboration Process", we investigated the potentials and the limitations of existing digital tools. We evaluated the impact of digital media on the behaviour of architects merely from the perspective of interaction and communication (Alaçam, 2008). At that time, we developed frameworks for collaborative architectural design environments in conceptual levels. We also developed and tested a usage of two mice simultaneously within a 3D modeling environment (Alaçam and Çağdaş, 2008).

In the very beginning of the dissertation, Pallasma's book of "The Eyes Of The Skin, The Architecture and The Senses" and afterwards the other book of his "The Thinking Hand: The Existential and Embodied Wisdom in Architecture" provided curiosity and insights to go deeper (Pallasma 2005; Pallasmaa, 2009). Moreover, Mark Johnson's book of "The meaning of the body: Aesthetics of human understanding" confronted me with embodiment theories (Johnson, 2008). I come up with the question of why designers' still tend to use traditional/physical media in the earlier phases of architectural design process in contrary to the theory of computation and digital design environment promise. At this point, the provoking propositions of Hubert Lederer Dreyfus were also very helpful to gain a critical distance to technology (Dreyfus, 1992).

In this dissertation, I aim to unfold the discussions on architects' way of interacting with digital media through a phenomenological approach, which have common foundations in philosophy, human-computer interaction and cognitive science. This dissertation is an attempt to understand the nature and aesthetic dimensions of bodily experience acquired and expressed through hand gestures and to explore the role of this bodily experience in the way architects develop spatial ideas.

Following questions were kept in mind during the investigations in this dissertation:

● Previous bodily (haptic/tactile/kinesthetic) experiences of the designers;

● Actual interaction with the design medium and its reflection.

It is possible to measure this reflection of bodily experience on designers' generating spatial ideas by:

● exploring the role of spatial dimensions of the iconic gestures;

● exploring the relationship between the metaphorical/conceptual ideas and their gestural/spatial qualities;

● approaching the role of body in holistic ways, instead of dual assumptions.

Apart from these theoretical investigations, numerous experimental studies have been conducted on how digital media may be utilized in architectural education and in particular,its impact on architects' way of thinking in the earlier phases of the design process. However, only a limited number of studies have been performed using the phenomenological approach. In this research, we go beyond object/representation or process-oriented approaches to focus on what goes on in the subject's mind by carrying out a phenomenological study and further, by approaching the subject's perspective ontologically and cognitively.

I argue that the aesthetic dimensions of bodily experience are fundamental concepts in the effort to acquire a deeper understanding of today's crisis and to gain insight into future directions of digital design environments. For this purpose, I looked at the bodily foundations of thought in philosophy, interaction design and psychology. Conventional analytic methods are insufficient for understanding the reflections of interaction with physical space and design media in the way architects develop spatial ideas. Therefore, I argue that a holistic point of view and phenomenological approach is needed.

The aim of this research is to explore if there are repetitive gestural patterns or common behavior patterns among different students during the externalization of design ideas. I analyzed the way in which gestural interaction and the vocabulary of verbal description is affected when the designers reveal more complex and abstract spatial relations or metaphoric concepts. This research is an attempt to understand the nature of bodily experience acquired and expressed through hand gestures and explore the role of bodily experience in the way architects develop spatial ideas. In the current digital epoch, the design environments of the future are expected to be designer friendly through promoting main body schemas such as source-path-goal and movement and encourage the designer's spatial thinking process.

One of the main motivations for this study is to investigate how and why the digital environment interfaces used in early stages of architectural design are insufficient in the designers' process of creating abstract and conceptual thinking, and to come across findings that will serve as the basis for digital environment designs in the future. For this purpose, a structured modeling exercise was created that allows the empirical observation of the process which was conducted in a digital environment. The modeling exercise was repeated two times with different participants from different universities. In each experiment two graduate-level students from the field of architecture participated, one of the participants was asked to describe to the other participant four architectural models that they had initially observed. The study was designed in a way to help the participants explain and understand geometrical and spatial relations, and the hand gestures and verbal expressions used in their dialogues were studied. Therefore, the role of the bodily experience, which consists of hand gestures conveying ideas not represented in words, in expressing or creating spatial ideas was examined.

Apart from the structured exercise, the second case study of the dissertation is based on empirical observations of jury meetings of final design studios/diploma projects of bachelor students in Istanbul Technical University, Faculty of architecture in 2013-2014 spring semesters.The verbal and the gestural transcripts of student presentations are analysed (Chapter 5).

Earlier versions of this dissertation was published in the proceeding of the 8th International Conference on Tangible, Embedded and Embodied Interaction (TEI) in Munich between the 16^{th} -19^{th} February of 2014. It will be presented and published in the International Conference on Human Behavior in Design (HBID): Analyzing Cognitive Processes in Design in Ascona between the 14-17th October 2014 and XVII Conference of SIGRADI 2014: Design in Freedom, in Uruguay, between the 12-14th November 2014.

1.1 Historical Perspectives: Changes and Thresholds in the Way of Making in Architecture

In this chapter, there are two overlapping layers. The first layer involves the changes in the relation of body and design thinking. In general, this part is concerned with how the distance between body and design thinking has increased through history until the disappearance of the body in the computational design discourse. This layer is organized in two sub-layers. From the manual construction through to the mechanic; secondly from the mechanic production through to the digital way of making in architecture. Therefore it can be traced back to the times in which one put bricks to the building by hand without the interference of design. Afterwards revisiting Renaissance and Alberti's perspective, on how the architect became the draftsman of the 20^{th} century. The second sublayer focuses on the changes after the second half of the 20^{th} century up to now. I particularly attempt to keep a critical distance to the disembodied approaches of the computational theory in the second half of 20^{th} century.

The second but overlapping layer is about the historical and the philosophical roots of the detachment between the way of making and the way of thinking in architecture. In respect to these detachments, I mention four focal points: empirical, rational, mechanic and digital approaches. I'm concerned with exploring insights into today's transformation. These trajectories of revolving around these focal points are important for understanding how the detachment of the body and the thought emerged in the ways of making in architecture in different traditions of thinking systems. I particularly focus on the changes within the earlier 20th century in which the detachment between "hand" and "mind", "the sensory experience" and "thought" occurred. Moreover, the other thresholds and equilibrium conditions in relation to the philosophy of science are also mentioned when needed, but not in a chronological way.

1.1.1 From craftsman through draftsman: the earlier changes

In this chapter the main focus will be on how the transition from craft to mechanic production over the first half of the twentieth century led to an aesthetic crisis, in Herbert Marcuse's words, the division of "thought and action", "conception and execution", "hand and mind", in several disciplines, including the field of architecture (Marcuse, 2002). This is because architectural discourse, theory and practice today have to additionally deal with a new crisis arising from the encounter with digital media. Carpo defines three technical ages: the ages of hand-making, mechanical making and the digital making (Carpo, 2010). He adds: "The sequential chronology of these three technical ages lends itself to various interpretations" (Carpo, 2010). To mention, how the crisis of architecture was formulated by Isozaki in the introduction part of the Karatani's 1995 book "Architecture as metaphor: Language, number, money":

- 19th century – "Architecture as art";
- 20th century – "Architecture as construction" (necessity-based);
- 21th century – "Architecture as metaphor" (Isozaki in Karatani, 1995).

Isozaki remarks that the concept of "architecture as construction" which proposes the marriage of art and architectural discourse which was proposed by Semper, Loos and Wagner, has been a guiding principle to overcoming the earlier crisis (Isozaki in Karatani, 1995).

On the other hand I will also mention the earlier departure of the design thinking from the making in archictecture and likewise the detachment of the body and the way of making during the Ancient Greek and the Renaissance periods (Figure 1.1). “The transformation that we are observing today is inseparable from conditions like globalization. They are also the result of a much longer and more complex historical process than the recent conversion of designers to digital tools” says Picon (Picon, 2010). This is why, the historical processes, their causalities and the systems of thinking beyond should be unfolded. Some of the basic thresholds in the way of making in architecture is shown in Figure 1.1.

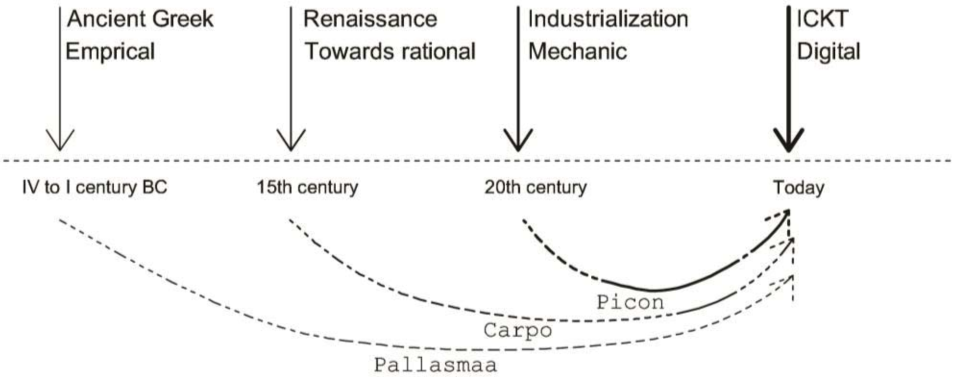


Figure 1.1 : Thresholds for the detachment of way of thinking and way of making.

One of the first separations between making and thinking on a conceptual level can be traced back to the terms that were introduced by Aristotle such as “technê”, “episteme” and “phronêsis”. This is also because, as Smith (2004) higlights Aristotelian scheme of knowledge with minor changes had been influential up to seventeenth century (Smith, 2004). The Greek word ‘‘technê’ is translated as “crafts or art” (Url-1). The term ‘Epistêmê’ is generally used in terms of knowledge, however the notion of knowledge it represented is different from what we understand from the contemporary version of the word which consists of experimentation (Url-1). “From earliest times until Plato the word techné is linked with the word epistémé. Both words are names for knowing in the widest sense” qoutes Heidegger (Heidegger, 1954). The meaning is more close to the geometrical axioms in terms of Aristotelian manner (Url-1). Smith expresses:

> The Greek disdain for manual work as deforming to mind and body was carried on in Western culture up into the seveth century and beyond. Aristotle maintained that craftsmen could not be full citizens because ‘no one can practice virtue who s living the life of a mechanic or laborer’ and because ‘there is no room for moral excellence in any of their employment (Smith, 2004).

Smith also mentions the tension between making and thinking by defining theory as a knowledge depending on logic, geometry and practice (Smith, 2004). Pallasmaa indicates the similarity between the "construction in traditional cultures guided by the body" and "a bird shapes its nest by movements of its body" (Pallasmaa, 2005). In parallel, Smith (2004) states that imitation of practice and manual works are the way to transmit the knowledge of the artisans. "Artisanal guilds, their rituals, apprenticeship training, and written techniques constituted the means by which artisanal knowledge was produced" Pamela Smith adds (Smith, 2004). Therefore as Smith underlines, this experience of craftsmanship was "nontextual" and "nonverbal" (Smith, 2004). On the other hand, we understand from Smith's (2004) expression that, there was a very tight relationship between the materiality and the artisan body:

> If scholars conceived of problems, or indeed of reality, primarily in terms of words and the manipulation of words, artisans must see reality as intimately related to material objects and the manipulation of the material, which could be taught about and understood as a 'material language (Smith, 2004).

"Not only handcraft manufacture, not only artistic and poetical bringing into appearance and concrete imagery, is a bringing-forth, poiésis" states Heidegger (Heidegger, 1977). Heidegger also adds, the poesis was brought by the help of physics (Heidegger, 1977). The word techné involves the meaning of "Technicon" says Heidegger and adds:

> We must observe two things with respect to the meaning of this word. One is that techné is the name not only for the activities and skills of the craftsman, but also for the arts of the mind and the fine arts. Techné belongs to bringing-forth, to poiésis; it is something poietic (Heidegger, 1977, p.5).

Heidegger (1977) also unfolds the meaning of techné through the word "altheuein". Therefore techné involves the affordance, however it "does not yet lie here before us" says Heidegger. The activities or the skill of the craftsman bring the potentials and the affordances of the techné into forth (Heidegger 1977). In Heidegger's words:

> Thus what is decisive in techné does not lie at all in making and manipulating nor in the using of means, but rather in the aforementioned revealing. It is as revealing, and not as manufacturing, that techné is a bringing-forth." (Heidegger, 1977)

This interpretation of Heidegger is important not only for the mechanical technologies but also the digital technologies. Here, Heidegger recovers the detached/isolated/disembodided assumption of "technology", giving reference to the Aristotalian meanings. Thence, "experience" and "praxis" are needed to bring up the affordances and reveal the "poiésis" of the instruments, in Greek word "aletheia". Coyne explains this relationship as:

> Technology is complicit in this transition from thought to ontic reason. It is not just that we now see thought instrumentally as if it were an object in technology to be crafted (techne) and manipulated. Rather there has been a corruption in our understanding of the craftsperson's art (techne) itself. According to Heidegger, to craft something (techne), originally meant to let a thing disclose itself, for it to be revealed or "brought forth." But to craft something soon came to mean to produce or manufacture an object (Coyne, 1995).

The disembodied interpretation of techné also caused the detachment between the craftsmen's body and the instrument. Both the body and the bodily experience neglected. "Phenomenological-philosophical descriptions of acting with technologies and cognitive-scientific analyses of it, can nevertheless clarify, up to a certain degree, the experience of technology and its conditions of possibility" says De Preester and adds:

> In contrast to the idea that the use of technology implies the ability for disembodiment, or a neglect of the body, I want to prepare the ground for the opposite claim, namely that this experience requires the capacity forre-embodiment, not for disembodiment. In order to do so, we have to examine the various domains and ranges in which the subject is capable of re-embodying itself. (De Preester, 2011, p.120)

To mention, apart from these detachment on conceptual and theoretical levels in the fourth century BC, we can assume that another detachment emerged in the 1st century BC by "The Ten Books on Architecture" (the original name is "De Architectura Libri Decem") of Vitruvius in terms of verbal description of making in architecture (Pollio, 1914). However the distance between the body and the way of making in architecture was relatively slight. Still, body and bodily experience were required in order to describe some concepts such as symmetry and proportion between the elements of the body. In the third book of Vitruvius, we see the title of "On Symmetry: In the Temples and in the Human Body" (Pollio, 1914). Vitruvius Pollio (1914) mentions the Greek word "analogy"/"αναλογία" in order to describe the principles of symmetry and proportion (Pollio, 1914). Vitruvius Pollio makes a comprehensive description:

> For the human body is so designated by nature that the face, from the chin to the top of the forehead and the lowest roots of the hair, is a tenth part of the whole height; the open hand from the wrist to the tip of the middle finger is just the same; the head from the chin to the crown is an eigth, and with the neck and shoulder from the top of the breast to the summit of the crown is a forth. If we take the height of the face itself, the distance from the bottom of the chin to the under side of trhe nostrils is one third of it; the nose from the under side of the nostrils to a line between the eyebrows is the same; from there to the lowest roots of the hair is also a third, comprising the forehead. The length of the foot is one sixth of the height of the body; of the forearm, one forth; and the breadth of the breast is also one fourth. The other members, too, have their own symmetrical proportions, and it was by employing them that the famous painters and sculptors of antiquity attained to great and endless renown (Pollio, 1914, p. 72).

Depending on the reflected spatial expressions in the verbal descriptions, we can assume that the role of body was still crucial for understanding and explaining the spatial concepts at those times. For example Vitruvius (1914) adds "… it was from the members of the body that they derived the fundamental ideas of the measures which are obviously necessary in all works, as the finger, palm, foot, and cubit" (Pollio, 1914). Vitruvius indicates that the roots of the "perfect number" of the Greeks, the number ten, can be traced back the number of the fingers of two hands (Pollio, 1914). Vitruvius also mentions that another perfect number was assumed six, derived from the ratio of the height of the man to the foot, which is called cubit and equals to six (Pollio, 1914). He concludes as:

> Therefore, if it is agreed that number was out from the human fingers, and that there is a symmentrical correspondence between the members separately and the entire form of the body, in accordance with a certain part selected as standard, we can have nothing but respect for those who, in constructibg temples of the immortal gods, have so arranged the members of the works that both the separate parts and the whole design may harmonize in their proportions ans symmetry (Pollio, 1914, p. 75).

In relation to this verbal detachment of the knowledge, Pallasmaa quotes from Ong's 1991 book that the transition from oral to written speech was crucial for the shift from sound to visual space which was influential on human consciousness (Ong, 1991; Pallasmaa, 2005). Pallasma adds "… and that print replaced the lingering hearing-dominance which had its beginning in writing" (Ong, 1991; Pallasmaa, 2005). In respect to the changes in the way of making in architecture, another important departure from the body emerges during Renaissance period. Picon argues that:

> At the Renaissance, the adoption of new tools and procedures, coordinated projections in plan and elevation, and perspective representation, was inseparable from broader phenomena like the emergence of the modern architect and engineer and the new importance given to conception (Picon, 2010).

"One of the most striking changes that occurred in the Renaissance was the development of visual perspective" Smith points out (Smith, 2004). Pallasma (2005) indicates Leon Battista Alberti and his perspective as a beginning of a crucial turn through the primacy of visual perception, harmony and proportion (Pallasmaa, 2005). Pallasma quotes the statement of Alberti as, "Painting is nothing but the intersection of the visual pyramid following a given distance, a fixed centre and a certain lighting' outlines the perspectival paradigm which also became the instrument of architectural thinking" (Levin, 1993; Pallasmaa, 2005). The vision-dominance roots of the thought have grown up gradually in the Western thought. For instance, Pallasma quotes, according to Lucien Febvre:

> The sixteenth century did not see first. It heard and smelled, it sniffed the air and caught sounds. It was only later that it seriously and actively became engaged in geometry, focusing attention on the world of forms with Kepler (1571-1630) and Desargues of Lyon (1593-1662). It was then that vision was unleashed in the world of science as it was in the world of physical sensations, and the world of beauty as well' (Jay, 1994, p.34; Pallasmaa, 2005, p.25).

In their 1977 "Body, Memory, and Architecture" book, Bloomer and Moore trace back the mechanisation of architecture in Louis XVI, 17th century (Boomer and Moore, 1977). Indeed, it is difficult to mention a precise date as a beginning of the paradigm of mechanisation and rationalization. Instead, there had occurred a lot of complex causalities in the constitution of the idea of the disembodiment. Bloomer and Moore mention the relation between how the body was conceived and how the scientific paradigms evolved at that time. The body was present as a divine organism in architecture before Galileo. It was altered to a mechanical organism by his inferences about how physical truth depends on "mathematical measurement and experiment" (Bloomer and Moore, 1977).

To consider Descartes (1596-1650, Galileo (1564-1642) and, Kepler (1571-1630) were contemporaneous, the way of observing had been probably influential on Descartes' dual assumption the subject and the object as the distance between the'observer' and the 'observed sky'. Moreover, Bloomer and Moore add:

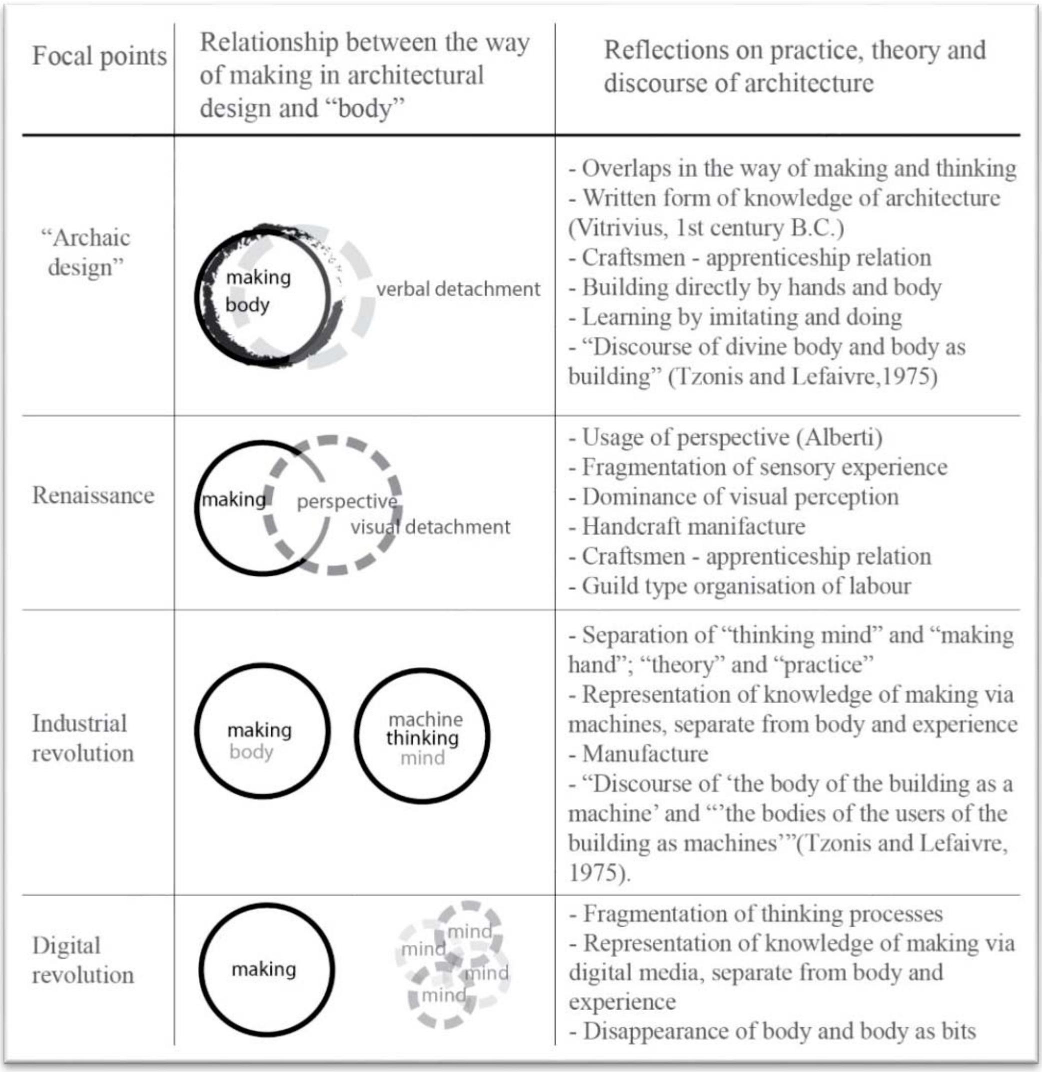
> Telescopic observation and the mathematical analysis of freely falling bodies could describe for Galileo a world which obeyed mechanical laws, and the human body as well as the starry skies belonged to that world (Boomer and Moore, 1977, p.15).

The hypotheses of Descartes on space and body are defined as: "a continuation of a long debate within Medieval/Renaissance philosophy centred upon the Aristotelian dictum that whatever possessed dimensionality was body (Url-2). According to Descartes, space was assumed as a conceptual abstraction from the bodily spatial extension (Url-2):

> We attribute a generic unity to the extension of the space [of a body], so that when the body which fills the space has been changed, the extension of the space itself is not considered to have been changed or transported but to remain one and the same; as long as it remains of the same size and shape and maintains the same situation among certain external bodies by means of which we specify that space. (Url-2).

During 18th century, the growth of the scientific studies continued, like the specialization in the professions. Instead of embodiment, various methods emerged not only in architecture but also in other fields. The differentiation between the art and the engineering schools can be traced back to this century. Therefore, the distinction between the Cartesian rationalism and relatively holistic experience of art had deepened (Boomer and Moore, 1977). Pallasmaa (2005) remarks that architecture was negatively affected by the abstract and universal structure of the 'technological rationality' and also by the processes of management, organisation and production.

This separation in the attitude caused the search for the methods and theories which can bridge the gaps. Boomer and Moore indicate "Beginning about 1910 a new theoretical model emerged from the findings of the Berlin school of Gestalt psychology" (Boomer and Moore, 1977). The overview of the focal points can be seen in Figure 1.2.



Focal points	Relationship between the way of making in architectural design and "body"	Reflections on practice, theory and discourse of architecture
"Archaic design"	making body / verbal detachment	- Overlaps in the way of making and thinking - Written form of knowledge of architecture (Vitrivius, 1st century B.C.) - Craftsmen - apprenticeship relation - Building directly by hands and body - Learning by imitating and doing - "Discourse of divine body and body as building" (Tzonis and Lefaivre,1975)
Renaissance	making / perspective / visual detachment	- Usage of perspective (Alberti) - Fragmentation of sensory experience - Dominance of visual perception - Handcraft manifacture - Craftsmen - apprenticeship relation - Guild type organisation of labour
Industrial revolution	making body / machine thinking mind	- Separation of "thinking mind" and "making hand"; "theory" and "practice" - Representation of knowledge of making via machines, separate from body and experience - Manufacture - "Discourse of 'the body of the building as a machine' and "'the bodies of the users of the building as machines'"(Tzonis and Lefaivre, 1975).
Digital revolution	making / mind mind mind mind	- Fragmentation of thinking processes - Representation of knowledge of making via digital media, separate from body and experience - Disappearance of body and body as bits

Figure 1.2 : Detachment of body from the way of making in architecture.

In relation to "body", Tzonis and Lefaivre define the shift of the conceptual framework in architectural design in two directions. "Archaic design" and "mechanical era". In their 1975 article, they underline the role of the changes in the way of making in the 17th century and they assume that what drives the transformation is simply based on the requirement for maximizing utility and minimizing cost as a consequence of the demand for rationalization of architecture (Tzonis and Lefaivre, 1975). This approach of mechanical era was different than the previous archaic conceptual framework which had referred to the divine law (Tzonis and Lefaivre, 1975). "References to the human body relate simultaneously to all levels of the framework of archaic design", Tzonis and Lefaivre express.

"The new framework has two variants: one is the body of the building as a machine, the other is the bodies of the users of the building as machines" write Tzonis and Lefaivre and they add:

> The commitment to the building as a machine accelerates the development of a design methodology which, after a systematic collection of emprical and a long series of experiements, succeeded in establishing a causal relationship between architectural means and desired utilitarian effects (Tzonis and Lefaivre, 1975).

On the other hand, previously during the archaic era, the role and the conceptualization of the body had depended on the "cosmological order of the world".

> The building is a human body to accept such a concept is to commit oneself to the overal framework of archaic methodology, i.e. sacred harmony as an ultimate warrant, a quasi-deductive logic of interference, a classificatory foundation for the justification of design decisions and authority backings to validate them, and a concentration of the repertory of design decisions around proportion, size and shape (Tzonis and Lefaivre, 1975).

Tzonis and Lefaivre express that: "The manual and the theoretical spheres of architecture were fused into one" (Tzonis and Lefaivre, 1975). Later in the 17th century the separation between theory and practice; thought and making; designer and the laborer had increased. "At the same time the laborer was exempted from any theoretical activities" write Tzonis and Lefaivre (1975) and they mention the constitution of the Royal Academy and formal methods of teaching. In their words: "As the divison of labor changed, so did the training of the architect" (Tzonis and Lefaivre, 1975).

Pallasmaa points out that artists and craftsmen are commonly occupied with bodily and existantial experiences instead of dealing with "external and objectified" problem. (Pallasmaa, 2005). In the 18th century, the guild type organisation gradually had lost its importance. Tzonis and Lefaivre state that engineers and artists in the architectural field reached freedom after the elimination of the guilds and the decayed meaning of 'divine human body' belief (Tzonis and Lefaivre, 1975).

To sum up, the division of labor, the degration, the specialization, the liquidation of the guilds, and the distance between theory and practice had growth and had formed in a centuries-long period. How/if the knowledge of an expert/craftsman could be transferred became an important curiosity in the mechanical era for not only architecture but also for engineering. Disembodied approaches of the knowledge and the dominance of the bodiless experience became distinctive. As Pallasma states, "The eye conquers its hegemonic role in architectural practice, both consciously and unconsciously, only gradually with the emergence of the idea of a bodiless observer" (Pallasmaa, 2005). The holistic conceptualisation of human body was replaced by the mechanic conceptualization of the body, with Tzonis and Lefaivre's words, "the body of the building as a machine" and "the bodies of the users of the building as machines" (Tzonis and Lefaivre, 1975). The industrial revolution also marks the period when the work of the craftsman is fragmented into pieces, whereas before the craftsman had complete control over the decisions made throughout the process, from the beginning to the end (Sennett, 2009). These seperations in the attitude caused the search for the methods and the theories which can bridge the gaps. Bloomer and Moore indicate "Beginning about 1910 a new theoretical model emerged from the findings of the Berlin school of Gestalt psychology" (Boomer and Moore, 1977). Moreover, as a reflection of this refraction in the way of making, some attempts occured in architecture education such as "multi (sensory)/folded experience of making" of the Bauhaus Ateliers, revisiting the aesthetic theory, studies on perception, and Dewey's recovery of the experience in the "Art as experience".

In the earlier 20th, some attempts for bridging the gap between "producing hand" and "thinking mind" in terms of architectural design education are seen in the Bauhaus curricula (Figure 1.3 and Figure 1.4). In the 1937 book, Moholy-Nagy (2012) asserts that: "The future needs whole man". Mogoly-Nagy (2012) introduces the sensory and tactile training exercises in Bauhaus education, some of them are shown in Figure 1.3 and Figure 1.4.

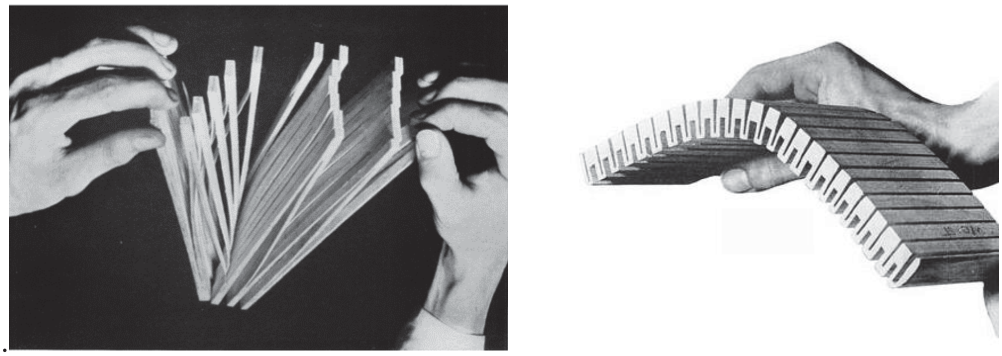


Figure 1.3 : (a) Woodcutting, Hin Bredendieck, 1937 (Moholy-Nagy, 2012).
(b) Woodcutting by machine, William Worst (Moholy-Nagy, 2012).

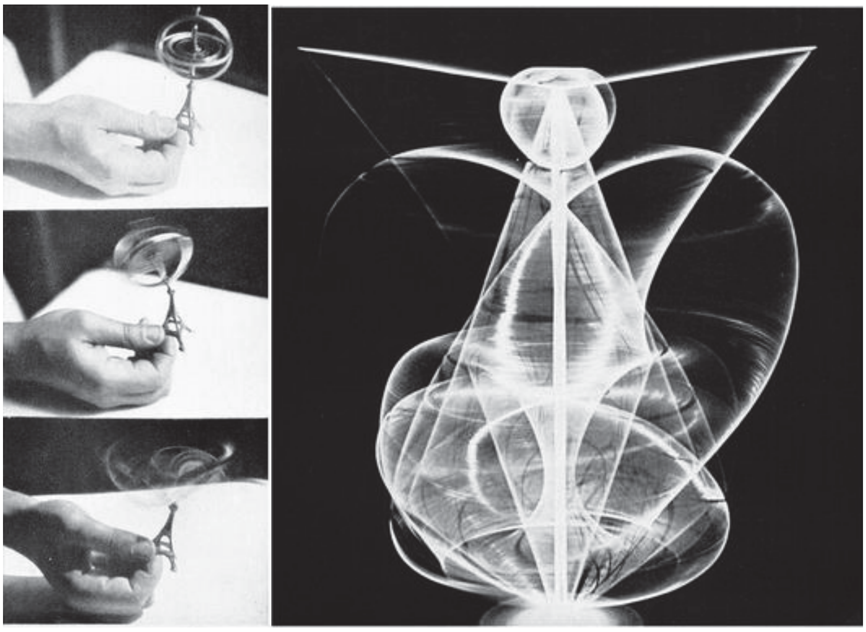


Figure 1.4 : (a, b, c) Toy, gyroscope (Moholy-Nagy, 2012).
(d) Virtual volume constituted by motion (Moholy-Nagy, 2012).

1.1.2 From draftsman through renderman (renderer): the disembodied conceptualizing of knowledge and thought in the computational epoch

During the 20th century and in particular in the second half of it, the detachment of experience from the knowledge and the idealist paradigm in knowledge theories, give an impetus to the progress in technology. The intensification of researches about the representation of knowledge by the means of symbols and language enabled communication with computers. Vice versa, the emergence of computers and the progress in digital technology have also increased the number of researches that approach the representation of knowledge via rules, structures and algorithms. In other words, the symbolic, verbal, formal and language based assumptions became more a distinctive medium of the knowledge (Figure 1.5). Therefore, the second half of the 20th century has brought a refraction in terms of changes in the way of making in architecture. The transformative effect of ICKT (Information, communication and knowledge technologies) has been influential in all the fields and in the architecture as well.

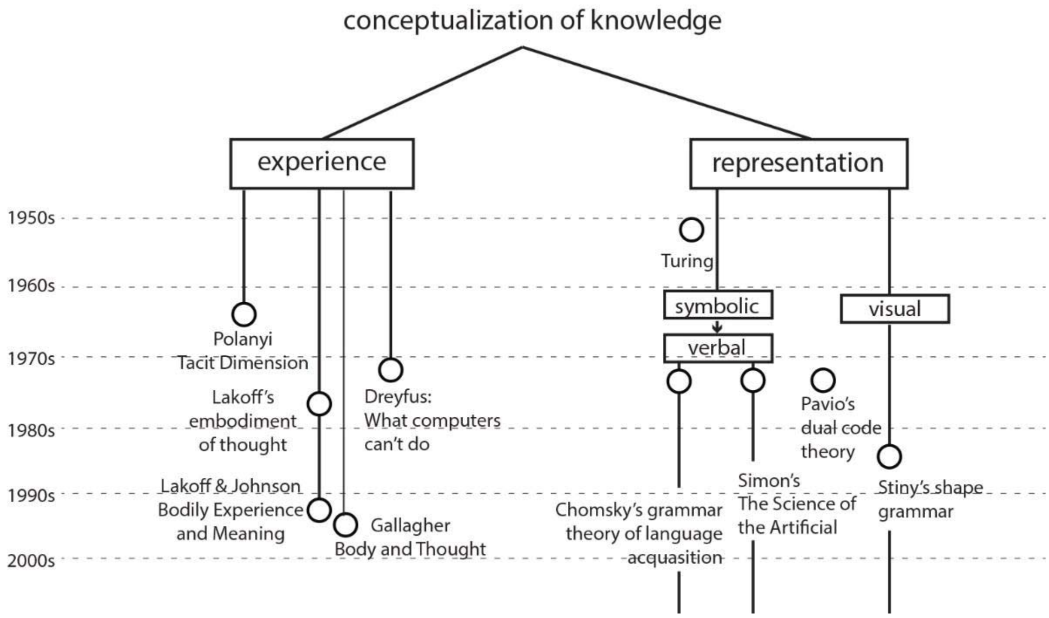


Figure 1.5 : The conceptualisation of the knowledge in the digital era

In order to understand the current situation Picon (2010) compares the recent developments in architecture with what was happening a century ago. Picon asserts that the digital architecture needs to be examined with the phenomenon of the information and the communication technologies (Picon, 2010). Similar with the concerns of the mechanic era, how to translate the information and knowledge to the machine and digital media had been one of the important drives of the computational epoch.

In terms of digital era's polarisation and differentiation in the approaches among the theorists and practitioners, Picon lists "Greg Lynn, William Mitchell, Peter Eisenman, Frank Gehry" on one hand and "Kenneth Frampton and Juhani Pallasmaa" on the other (Picon, 2010). In a wider perspective which consists of names from other disciplines, it is possible to increase these names and the theories.

Alan Turing's "Turing Test", which is based on verbal form of communication, was mentioned in his 1950 article, "Computing Machinery and Intelligence". Noam Chomsky's language theory can be traced back in the 1950s. Chomsky's "Logical

Structure of Linguistic Theory" was published in 1955. Later Chomsky developed the theory of language which allows the translation of one language to another via grammar, syntax and rules. Christopher Alexander's "Notes on Synthesis of Form" was published in 1964, "A Pattern Language" was published in 1977. Simon's "The sciences of the artificial" was published in 1969. Moreover Paivio's "Dual Coding Theory" which considers the nonverbal imagery and verbal processes discretely, was firsly published in 1969. In 1970s, studies on artificial intelligence (AI) increased. Taking a different approach, it is possible to mention the metaphysical and ontological distinction between Dreyfus and Heidegerian point of view on one hand, Simon and Newell on the other hand.

In 1980s, apart from the verbal representation, the visual representation and visual forms of communication gained an acceleration in their progress. There had been a shift in the interest from verbal towards visual. How to translate visual information to the computers became more prominent in 1980s. In that manner, Stiny's theory of the Shape Grammars can be assumed as a reflection of this interest shift.

In 1990s, CAAD (computer aided architectural design) tools were began to be used in architectural design process. In that decade, the usage of the CAAD softwares was replica of the traditial design media. The discourse of digital technology in architecture slowly evolved. "Computers as tools", "computers as media", "computer as partners" were discussed (Schmitt, 1997). Besides CAAD, computer mediated design (CMD) emerged. However, the concern for the disembodiment of knowledge still remained as a main stream approach in 1990s. Today there is a common tendency in to avoid using the term "computer". Instead, the term of the "digital media" provides a more accurate description.

In respect of the relation of body and tools, and the conceptualisation of the body, in the digital era the visual representation becomes much more dominant. Apart from the distinction between the hand and the mind of mechanic era, the fragmentation of the senses emerged. Approaching the senses separately has become the common attitude in scientific reseach. There has been a limited number of people who criticised the reductionist growth of the computational approaches, so to mention, Pallasmaa, Dreyfus, Lakoff and Johnson's embodiment theory, and Gallagher. As a key point of the critics of Pallasmaa, the suppression of hapticity among the other senses has become a problematic for the architects in the digital epoch. Pallasmaa mentions that isolation of senses in the technological realm create experiences like detachment, alienation and solitude (Pallasmaa, 2005).

Considering the detachment of the senses, Pallasmaa also points out the natural "complexity, comprehensiveness and plasticity of the perceptual system" is broken up with seperation and reduction (Pallasmaa, 2005). Pallasmaa states:

> The problem arise from the isolation of the eye outside its natural interaction with other sense modalities, and from the elimination and suppression of other senses which increasingly reduce and restrict the experience of the world into the sphere of vision" (Pallasmaa, 2005).

Considering the dominance of vision, Pallasmaa states that vision can trigger other senses and its importance was more evident in historical architecture than contemporary architecture (Pallasmaa, 2005). He underlines a way to avoid from the dominance of the vision: "The loss of focus can liberate the eye from its historical patriarchal domination" (Pallasmaa, 2005). He also mentions that the design process was adapted into a passive execution process by the demoslishing effects of computer imaging on multi-sensory, simultaneous and synchronic visual handling process (Pallasmaa, 2005).Pallasmaa adds that a distance is created between the maker and the design object by computers. On the other hand the actions of drawing by hand and model-making provides a haptic interaction between the designer, the design object and the space (Pallasmaa, 2005).

The dominance of the vision can be also traced back in the discourse of the 20th century. "I am and I remain an impetinent visual – everything is in the visual" says Le Corbusier (Pallasmaa, 2005). "One needs to see clearly in order to understand" and "I exist in life only if I can see" Le Corbusier expresses (Pallasmaa, 2005). "Architecture is the masterly, correct and magnificient play of masses brought together in light", unquestionably defines an architecture of the eye" (Pallasmaa, 2005). Despite the concrete clarity in the discourse of Le Corbusier on the primacy of vision, Pallasmaa still remarks the tactile and kinesthetic quality of Le Corbusier's skecting and its contribution (Pallasmaa, 2005). Pallasmaa's (2005) opinion about Frank Lloyd Wright:

> The same counter current against the hegemony of the perspectival eye has taken place in modern architecture regardless of the culturally privileged position of vision. The kinesthetic and textural architecture of Frank Lloyd Wright, the muscular and tactile buildings of Alvar Aalto, and Louis Kahn's architecture of geometry and gravitas are particularly significiant examples of this (Pallasmaa, 2005, p. 35).

In brief, there had been a common tendency of dominating the vision in the theories, approaches, and assumptions in 20th century. In the second half of the 20th century this tendency gained acceleration by the impact of development in the information and communication technologies. The disembodied assumptions of knowledge neglected the aesthetic qualities of experience and the spatial dimensions of the experience. The encounter of architecture with the digital world could not become fruitful enough because of the reductionist and disembodied approaching. The communication and interaction between the architect and the digital media remained insufficient, without utilizing both the potentials of the digital media and the potentials of multisensory experience. The theories of knowledge neglected the tacit dimensions of the experience. Moreover, similar with the previous mechanic era, the specialization brought degregation in the architectural practice. The draftsman of the mechanic era, slightly had been transformed into the render operator of the digital era. This is also because, the technological development has not provided architect friendly interfaces

1.2 Ontological Perspectives: "Being for itself" – "Being for Others"

> "...post-Kantian Continental philosophers, in a long tradition which includes Jean-Paul Sartre among others, have considered an investigation of the human body to be indispensable to any account of human reality" (Morris, 2010).

Sartre, writing apropos bodily experience, proposes that two ontological levels emerge called: "being-for-itself" and "being-for- others" (Sartre, 1984). Merleau-Ponty interprets the integration of Sartre's two ontological notions as perception and experience (Pallasmaa, 2005). Pallasmaa underlines the continuous character of interaction of our bodies and our motion with the environment (Pallasmaa, 2009). Young draws attention to Merleau-Ponty's revolutionary step of theorizing consciousness itself as embodied, existing in a tangible encounter with human and nonhuman others (Young, 2005). With this new theory, he reoriented the entire tradition of inquiry by locating subjectivity not in the mind or consciousness, but in the body (Young, 2005). In contrast to the Cartesian duality between the mind and the body, these investigations raise the issue of the dependency and interaction between conscious action and unconscious bodily experience.

In architectural discourse, the writings of Pallasmaa had a major influence on recent discussions on the role of the body and the senses in architectural discourse and teaching (Pallasmaa, 2005; Pallasmaa, 2009). In refence to Kearney, Pallasmaa quotes:

> The notion derives from Marleau-Ponty's dialectical principle of the intertwining of the world and the self. He also speaks of the 'ontology of the flesh' as the ultimate conclusion of his initial phenomology of perception. This ontology implies that meaning is both within and withoıut, subjective and objective, spiritual and material (Kearney, 1994; Pallasmaa, 2005).

Pallasmaa (2005) also mentions Merleau-Ponty's philosophy, which claims that the center of experimental world is human body. He refers to the summary of Richard Kearney that '[i]t is through our bodies as living centres of intentionality that we choose our world and our world chooses us' (Kearney, 1994; Pallasmaa, 2005:40). Pallasmaa quotes from Merleau-Ponty that:

> Merleau-Ponty's own words, 'Our own body is the world as the heart is the organism: it keeps the vsible spectacle constantly alive, breathes life into it ans sustains it inwardly, and with it forms a syste'; and "[s] sensory experience is unstable and alien to natural perception which we achieve with our whole body all at once, and which opens a world of interacting senses" (Merleau-Ponty, 2012; Pallasmaa, 2005).

Kant proposes the concept of "aesthetic activity" in which the sensing subjects constructs spatial relationships and potential links between the sensible and transcendental realms (Rawes, 2008). He also argues that different modes of thinking such as pure intuition, sense-intuitions, technical and aesthetic activities are emerged through experiencing the geometry (Rawes, 2008). Morris points out:

> For us, the interrelation between our identities as living, perceiving, cognising, philosophising beings and the identity of other beings, is manifest as an ontological issue in our expenence of space. This has been shown, for example, by Sartre in Being and Nothingness, Heidegger in Being and Time, and Merleau-Ponty in the Phenomenology of Perception and "Eye and Mind" (Morris, 1997, p.3)

Morris adds:

> The space that we sense has a direction: to sense things as spatial is to have a sense of how things fit into a larger whole that orders the world around each one of us, and this fit is inherent to our sense of space (Morris, 1997).

Sartre (1984) reveals the interrelationship between the touch and being touched that they are seperate types of phenomena and "double sensation" term is an unnecessary attempt to combine them (Sartre, 1984). Pallasmaa underlines the significiance of the multi-sensory experience:

> Every touching experience of architecture is multi-sensory; qualities of space, matter and scale are measured equally by the eye, ear, nose, skin, tongue, skeleton and muscle. Architecture strengthens the existential experience, one's sense of being in the world, and this is essentially a strengthened experience of self. Instead of mere vision, or the five classical senses, architecture involves sevelarl realms of sensory experience which inetarct and fuse into each other (Jay, 1994; Pallasmaa, 2005).

“The world is reflected in the body, and the body is projected onto the world. We remember through our bodies as much as through our nervous system and brain” adds Pallasmaa (Pallasmaa, 2005). As Pallasmaa quotes from Jay, “(Sartre) was concerned with ‘the objectifying look of the other, and the ‘medusa glance’ [which] “petrifies” everything that it comes in contact with” (Jay, 1993; Pallasmaa, 2005). This “medusa glance”, in other words the dominance of the static/frozen vision in which the motion, the kinesthetic experience and the sensation of touch neglected, can be defined as “hegemony of the eyes”. Pallasmaa expresses:

> “The hegemonic eye seeks domination over all fields of cultural production, and it seems to weaken our capacity for empathy, compassion and participation with the world. The narcissistic eye views architecture solely as a means of self-expression, and as an intellectual-artistic game detached from essential mental and societal connections, whereas the nihilistic eye deliberately advances sensory and mental detachment and alienation” (Pallasmaa, 2005, p. 22).

In reference to Merleau-Ponty, Pallasma quotes:

> “My perception is [therefore] not a sum of visual, tactile and audible givens: I perceive in a total way with my whole being: I grasp a unique structure of the thing, a unique way of being, which speaks to all my senses at once’ (Merleau-Ponty, 2012; Pallasmaa, 2005).

Therefore it can be said that the nature of perception and cognitive processes are more complicated than the discrete domination of the vision.

1.3 Epistemological Perspectives: The Unity of Sensory Experience

This chapter is based on epistemological grounds of sensory experience. Deriving from the science philosophy, it is investigated “how” and “how much” one can know about the mechanism of the sensory experience. Beyond the “five senses” assumption, the historical and epistemological origins of the senses and the haptic/tactile/kinaesthetic sense in particular are examined in the light of the unity of the senses.

The term Epistêmê is the Greek word most often translated as knowledge (Url-1). It is a common agreement that the number of the senses are limited (Connor in Serres, 2008). “It is generally agreed that there is a finite number of senses, even though there is much less sameness of report on the precise number than we might expected” says Steven Connor in the introduction of “The Five Senses” (Connor in Serres, 2008). In reference to Soesman, Pallasmaa quotes that “Steinerian philosophy assumes that we actually utilise no less than 12 senses" (Soesman, 1998; Pallasmaa, 2005). Pallasmaa also highligths:

> "Multi-sensory experience, epistemology, 12 senses: "The anthropology and spiritual psychology based on Rudolf Steiner's studies of the senses distinguishes 12 senses: touch; life sebse; self-movement sense; balance; smell; taste; vision; temperature sense; hearing; language sense; conceptual sense; and ego sense. Albert Soesman, (1998). Our Twelve Senses: Wellsprings of the Soul, Hawthorn Press, Stoud, Glos" (Pallasmaa, 2005, p. 77).

In relation to the multi-sensory roots of experience Pallasmaa quotes that:

> The psychologist James J Gibson regards the senses as aggressively seeking mechanism rather than mere passive receivers. Instead of the five detached senses, Gibson categorises the senses in five sensory system: visual system, auditory system, the taste-smell system, the basic-orienting system and the haptic system (Bloomer and Moore, 1977, p. 33; Pallasmaa, 2005, p. 41).

Considering the historical roots of the separation of the senses, Aristotle accepts four senses: "…since he was anxious to correlate the senses with the four elements- vision with water, sound with air, smell with fire and touch with earth, with taste being regarded only as a "particular form" or "modification" of touch" (Beare , 1931; Connor in Serres, 2008). Connor adds the suggestion of Aristotle about the necessity of an intermediate sense between the five other senses (Connor in Serres, 2008). Some drawings of Abidin Dino from one of his exhbitions titled "Edition De Kuxe" which was held in Ankara Gallerie Nev can be seen in Figure 1.6.

Figure 1.6 : The Hand, Abidin Dino, 1984.

In relation to the separation of the senses, the dominance of vision can be dated back to the ancient era. "The eyes are more exact witness than the ears" wrote Heraclitus in one of "his fragments" quotes Pallasma (Pallasmaa, 2005). "Plato regarded vision as humanity's greatest gift, and he insisted that ethical universals must be accessible to 'the mind's eye" (Pallasmaa, 2005). "Aristotle, likewise, considered sight as the most noble of the senses, because it approximates the intellect most closely by virtue of the relative immateriality of its knowing" (Pallasmaa, 2005).

Connor expresses: “Democritus, who explain sensation by the friction of the atoms of different shapes and sizes, thought that all the senses were really only variations of the one sense of touch” (Connor in Serres, 2008). Moreover Pallasmaa adds: “Aquinas even applies the notion of sight to other sensory realms as well as to intellectual cognition” (Pallasmaa, 2005).

2. THEORIES AND CONCEPTS ON EMBODIMENT

The term embodiment inherits its conceptual roots from the Continental Philosophy, in particular from the works of Merleau-Ponty. It is a well established concept which has been used in different contexts in various disciplines. The common denominator of different approaches is the phenomenal assumption of body, apart fom the subjective assumption of body. In the Cambridge Dictionary of Philosophy, in relation to the term embodiment it is written that:

> The distinction between the objective and phenomenal body is central to understanding the phenomenological treatment of embodiment. Embodiment is not a concept that pertains to the body grasped as a physiological entity. Rather it pertains to the phenomenal body and to the role it plays in our object-directed experiences (Audi, 1999).

The concept of embodiment has been influencial in various theories and concepts. Gallagher states that there is a widespread claim in varying disciplines about the necessity of embodiment for the comprehension of cognition (Gallagher, 2005). Embodied cognition theory, proposes that bodily experience plays an important role in constituting our way of thinking. We acquire and perceive data through bodily communication with the physical environment. Gallagher associates body and experience within embodiment:

> The human body, and the way it structures human exprience, also shapes the human experience of self. If the self is anything more than this, it is nonetheless and first of all this, an embodied self (Gallagher, 2005, p.14).

Using Atkinson's "inseparability of body-mind-world", body, mind and the environment that one interacts with are seen as inseparable parts of embodied cognition (Atkinson, 2010). Seitz's (2000) concept of the "embodied mind" postulates the bodily basis of thought. This is in contrast to classical cognitivist and connectionist theories, which rely on Cartesian disembodiment of mind (Seitz, 2000). Thompson presents a phenomenological perspective that goes beyond the previous computational theory of mind (Thompson, 2007). Thomas and Banks, in their Encyclopedia of Consciousness, address different theories concerning imagery, such as picture, description and enactive theory (Thomas and Banks, 2009). In addition to these, the concept of “embodied interaction”, introduced by Dourish, refers to how one creates meaning in the world through embodied practice within it (Fogtman, 2012; Dourish, 2004; Schick and Malmborg, 2010; Penny, 2010).

2.1 Embodiment of Experience in Architecture

Embodiment of the experience can be discussed under an infinite number of titles in the context of architecture. However, within the scope of this dissertation, I aim to indicate the necessity for unfolding discussions on embodiment, instead of explaning them one by one. In a broader sense, experience is embedded in time, space and body. The two dimensions of experience, space and time are folded with/in body. Time makes the space spatial. In other words, space, time and embodied experience are the complementary dimensions of each other. In the context of architectural design, not only the design representations and their locations in the space but also the bodily dimensions of experience become important. Here the term “bodily experience” refers to both sensory and cognitive dimensions of experience. However, beyond the realtime sensed experience, there is also a non reductable whole. This nonreductable holistic experience includes the collection of experiences since the early childhood. To mention but not to extend, bodily experience has also cultural, social and biological roots.

In reference to Merleau-Ponty, Morris expresses that:

> “Merleau-Ponty has shown that perceived space has a meaning for our embodied being in the world, that space is sensed around us. To understand this is to understand that our perceptual relation to a space of things and others beyond us cannot be rooted in a fixed, abstract and idealised connection between our senses, our mind and dimensions that are fixed beyond us” (Morris, 1997, p. 7).

Pallasmaa argues that “architecture articulates the experiences of being-in-the-world and strengthens our sense of reality and self; it does not make us inhabit worlds of mere fabrication and fantasy” (Pallasmaa, 2005). Vroman et al. (2011) discuss how/if tacit dimensions of embodied experience and movement provide spatial awareness through dance for architecture. Morris underlines the relation between the topology of the lived body and our sense of space (Morris, 1997). Kotnik introduces bodily experience as a key concept in understanding geometrical knowledge, essential in the age of computation (Kotnik, 2013).

2.1.1 The primacy of touch

> "It is strange that the tactile sense, which is so infinitely less precious to men than sight, becomes at critical moments our main, if not only, handle to reality".
> Vladimir Nabokov (quoted in Bliss, 1961).

The sense of touch is one of the oldest senses among all (Pallasmaa, 2005). This is why from an evolutionary point of view, it always has an important role. Serres underlines the importance of pure touch which allows these access to information and it provides a soft correlate of what was once called the "intellect" (Serres, 2008). In respect to the primacy of touch, Pallasma asserts that: "The primacy of the tactile sense has become increasingly evident. The role of peripheral and unfocused vision in our lived experience of the world as well as in our lived experience of interioty in the spaces we inhabit [..] " (Pallasmaa, 1996). Ashley Montagu, the anthropologist, based on medical evidence, confirms the primacy of the haptic realm:

> "[The skin] is the oldest and the most sensitive of our organs, our first medium of communication, and our most efficient protector… Even the transparent cornea of the eye is overlain by a layer of modified skin … Touch is the parent of our eyes, ears, nose, and mouth. It is the sense, which became differentiated into the others, a fact that seems to be recognized in the age-old evaluation of touch as 'the mother of the sense'" (Montagu, 1986; Pallasmaa, 2005).

Pallasmaa adds that senses including vision are different specialisations of tactile senses and touching and tactiliy creates the different types of sensory experiences (Pallasmaa, 2005). From the perspective of neuroscience Millar (2006) states that:

> Traditional division of sense modalities into "proximal" and "distal" senses has had a considerable influence on the view that visuo-spatial concepts differ radically from spatial concepts derived from touch. Touch has typically been considered as a proximal sense, because the stimuli arise from direct contact of objects with the body.

2.1.2 Reflection-in-"inter"action

The cyclical relationship between physical action and thought process has been emphasized by Klemmer et al., using the concepts of "thinking through doing" and "thinking through prototyping" . In addition, they underline the role of artifacts providing tacit and tactile "backtalks" (Klemmer et al., 2006).

Streeck examines the interaction of body in the context of sight based perspective by highlighting "…the need for a more comprehensive and holistic conception of the interacting body by pointing to a handful of aspects that are not easily accomodated to our customary, vision-based accounts" (Streeck, 2013). Although Streeck (2013) mentions and focuses on "vision-based account" he does not neclect the holistic nature of interaction involving hapticity:

> "Among these aspects are the body's skilled familiarity with the material world (embodied knowledge); the role of the ''haptic system'' (Gibson, 1966) in the production of embodied knowledge; kinesthesia; and the heterogeneity of the ways in which bodily actions contribute meaning in social interaction" (Streeck, 2013).

Streeck claims that he does not want to bring a new conception of the human body into forth, instead he discusses the underlying reasons of necessity of a holistic conception (Streeck, 2013). He adds:

> "My aim is not to provide a new conception of the human body in interaction, but simply to provide arguments why it is needed and make suggestions where elements of a holistic conception can be found. How we can study the moment-by-moment production of intersubjective understanding and concerted action in a fashion that accounts for phenomena presumed to be ''internal'' such as kinesthesia (the subject's perception of his or her own movements) while maintaining rigorous standards of observability, is a question that is beyond the scope of this paper and will have to be answered by future research" (Streeck, 2013)

Greeno quotes that an interactionist view of perception and action focusing on information that is available in the environment was developed by Gibson (Greeno, 1994). He adds Gibson's discussions on perception of motion and movement (Greeno, 1994).

2.1.3 Tacit knowledge

The concept of "tacit knowledge" was first proposed by Polanyi who used the term to refer to knowledge that a person has in her ability, but she might not be able to express explicitly (Polanyi, 1958; Long, 2011). Polanyi's concept of the "tacit dimension", takes its root in Gestalt psychology and is in the intellectual tradition of Husserl's phenomenology, Heidegger's "dasein" and Sartre's existentialism concepts (Long, 2011). One of the significant contributions of Polanyi is that he brought implicit and tacit dimensions of knowledge into the discussion on classical computational theory (Long, 2011). Polanyi's contribution made it possible to deal with the implicit dimension of knowledge, which is not represented verbally but rather derived from the living experience of one's body. Furthermore, Gallagher clarifies arguments on the ‘non-reductionist science of the embodied mind’ by conducting a phenomenological investigation (Gallagher and Schmicking, 2010).

Regarding theories on imagery, Seitz (2000) deals both external mental imagery and internal kinesthetic imagery in which muscle memory and kinesthetic experience play an important role.

2.1.4 Experience with/in the space

According to Pallasmaa, the exchange between the space and self in art takes place by leaving the emotions of self through space and letting the space liberate perception and thought (Pallasmaa, 2005). The experience is consitutued in the space and in relation with the space. Therefore it is not a static image. Instead, experience is embodied. It is embedded in space, time, memories and the perception. The spatial dimensions of experience involves preconscious perception too. In the context of the dominance of vision dominance, Pallasmaa says that both focused image and the ‘preconscious perceptual realm’ experienced outside the sphere of the focused image are equally significant for existance (Pallasmaa, 2005).

Taking orientation and motion into consideration Morris says:

> We do not perceive space itself as such, but every thing and person that we perceive, we perceive as being in space and as having spatial dimensions: other people and things appear in depth and have depth, height and width, as well as an orientation; and our bodies have a height, depth, width and orientation for others and for ourselves. (Morris, 1997)

Morris also adds the we exist with things in the space together, where the spatiality of each can be sensed by moving around them and they moving around us (Morris, 1997).

Before assuming the image-schema as an abstract, cognitive structure, we need to consider its embodied roots (Johnson, 2008). At this point, a dialectic approach is needed to study the interaction between abstract conceptualization and reasoning processes with concrete bodily experience. Image schemas constitute an important part of our unrepresented world and thoughts, in addition to our sensory-motor experience (Johnson, 2008). Image-schemas function as activation patterns in the topological nervous system maps (Johnson, 2008). Studies in neurology support this argument. For example, in a study conducted by Rizzolatti and Craighero in 2004 on monkeys, it was observed that after seeing a picture of a monkey holding a banana, the related neurons of the observing monkey would be stimulated (Rizzolatti and Craighero, 2004;

Johnson, 2008). The phenemenon of the stimulation of the neurons involved in the execution of action being observed in other humans or animals was coined “mirror neurons” by Rizzolatti and Craighero (Rizzolatti and Craighero, 2004).

2.2 Embodied Cognition Theory

The theory of embodied cognition is based on the assumption of interrelationship between the high-level cognitive activities and the low-level sensory-motor activities. The main difference from the traditional theory of mind is, in embodied cognition the conscious self is taken into account as an experiencing agent located in the world. Therefore the theory of embodied cognition proposes the hoılistic assumption of the mind and the body. In this part I explain Lakoff and Johnson’s theory of image schema and the related concepts.

2.2.1 Body image, body schema and image schema

The first source in architecture to refer to the body-image theory is considered to be Bloomer and Moore’s “Body, Memory, Architecture” published in 1977. They stated that body image develops with ‘haptic and orienting experience’ in earlier stages of life than the visual images which depends on the previous haptic experiences (Bloomer and Moore, 1977; Pallasmaa, 2005).

Bloomer and Moore state that the term “body-image,” or the term “imagery” in its extended meaning, already includes the concepts of “body-perception” and “body-schema” (Bloomer and Moore, 1977). They state that “For our purpose we mean to accept the body-image as the complete feeling, or three dimensional Gestalt-sense of form- that an individual carries at any one moment in time - his spatial intentions, values, and his knowledge of a personal, experienced body” (Bloomer ve Moore, 1977). As for their body-image schemas, they list schemas such as “up/down”, “front/back”, “right/left” and “here-in-the-center” (Bloomer ve Moore, 1977).

Going all the way back to 1890s to study their etymological and historical roots, Gallagher uncovered the historical roots of this concept and clarified the difference in the meaning of “body image” and “body schema”, Johnson subsequently used the term “body schema” to refer to recursive mental patterns of the cognitive process (Gallagher, 2005; Johnson, 2007). Lakoff and Johnson (1980) argue that while at the conscious level the thinking process is linear, there are parallel mechanisms that are bound to the thought process simultaneously and unconsciously.

Having referred to the concepts of "body-schema" and "body-image" in their prior work and having developed the term "image schema", Lakoff (1987) and Johnson (1987) have also adapted to Gallagher's suggestions . Body schemas were described as "sensory-motor capacities that function without the awareness or the necessity of perceptual monitoring" (Galllagher, 2005: Johnson, 2008). Johnson highlights that in addition to this, the body schemas govern the tacit performances that operate below the level of self-refential intentionality, at the preconcious level (Johnson, 2008). Therefore, "our perception, bodily movement and kinesthetic sensibility" can operate at the preconscious level, in an integrated and spontaneous way (Johnson, 2008). For body-schema, Merleau-Ponty gives the example of reaching over to something using gestures (Merleau-Ponty, 2012). Body image, on the other hand, is described as "a person's perception, behavior and belief system about one's own body" (Gallagher, 2005; Johnson, 2008).

2.2.2 Lakoff and Johnson's theory of image schema

Lakoff (1987) and Johnson (1987) have contributed to the embodiment theory with their concept of the "image schema" (Lakoff, 1987; Johnson, 1987). This concept lies at the foundation of the sensory motor experience, which encounters a world that we comprehend and participate in through our executive functions (Johnson, 2008). In other words, according to Johnson, at the basis of all aspects of perception, motor activities and our understanding of spatial terms, lies the image-schematic structure (Johnson, 2008). Johnson adds the contours of our lived world are defined by recurring structures like up-down, front-back, near-far, in-out, on-under (Johnson, 2008).

In addition to these, Lakoff and Johnson (2008) state that abstract concepts are derived from spatial orientation concepts that can be bodily experienced. They explain that physical experience and experiencing the world physically and culturally using the body lies at the roots of spatial orientation concepts, such as up/down, in/out, front/back, open/closed or center/periphery. Based on this premise, they state that, although it could show cultural variations, abstract terms such as good/bad or happy/unhappy can be paired with orientation terms such as up/down. They add, for example, "a lot" would suggest a higher ground, or "little" would suggest a lower ground. They also have shown how the future events are “ahead of us”, whereas the past is “behind us” (Lakoff and Johnson, 2008). Some of the basic image schemas of Lakoff and Johnson are listed below.

- Containment: interior-exterior-boundary;
- Source-path-goal;
- Motion.

The containment schema has a spatial character. It works in connection with other spatial image schemas. According to Johnson, in its simplest terms, it contains abstract borders, and an inner and an outer part. It is created at a subconscious level at various types and scales, based on the interaction between our body, mind and environment (Johnson, 2008). It helps us understand and interpret any given scene in the world.

The source-path-goal schema consists of three components: “(i) a starting point, (ii) a destination (end point), (iii) a path from the starting location to the destination” (Johnson, 2008). The destination point is mapped as the interior of the containment schema (Johnson, 2008).

Motion schema relates to bodily movements through space and, manipulations of objects (Johnson, 1987). Apart from these basic image shemas, Johnson (1987) introduces body schemas under the titles of (i) spatial motion group, (ii) force group, (iii) balance group (Johnson, 1987).

2.3 Embodied Interaction Theory

The concept of “embodied interaction”, introduced by Dourish (2004), refers to how one creates meaning in the world through embodied practice within it (Fogtmann, 2012; Dourish, 2004; Schick, 2010; Penny, 2010). Dourish (2004) explains the term he introduced as :

> “Embodied interaction an approach to interacting with software systems that emphasizes skilled, engaged practice rather than disembodied rationality reflects the phenomenological approaches of Martin Heidegger, Ludwig Wittgenstein, and other twentieth-century philosophers. The phenomenological tradition emphasizes the primacy of natural practice over abstract cognition in everyday activity. He looks in particular at how tangible and social approaches to interaction are related, how they can be used to analyze and understand embodied interaction, and how they could affect the design of future interactive systems” (Dourish, 2004).

The theory of embodied interaction has become one of the key references for the studies in the context of tangible and full body interaction. Based on Dourish's theory of embodied interaction, Fogtman (2012) introduced kinesthetic empathy interaction. Kinesthetic empathy does not focus on the manupulation of the object by digital media but instead on the existence of body in space. Therefore, Fogtman (2012) extends the spatial dimensions of the interaction by counting body. Therefore, Fogtman (2012) extends the spatial dimensions of the interaction by counting bodies. Fishkin et al. examine the interaction issue as a mimic of our interaction with the physical world (Fishkin et al., 1998; Fogtman, 2012). Arguing from a phenomenological perspective, Larssen et al. (2007) propose the concept "The Feel Dimension" to study embodied interaction in a holistic sense. "The Feel Dimension" consists of four different aspects: body-thing dialogue, potential for action, action in space and movement expression (Fogtmann, 2012; Larssen et al., 2007). Klemmer et al. reveal how bodies play important role in the interaction process with the digital environment and they introduced five themes for interaction: "learning through doing", "performance", "visibility", "risk" and "thick practice". They evaluate the role of the gestıres under the title "learning by doing" (Klemmer et al., 2006).

Figure 2.1 : Mental model for usage of GUI (Klemmer et al., 2006; Igoe and O'Sullivan, 2004).

As it can been seen in Figure 2.1, within the interaction with graphical user interfaces there is loss of tactile dimension. The hand loses its main function in the interacting with the world and become one dimensional. There is a dominance of visual perception. However, the hand and gestures play a crucial role in the motor and the sensory level of perception (Figure 2.2).

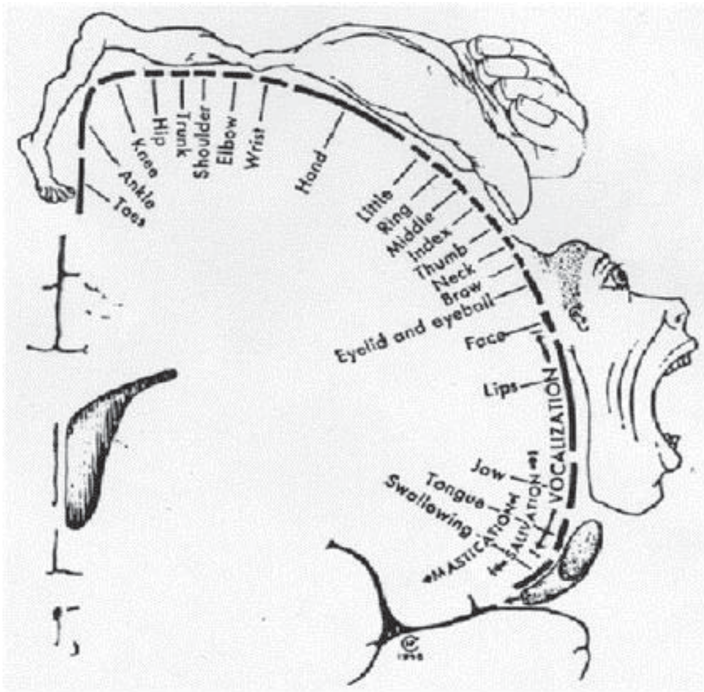


Figure 2.2 : Model for the primary motor area (Url-3).

Hurtienne et al (2010) and Hurtienne (2011) introduced a comprehensive study and developed evaluation criteria for digital user interfaces by utilizing image schemas. Hurtienne's methodology covers the dimension of visual perception by evaluation graphical use interfaces (Hurtienne, 2011). Different from his study, the scope of this dissertation is focused on the nonvisual and nonverbal aspects of thought.

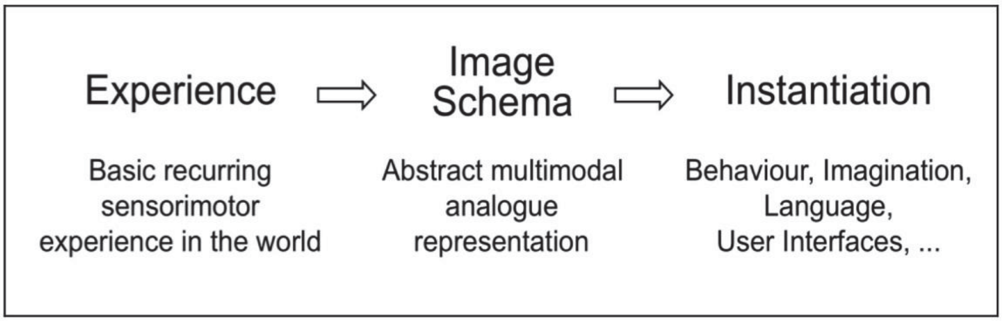


Figure 2.3 : A model for "Acqusition, representation and instantiation of image schemas" by Hurtienne (Hurtienne, 2011).

Fishkin asserts there will be change towards embodied and invisible uuser interfaces. From an evolutionary perspective, today it is possible to say Fishkin's 1999 paper is a pioneering work which is still partially valid (Figure 2.4; Fishkin, 1999).

Keyboard UI —>
  Graphical UI (GUI) —>
    Gestural UI —>
      Tangible UI —>
        Embodied UI —>
          ... invisible user interface

Figure 2.4 : Evolution of computer user interfaces (Fishkin, 1999).

Fishkin (1999) focuses on the question how to extend the richness and intuitiveness of the interaction experience. He proposes traceble overlaps between the world and the digital devices (Figure 2.5).

Real-World Task	Device-Embodied Task
Physical objects	Physical device
Real properties of objects	Represented objects & properties
Manipulations on objects	Manipulations on device *sensors on device* *input grammar and interpretation*
Feedback from objects	Feedback from device and representation

Figure 2.5 : A framework for user interface design (Fishkin, 1999).

Clifton (2014) introduces guidelines for designin tangible and embodied user interfaces which support the user's spatial abilities. Clifton uses the existing scales and methods in psychology. In this dissertation, different from Clifton I attempt to integrate some existing taxonomy of McNeill for gestures, and image schemas of Lakoff and Johnson but I do not use specialized methods of psychology to evaulate the spatial abilities of users.

To sum up, in the field of human-computer interaction there are a few attempts to improve the quality of interaction by counting bodily dimensions of experience. However the reflection of the theory of embodied interaction into the implications for the digital environments is insufficient.

3. NONVERBAL AND NONVISUAL FOUNDATIONS OF THOUGHT

3.1 Sensory Foundations of Thought

There have been a number of important studies on nonverbal foundations of thought and imagery in terms of tactile, haptic and kinesthetic experience (Bliss, 1961; Hatwell et al., 2003; Laban, 1966; Mandler, 2004; Mandler, 2012; Seitz, 2000; Sheets-Johnstone, 1999; Sheets-Johnstone, 2010); gestures (Ekman and Friesen, 1969; Goldin-Meadow, 2005; McNeill, 1992; Wilson, 1998); and dual codification as verbal and visual (Paivio, 1971; Paivio, 1990; Thomas and Banks, 2009). In this chapter I aim to discuss some key concepts of tacit foundations of conceptual thinking in three subtitles conducted with hapticity, motion and hand gestures.

3.1.1 Haptic experience in childhood

From early period childhood, humans constitute bodily experience by interacting with the world. “In the beginning, that is, at the time of our birth, our human capacities for perception and behaviour have already been shaped by our movement” says Gallagher (2005). Mandler focuses on the first year and particularly the first 6 months of the infant development (Mandler, 2012). Observing infant development, she presents spatial foundations of conceptualization (Mandler, 2012). She mentiones that image-schemas contain iconic qualities (Mandler, 2012). Mandler introduces perceptual meaning analysis (PMA) concept, asserting that during the conversion process from the unstructured sensory information through the form of image-shemas we perceive and make meanings depending on space, in other words this process happens in nature with spatial qualities (Mandler, 2004; Mandler, 2012).

Moreover, rooted in the early childhood development, the concept of “movement” constitutes a basis for manipulation of kinesthetic ideas (Seitz, 2000; Laban, 1966; Leiner et al., 1986).

3.1.2 Kinesthetics

In the Cambridge Dictionary (Url-4) the term “kinaestasia” is defined as: “the ability to know where the parts of your body are and how they are moving”. The term “kinesthetics” is also used instead of “kinaestasia” in the English of the United States. The sense of kinesthetics is strongly connected to the perception of proprioception which consists of the meaning of unconscious perception of movement and spatial orientation (Url-5). Within the scope of the dissertation the concept of kinesthetics is important. This is because hand gestures can be considered as interfaces that mediate the communication between the self and the world in terms of kinesthetic and tactile sensation particularly in the conventional design process.

Bliss underlines their spatial dimension of the kinesthetic and the tactile senses (Bliss, 1961). Bliss defines three aspects in relation to the sense of kinesthetics:

- Recognition of position;
- Active and passive movement;
- Resistence to movement (Bliss, 1961).

In relation to the passive movement, Bliss (1961) reports that:

> For information transmission by passive movement, there are several advantages to applying the stimuli to the hand. The hand is one of the most sensitive parts of the body; it has many degrees of freedom, and its size is such as require equipment of moderate size and power.

Bliss (1961) adds that direction in 3 dimensional space is another important aspect of the passive movement which is acquired by hand gestures. Another researcher, Seitz, deals with external mental imagery and also with internal kinesthetic imagery which involves muscle memory and kinesthetic experience (Seitz, 2000).

Çelik (2006) uses the term “kinaesthesia” in reference to the sense of bodily movement. She underlines that the sense of bodily movement had been studied under different the names such as “inner sense” and “organic” or “visceal” sensibility until the nineteenth century (Çelik, 2006). She says: “It was not until the early nineteenth century, however, that ‘muscle sense’ was officially declared a ‘sixth sense’ in its own right” (Çelik, 2006). Sheets-Johnstone deals with the kinesthesia concept as an awareness of “qualitatively felt kinetic flow”. Sheets-Johnstone (2010) applies the phenomenological approach to exhibit the felt qualities and patterns of body movement, and after analyzing kinesthetic consciousness, she suggests that “tension”, “linearity”, “amplitude”, and “projection” are the four primary qualities of body movement (Sheets-Johnstone, 2010).

Laban introduces the concept of “choreutics” to indicates the relationship between movement and perception (Laban, 1966). He asserts: “Space is a hidden feature of movement and movement is a visible aspect of space. We must not look at the locality simply as an empty room. Continuous flux within the locality itself” (Laban, 1966). Petit highlights the living and dynamic foundations of experience through the etymological investigation of the concept of ‘kinesthesia’, which covers the sensation mechanism of moving body, and he proposes the idea of blind preverbal, implicit and immanent knowledge of daily experience (Petit, 2010).

3.1.3 Hand Gestures

> “Architecture is also a product of the knowing hand. The hand grasps the physicality and materiality of thought and turns it into a concrete image” (Pallasmaa, 2009, p.16).

Recent research in neuroscience suggests that spatial tasks are executed in more complex relations than was previously assumed, via multiple, distributed areas of the brain and using complex connecting circuits (Millar, 2006). Therefore it is extremely difficult to evaluate the impact of each modality separately (such as tactile, visual, etc). On the other hand, “touch” and “movement” can be considered as an important basis of spatial coding where hand gestures play a fundamental part (Millar, 2006). In addition, hand gestures both guide and govern meaning making during interactions with artefacts and convey non-verbal, spatial knowledge. Using the gestural taxonomy of McNeill, Gullberg (1999) designs an experimental setup with two participants, where one of the participant was asked to look at a 2D stimulus image of a narration and describe it; the second participant was asked to draw, based upon this description (Gullberg, 1999). Gullberg reports that even though there was no clear structure to the speech and thought the drawer could see the narrator, the “deictic” gestures played an important role in mapping spatial relations explicitly, revealing spatial orientation and directions of the given 2D image (Gullberg, 1999). In addition, gestures helped understand dynamic concepts, motion and action in a more effective way (Kang, et at., 2012).

3.2 Bodily Experience and Metaphors

Lakoff and Johnson investigate how the bodily experience affects the constitution of language, by criticizing dominant thinking about meaning in Western philosophy (Lakoff and Johnson, 1980). They showed that the constitution of abstract concepts is related to bodily experienced spatial orientation concepts (Lakoff and Johnson, 1980). Johnson (2007) states that "movement" is one of the principal ways by which people learn the meaning of things and acquire an ever-growing sense. Gentner (2001) reveals that existence of spatial metaphors in linguistic levels during temporal reasoning (Gentner, 2001).

3.3 Bodily Experience in the Conceptualizing Process

Borodistky (2000) and Borodistky et al. (2001) propose that abstract conceptual domains are structured through metaphorical mappings of experience and that the perception of time is related to the experience as well (Borodistky, 2000; Borodistky et al., 2001). Regier and Carlson (2001) demonstrate the constitution of spatial expressions in six different languages and concluded that they are all based on bodily experience. Casasanto (2005) explores the perceptual ground of abstract thought. It is argued that body is a central to mathematical understanding (Seitz, 2000; Lakoff and Nuñez, 2000), that speech and gesture form parallel computational systems (Seitz, 2000; McNeill, 1996; McNeill, 2005).

3.4 Bodily Foundations of Spatial Thinking

Trafton et al. (2006) examine how spatial language can be gestured and which spatial aspects affect iconic gesture production. Golledge (1995) proposes four spatial primitives: identity, location/relation, magnitude and time in respect to the relation between human cognition and spatial language (Golledge, 1995; Trafton et al., 2006). The term "spatial relationship" was used by Ekman and Friesen (1969) to denote "On which the movement indicates distance between people, objects, ideas" (Ekman and Friesen, 1969: 62). In this sense, the term is also intimately related to abstract and conceptual ideas as well, apart from the location of physical object in the space. In addition to these, as a reflection of gesture studies in the domain of architecture, there exists few studies in this matter (for an historical overview see:

Visser and Maher, 2011). Borodistky (2000) and Borodistky et al. (2001) propose that abstract conceptual domains are structured through metaphorical mappings of experience and that the perception of time is related to experience as well (Borodistky, 2000; Borodistky et al., 2001). Regier and Carlson (2001) demonstrate the constitution of spatial expressions in six different languages and concluded that they are all based on bodily experience (Regier and Carlson, 2001). Millar (2006) addresses the question how we process the spatial information.

4. BODILY EXPERIENCE IN PROTOCOL STUDIES

Since the introduction of the protocol analysis method by Eastman in 1969, numerous contributions showing how designers think and the way in which researchers can measure design activity or cognitive activities of designers have been made to the field of design studies. We have attempted to use phenomenological method to explore how designers constitute spatial and abstract ideas during a modeling task. In our literature review, we examined the codification schemas of spatial ideas, abilities and segmentation of bodily experience.

4.1 Overview of the Protocol Studies in Design Thinking

Protocol analysis methods are now regularly used in design research. These methods provide an analytic approach to breaking down the design process. The act of design is a highly complex one; Breaking down the act into components is important to a thorough understanding of it. The reductions, even if they do not permit us to understand the nature of the design process or all the relations that constitute it, allow us to focus on specific aspects of the process. Several different protocol analysis methods and approaces have been developed.

● The 'Concurrent' or 'Think aloud' method: In this method which utilizes short term memory recall, the designer is asked to verbalize her/his thoughts during the design process. This method was introduced by Ericson and Simon (Ericson and Simon, 1993). This method has been criticised for being artificial and for interfering with the natural flow of thought (Lloyd, Lawson and Scott, 1995).

● The 'Retrospection' protocol: Participants are recorded during the design process, shown the video recording and asked to describe their thoughts at relevant points in the video. This protocol taps into and utilizes the long term memory of the participants. (Suwa and Tversky, 1997).

Cross et al. (1994) divided the student activities into three parts as: Information gathering, sketching and reflecting. Goel (95) suggested that sketches help the designer to make not only ‘vertical transformations’ in the sequential development of a design concept, but also “lateral transformations” within the solution space: the creative shift to new alternatives. Another classification is that process-oriented and content-oriented protocol analysis, as it can be seen in Table 4.1.

Table 4.1 : Classification of protocol studies in design thinking.

Process-Oriented	Content Oriented	
	Goal-driven Newell and Simon (1977)	Sensor-driven Schön (1983)
	What designers see and what do they possibly think? Interaction with external representation in the early phases of design process. Larkin and Simon(1987); Suwa ve Tversky (1997)	
	Sketch-Inspect-Revise Loops Inspection phase, “seing as, seeing that” “Why are sketches a good medium for reflective conversation with one's own ideas and imagery? (Goldschmidt, 1991).	

4.2 Segmentation of the Bodily Experience

In Figure 4.1, an overview of the protocol studies which focus on either segmentation of spatial aspects or segmentation of bodily experience can be seen. Charles observes the role of bodily experience during the design process intuitively without initial assumptions by looking at what designers draw, say, do and gesture (Charles, 2000).

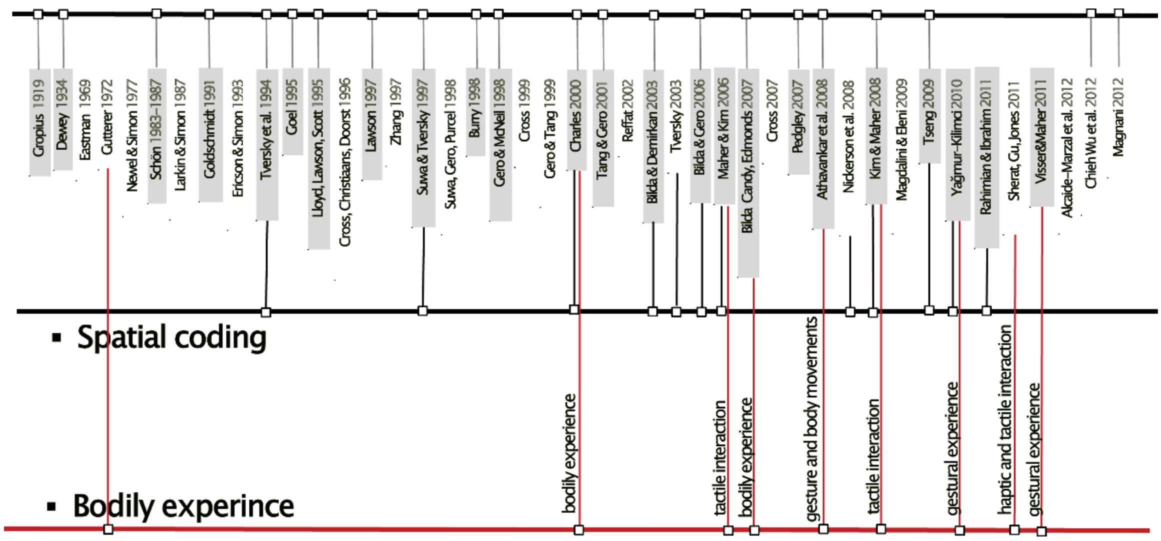


Figure 4.1 : Segmentation of bodily experience in protocol studies

Athavankar et al. (2008) compare the architectural space image constructed in the mind and the space physically experienced using the ‘thinking aloud method’ to produce a verbal transcript. Along with this verbal transcript, body and hand gestures are used as data source for analysis (Athavankar et al., 2008). Visser and Maher (2011) summarize the state of art on the role of gestures in the design process of an editorial presentation.

Table 4.2 : Athavankar's segmentation of speech, gesture and body movements (Athavankar et al., 2008).

Time	Transcript	Gesture & Movements
00:33:16	A3: **I** want the entry for this hangout place	Hands in front
00:33:20	A3: so **I** am entering this site	Walks with small steps
00:33:30	A3: now *this will be entrance pathway* to the…. that complex.. pause ….. Now	Both hands in front folded horizontal to ground
00:33:48	A3: on both side of **me** there will be the landscape areas	Hands down, slightly away from body showing sideways

As it can be seen in Table 4.2, Athavankar et al. compare the verbal and gestural content. In the comparison they include the body movements as well. The method for extracting verbal content is basicly asking the question of "Wh"re are you now?". The participanr were expected to answer this question and their both gestural and bodily movements were analysed by (Athavankar et al., 2008).

In respect to hand gesture, different classifications are shown in Table 4.3.

Table 4.3: Sample analysis of bodily experience

Miller (1956)	Limitations of short term memory
Seemüller (2010)	Form, geometry and location as a perceived kinethtetic properties
Lederman & Klatzky (1993)	Classifications of intentional hand movements during extracting object properties by haptic exploration
Savini et al. (2010)	Passive haptic sensation and perception objects
Lederman &Klatzky (1993)	Objects and their relation with the environment
Athavankar v et al. 2008)	Comparison of verbal data and gestures
Milner (1962); Blakemore (1977); Solso et.al. (2011)	Mirror experiment, repetititon, perception of space which is able to be improved through repetition
Suwa ve Tversky (1997).	Segmentation of design process and spatial data

4.3 Classification of Gestures

The gesture classification of McNeill is used within the scope of this dissertation. McNeill (1992) makes a comparision table between the type of the gestures he introduced and the earlier classifications ın gesture (Table 4.4).

Table 4.4 : McNeill’s comparison of different gesture categories.

Present Categories	Efron	Freedman and Hoffman	Ekman and Friesen
iconics	physiographics kinetographics	literal-reproductive	kinetographs pictographs
metaphorics	ideographics	concretization minor and major qualifying	ideographs underliners spatials
deictics	deictics		diectics
beats	batons	punctuating	batons rhythmics
Butterworths		speech failures	

4.3.1 McNeill’s classification of gestures

McNeill (1992) classifies gestures under four main groups: (i) iconic, (ii) metaphorical, (iii) deictic and (iv) beats (McNeill, 1992).

4.3.1.1 Iconic gestures

The term “iconic gesture” was first used by McNeill and Levi in 1982 (McNeill and Levi, 1982). The semantic content of the verbal expression and the iconic gesture is required to have a formal relationship (McNeill, 1985). These iconic gestures are those that express concrete beings and/or actions and convey semantic content that has a formal or pictoral representation (McNeill, 2005). McNeill lists drawing a trajectory through hand gestures, grabbing an object that has width or pointing out to a direction as iconic gestures (McNeill, 2005). The iconic gestures include the “kinetographic” and “pictographic” categories suggested by Ekman and Friesen (1972) (Ekman and Friesen, 1972; McNeill, 1992). Therefore, they can correspond to the portrayal of a bodily movement or a drawing in the air for the content referred to.

4.3.1.2 Metaphoric gestures

Metaphoric gestures differ from iconic gestures in expressing semantic content that refers to abstract concepts, memories or thoughts. In McNeill's words, they are the "images of the abstract", and they match the concrete gestures that carry pictorial quality with a content that carries metaphorical content (McNeill, 2005).

4.3.1.3 Deictic gestures

Deictic gestures refer to those that involve pointing to a certain place in an area using the index finger, but sometimes, the head, nose, eyebrows or feet can accompany the deictic gesture. (McNeill, 2005). Deictic gestures are among the first gestures to be learned in children (Bates ve Dick, 2002; McNeill, 2005). However, in adults, they are used more often to point to abstract concepts rather than entities in a physical environment (McNeill, 2005). Such abstract deictic gestures are considered to be a sub-group of metaphorical gestures (McNeill, 2005).

4.3.1.4 Beats gestures

Beats gestures are used while breaking down a verbal narration into pieces (McNeill, 2005). Two types of beats gesture were observed, beats with and without spatial qualities. Some of the gestures were directing a side such as left or right part of the participant. Other type of beats were nıt invoving a directional or orientational quality and executed as a repetition of the same movement.

4.3.2 Other classification for gestures

When verbal content and gestures are compared, the meaning may not match. For situations wherein a gesture corresponds to a word that is expected to come at a prior time or at a later time in a speech, McNeill (2005) uses the term "offset". An analysis conducted specifically for Turkish can be seen in Table 4.5. In this table, the the gestural movements indicate the next part of the speech. For example, where the participant says "top bi şekil-<u>de"</u>, her/his hand simulates the movement of hopping (Table 4.5).

Table 4.5: Offset in the meaning in the correlation of verbal and gestural content in Turkish language (McNeill, 2005).

Gesture	Speech
1.eller zıplar (hands hop)	1. top bi şekil-de (Ball somehow)
2. eller yuvarlanır (hands roll)	2. zıpla-ya zıpla-ya (while hopping)
3. eller sağa hareket eder (hands move to tight)	3. yuvar-lan-a yuvar-lan-a (while rolling)

4.4 Spatial Coding Scheme

Regarding spatial codifications in the design process, Suwa and Tversky use spaces, things, shapes, and angles as emergent properties and; size, local and global spatial relations as subcategories of their segmentation (Suwa and Tversky, 1997). Bilda and Demirkan analyse design activity in relation to categories such as ‘physical’, ‘perceptual’, ‘functional’, and ‘conceptual’ actions (Bilda and Demirkan, 2003; Rahimian and Ibrahim, 2011). Sutton and Williams use conventional spatial methods such as spatial relations in 3D, mental rotation, spatial and perceptual visualization, and object-decision tests in order to measure designers’ spatial abilities (Sutton and Willliams, 2007). Nickerson et al. (2008) investigate the relationship between representations, in particular diagrams and spatial thought (Nickerson et al., 2008). Kim and Maher use ‘action’ and ‘perception’ as primary categorization and a combination of ‘3D modeling action’, ‘perceptual activity’ and ‘set-up goal activity’ as sub-categorization in their analysis (Kim and Maher, 2008).

4.4.1 Suwa and Tversky’s Spatial Coding Schemas

Apart from various protocol analysis in the field of design research, Suwa and Tversky’s codification schema provides a rich vocabulary to explore spatial ideas in design process (Suwa and Tversky, 1997). As an information category they introduce four main classes as: emergent properties; spatial relations; functional relations and past experience (Suwa and Tversky, 1997). They define “spaces”, “things”, “shapes” and “angles” under the category “emergent properties” (Table 4.6). Other categories and the subclasses can be seen in Table 4.6.

Table 4.6 : Suwa and Tversky's categories and subclasses (Suwa and Tversky, 1997).

Major category	Subclasses	Examples of phrases in protocols as evidence
Emergent properties	Spaces	"Areas", "places"
	Things	Descriptions or names of something
	Shapes/angles	"Round", "prolonged", "wavy line", "too sharp a corner"
	Sizes	"Big", "tiny", "narrow"
Spatial relations	Local relation	"Adjacent", "far", "connected", "lined up"
	Global relation	"Symmetrical", "configuration", "axis"
Functional relations	Practical roles	"A ticket office should be close to an entrance.."
	Abstract features/reactions	"Waves/forces (from this shape)", "good show to visitors"
	Views	"View line", "the appearance (of this building)"
	Lights	"(This place is always) bright, having sunshine"
	Circulation of people/cars	"People meander through (this narrow space)"
Background knowledge	-	"Post/beam structures", "An important thing in an urban setting is..."

In Figure 4.2, the segmentation method can be seen below. This schematic representation of the segments not only show the relationship between the different segments, but also the situation of dependency .

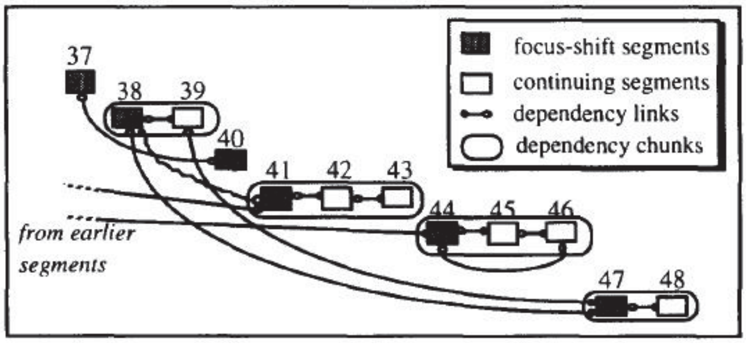


Figure 4.2 : Suwa and Tversky's evalution (Suwa and Tversky, 1997).

5. METHODOLOGY AND CASE STUDIES

This part consists of two separate phases. One of them is a structured digital modeling exercise and the second one is an empirical observation of the fourth-year architecture students' jury presentation. The case study designed focuses on the following questions:

1. By investigating the bodily experiences obtained through the direct interaction between the physical model and/or the drawing and the designer through the use of their hand gestures, as well as the modeling experiences in the digital medium, can we understand how the digital medium is insufficient in supporting the designers' conceptual or abstract thoughts?

2. How is the role of hand gestures different than verbal expressions in expressing spatial thoughts in the processes of examining, remembering and describing a physical model, as well as in recreating it in the digital medium?

3. Can we find common and recurrent patterns that people use while explaining a scaled model to another person after having sensorily observed it with hand gestures and touch?

4. Can we deepen our knowledge and understanding of the role of bodily experience in the designing process by making a connection between Lakoff and Johnson's body schemas and McNeill's gesture categories?

5. 1 Methodology

The purpose of this part is to explore the impact of haptic and kinesthetic experience perceived via hand gestures on designer's spatial thinking process and thereby enhance the understanding of the aesthetic qualities of bodily experience during their architectural modeling activity.

5.1.1 Data source

The case studies were recorded, and the verbal content transcribed. We extracted two main data types from the video record: Nonverbal spatial content in the form of gestures and spatial expression in the transcript.

5.1.2 Segmentation of the gestural content

The analyzed video recordings were segmented into pieces, consisting of gestures. In this step, McNeill's (1992) gesture definitions, which consist of four categories: iconic, metaphorical, deictic and beats, were used. The first case study which as a structured modeling exercise was repeated two times. The first modeling exercise, Experiment-1, provided 120 pieces (Appendix A) and the second one (Appendix B), Experiment-2, provided 103 pieces.

Three presentations per student were analysed within the second case study. The duration of each presentation is different from each other. The number of segments are shown below, by order (Appendix C):

- Student 1, Presentation 1: 6 minutes and 55 seconds; 87 pieces.
- Student 1, Presentation 2: 4 minutes and 41 seconds; 70 pieces.
- Student 1, Presentation 3: 4 minutes and 30 seconds; 44 pieces.
- Student 2, Presentation 1: 8 minutes and 58 seconds; 78 pieces.
- Student 2, Presentation 2: 4 minutes and 20 seconds; 30 pieces.
- Student 2, Presentation 3: 54 seconds; 13 pieces.

5.1.3 Analysis of the verbal content

In this step, the rough segmentation of the gestural content was ready. In order to clarify the types of the gesture, I needed to control the verbal content. For example, there is a semantic separation between iconic and metaphoric gestures that should be evaluated depending on the semantic dimensions of the verbal content.

In the comparison of verbal and gestural data, I observed four types of relationship shown in Figure 5.1. The verbal and gestural content might overlap in terms of semantic depth. Secondly, there might be shifts in the meaning. For example gesture can convey the meaning before mthe verbal expression, I called this situation as shifted forward. The viceversa is defined as shifted backwards. Finally there observed some gestures which convey information about geometrical or spatial relations without verbal content.

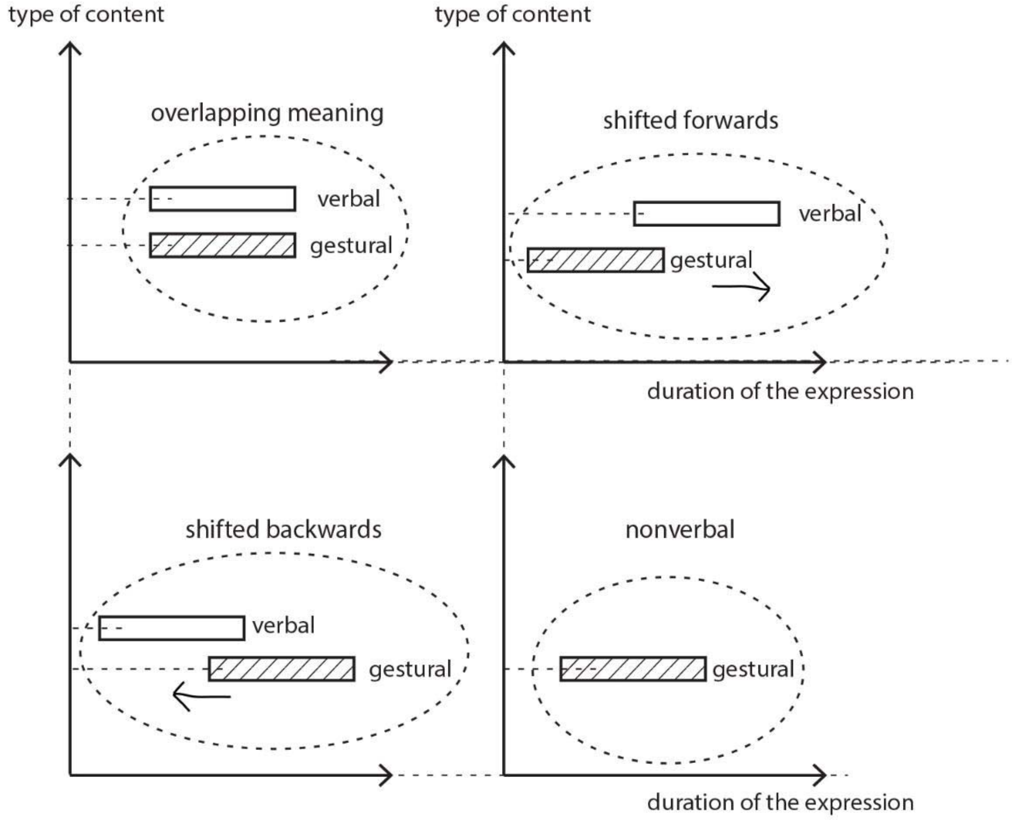


Figure 5.1 : Comparison of verbal and gestural content.

5.1.4 Medium

This category was established after the case studies depending on our initial inference. In the first case study, the participants were observed to be focusing on the computer screen or conveying the model's geometrical information by sketching or engaging in a face-to-face dialogue, in no particular order. Based on these different types of engagement, three categories were determined where gestures were executed: computer screen, paper and none. If the computer screen became the main focus of the communication between two participants, we tagged the medium of the gesture as "computer screen". In the case of touching to the computer screen, and/or the case of pointing the screen by the hand were evaluated under this category. If one of the participants make sketching by using a pen or a pencil; or if one of the participants points out a detail on the sketching paper whether touching or not; we evaluated these situations under the category of “paper”. A third item, “none” refers to the usage of hand gestures in the air without a supporting media.

In the second case study which was based on empirical observation of students’ presentation, we similarly defined thee categories. These categories are 3D “physical model”, 2D “drawings” which were vertically located during the presentation and “none”. These categories can be considered as indicator of the scale and orientation. They provide information about the orientation of the narrator and how the narrator located herself/himself in the space. Thus, physical model has its own scale. The iconic or deictic gestures might be executed in relation with the physical models. In this case, physical model becomes the focus of the expressions. Whet it comes to 2D papers or 2D digital projections which were vertically located, 2D media becomes the focus. In addition to these as a third way, the students express their spatial ideas as they are in the space. In that case, they express their spatial ideas without an additional media and take their own bodies as reference or focus.

5.2 Case Study 1: Structured Modeling Exercise

The purpose of this part is to explore the impact of haptic and kinesthetic experience perceived via hand gestures on designer's spatial thinking process and thereby enhance the understanding of the aesthetic qualities of bodily experience during their architectural modeling activity.

5.2.1 Aim and Scope

In the first case study, we aim to explore the aesthetic dimensions of bodily experience in the architectural modeling process and attempt to understand how bodily experience plays a role in the constitution of spatial ideas. We designed and evaluated a 30-minute modeling exercise performed by graduate level architecture students. This modeling exercises contains two parts (see Figure 5.1 and Figure 5.2). The first step consisted of one of the students observing the physical models, and the second step consisted of the other student, who has not seen the models, performing a 3D modeling of these physical models on the computer based on the verbal and gestural directions of the first student.

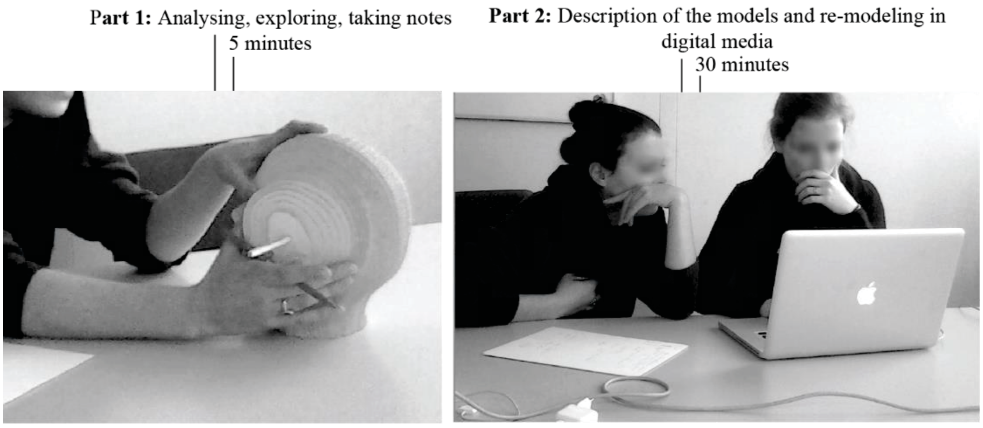


Figure 5.2 : Timeline of the process

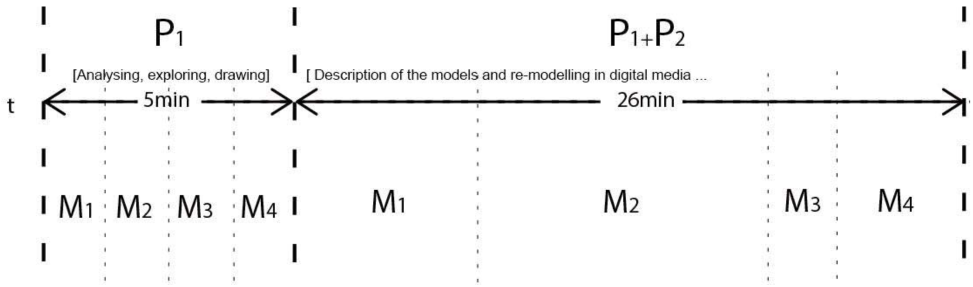


Figure 5.3 : Timeline of the process.

Shown in Figure 5.2, each M represents a different model in terms of physical and/or digital model, with t representing time and, P representing a participant. The physical models were adapted from same surface data, but had been produced using different fabrication methods such as parallel stacking (M1), articulated expandable structure (M2), waffled-grid structure (M3), and triangulated panelization (M4), as shown in Figure 5.3. In the first part (Figure 5.2), one master's level architecture students with a basic knowledge of 3D modeling, was asked to explore the geometry of four physical models. P1 was allowed to take notes and make drawings during the first part of the experiment. Physical models were introduced sequentially. In the second part (Figure 5.2), P1 was asked to describe the geometry of four 3D models, sequentially. P2 was asked to apply the described approaches and operations on a sphere as an initial shape in digital media.

We observed how participants interact with the design representation during the making/modeling process and how they reveal spatial aspects through their hand gestures. In effect, this study may be considered as a kind of reverse way of thinking.

For the experiment, different physical models produced with laser cutters were used. Four physical models were selected among fifteen physical models that, had been produced as part of a masters-level course titled “Digital Architectural Design and Modeling” at Istanbul Technical University in the 2012-2013 fall semester. The four models (Figure 5.3) were re-produced using laser cutters from their digital files, before their usage in the case study. There were differences in the complexity of the geometry of the models and also in the way the models could be fabricated. The participants were expected to re-model the given physical models by using digital media.

Figure 5.4 : Physical models which have been used in the modeling experiment.

5.2.2 Participants

This case study was repeated two times. In one of the case studies, two master's level architecture students participated to this study in 2013-2014 fall semester at ETH Zurich, Faculty of Architecture in Zurich. Later in 2013-2014 spring semester at ITU, another two master's level architecture students participated to the case study.

5.2.3 Evaluation and findings

5.2.3.1 Distribution of the gestures

The distribution of these gestures in the verbal analysis can be seen in Table.5.1. As it can be seen from the Table 5.1, the amont of iconic gestures is higher than the other types. The deictic gestures follow this order, as being the second high category.

Table 5.1 : Distribution of the gestures in two modeling exercise.

	Iconic	Metaphoric	Deictic	Beats
Experiment 1	61	10	49	0
Experiment 2	45	3	41	14

Another visualization of the distribution of the gestures can be seen in Figure 5.5. In the modelin exercise which based on modeling and ezisting and a defined geometry, the iconic gestures convey an important amount of the spatial information. However, in the second case study (Chapter 5.3), the amount of deictic gestures becomes higher during the expression of unstructured spatial ideas in the jury presentations.

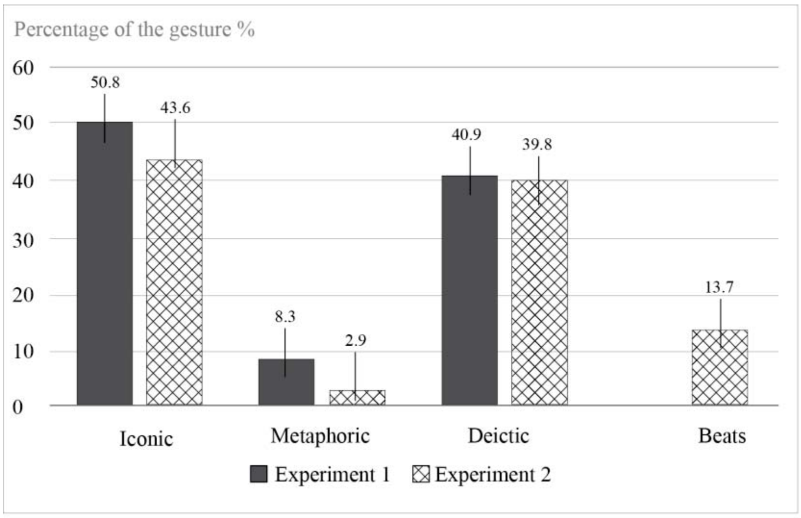


Figure 5.5 : Distribution of the gestures as a percentage in two modeling exercises.

5.2.3.2 Shift in the meaning

When verbal and gestural content are compared, shifting the meaning forward or backward has significance in terms of Lakoff (2008) and Johnson's (2008) source-path-goal schema. McNeill calls these shifts as "offset" (McNeill, 2005). While explaining the physical model using a sketch or using hand gestures while sitting face-to-face, iconic gestures were used in "forward" and "backward" offsetting. While the focus was on the computer, the offsets were encountered less often and in the form of deictic gestures (Figure 5.6).

5.2.3.3 Spatial qualities of the gestures: spatial augmentation

7 of the deictic gestures in Experiment-1, and 6 of the deictic gestures in Experiment-2 carried iconic and spatial qualities. These "iconic/deictic" gestures did not only point to the geometric object as a singular object in the environment, but also gave information on its direction, angle, its sphere-like quality and its representation of an area as a circle. These "iconic/deictic" gestures that contain spatial qualities are evaluated under the category of deictic gestures (Figure 5.5, Deictic gestures).

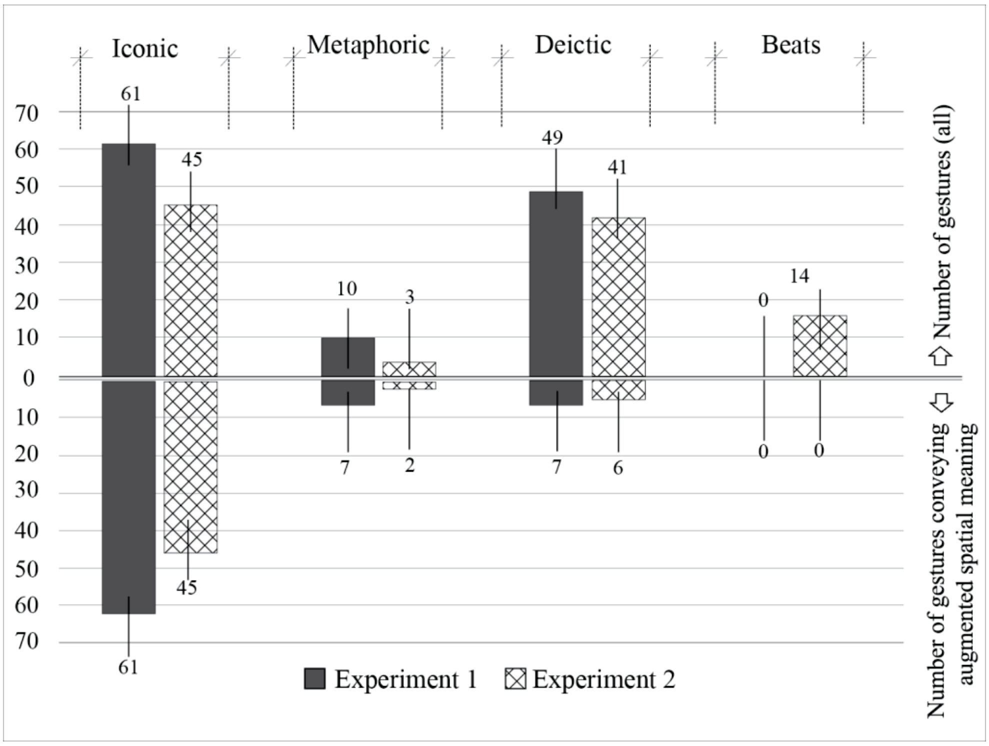


Figure 5.6: Occurrence of spatial qualities with/in the gestures

The following spatial qualities are seen both in Experiment 1 and Experiment 2: verticality, horizontality, sequentiality, expansion of the piece of the model, direction, orientation, angle, spatial relations, circular movement, connections, frames, simulation of the shape in 2D, simulation of the geometry in 3D. As it is seen in Figure 5.5, all the iconic gestures are assumed to convey spatial qualities. More than half of the metaphoric gestures convey spatial qualities. For example where the verbal content is "column like trees", the participant simulated the growth of the brunches of a tree by two hands in the air. This metaphoric gesture has motion quality and it also shows the direction of the growth. In general deictic gestures are expected to point some point in the space. Therefore at least the indicated point has a direction. However in Figure 9 we disregarded this one dimensional information and counted the deictic gestures as not conveying spatial quality.

5.2.3.4 Gesture –medium relationship

The expression of the physical model through hand gestures in the space above the table plane ("none") and on the sketches made on paper ("paper") involved more iconic gestures compared to those used for the computer screen (Figure 5.6). When the computer screen was the main focus of the participants, deictic gestures were used significantly more often (Figure5.6). The execution of the deictic gestures involved the index finger touching the computer screen to point to the digital model as a whole or in part. In the 33 deictic gestures where the model was pointed to on the computer screen, 4 of them carried an iconic quality as well. For example, the sentence “Let’s carry this from here to here” was accompanied by pointing to a starting point, the direction towards which the action was to take place, as well as the destination point on the computer screen.

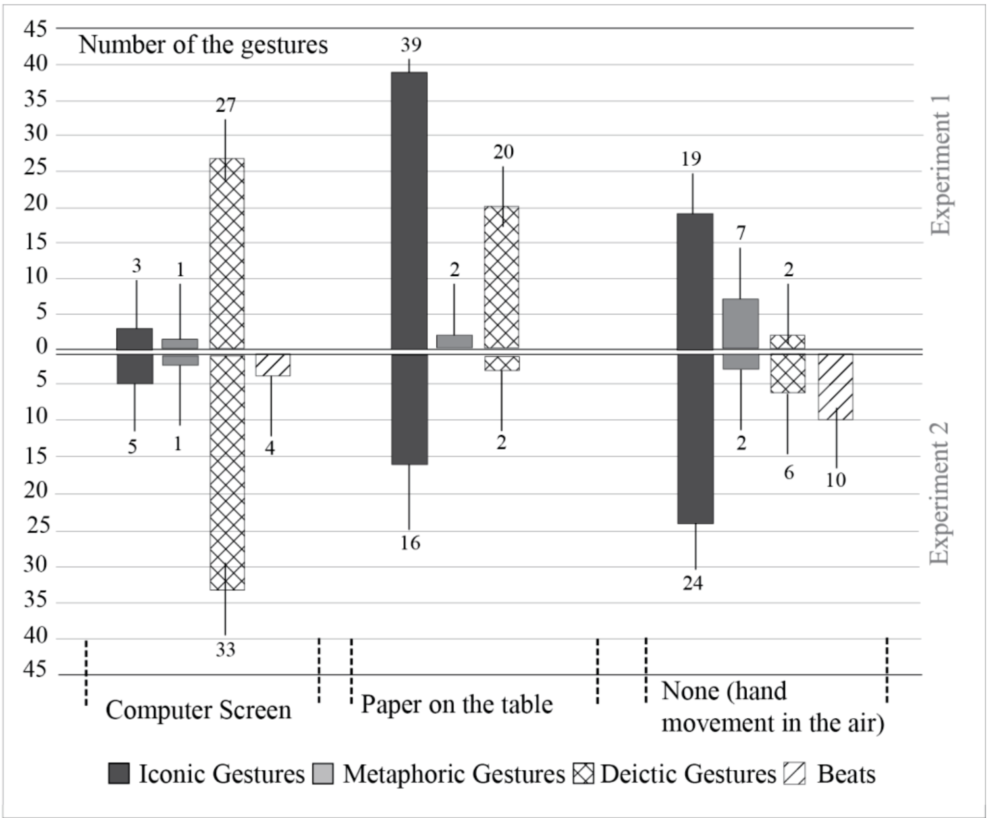


Figure 5.7 : Comparison of two modeling execises in terms of the type of medium

5.2.3.5 Gesture –image schema relationship

Considering the relationship between iconic gestures and the image schemas (Figure 5.5 and Figure 5.6), iconic hand gestures can be said to offer stronger support of the source-path-goal schema during communication in a physical environment.

Both in the two exercise it seen that, participants might utilize different gestures for the same verbal data. For example, once they expressed the geometry of the model in detail by using iconic gestures, for the second or third time they tend to use deictic gestures and only point the location in the space. This location can be both a detail on the drawing/sketch or an arbitrary space in the air. This situation is shown in Figure 5.8.

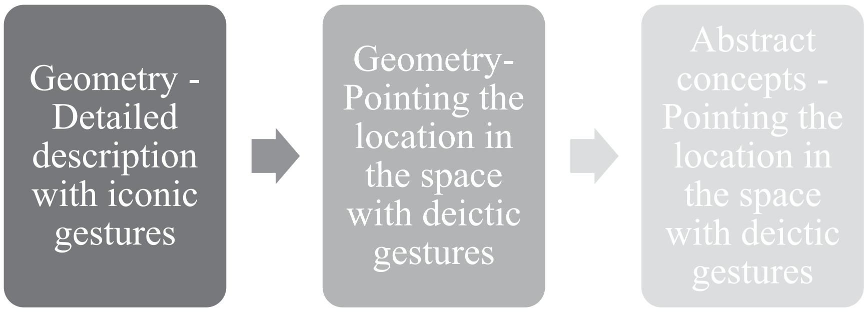


Figure 5.8 : Iterations and transitions.

It is observed that the same student use different types of gestures for the same verbal content. For example for the same object or concept, one can use detailed explanation by hand gestures. On the other hand sometimes they used deictic/pointing gestures for the same content. This deictic gestures can indicate some place in the air, in the space, or it can show a point on the physical model or on the 2D drawing. In other words, once a student explained a concept or detail on the physical model, he/she recalls the same information only by pointing in the space. To sum up there are three types of matching/mapping seen in the analysis of the student presentation:

- Matching a concept and a location in the space.
- Matching a concrete spatial element and physical model.
- A detail of a geometry and its location in the space (on the table/on the floor, right-left side of the body, etc.).

5.3 Case Study 2: Empirical Observation of Student Presentations

In this part, we examined the fourth-year senior architecture students' presentations of their graduation design project juries. The graduation project, called also diploma or final project, should be considered as a final step for students to become professional architects. The aim of this phase is to explore if there are repetitive gestural patterns or common behavior patterns among different students during the externalization of design ideas. We analyze the way in which gestural interaction and the vocabulary of verbal description is affected when the designers reveal more complex and abstract spatial relations or metaphoric concepts.

5.3.1 Aim and Scope

The graduation project, differentiating from conventional architectural design studios, has some specific regulations in terms of prerequisites and process at the selected architecture school. Firstly, students are expected to be successful in the previous seven architectural design studios and complete all the other required credits of architecture courses before they can attend to the graduation design project. Secondly, the graduation design projects are directed by five to seven jury members. The students are not allowed to take feedback from the jury members or another professionals except their presentations during the juries. In addition to two to four juries in the semester, there are one final presentation and one-day mid-term exam, which is based on solving a planning or design problem via sketching.

The purpose of the graduation project is to evaluate whether or not the students fulfil the satisfactory professional level in terms of the usage of skill, knowledge and ability which are supposed to be gained through their architecture education, in relation with the technical, aesthetic and social domains of architectural knowledge. The students are expected to reflect on the jury critics in their design development process at intellectual and interpretational levels. Although the overall topic of the graduation project is specified by the jury members, as a common denominator, students' design proposals should be approaching for an architectural product and also concern the urban context. Moreover, the students are encouraged to work independently.

As the jury meetings provide the only possibility to take critics for the students, it becomes important to use the limited time efficiently. Students usually are asked to present their design proposals in five minutes via using perspective, section, plan drawings and diagrams; animations, models and other required design representations. Some juries define the scale of the expected representation as 1:1000 for the first meeting and 1:500 and 1:200 in the consequent meetings; while some other juries might be more flexible with the scale of the design representations.

5.3.2 Participants

The video record of two students were analysed in detail. Each student made three presentations in intervals of a month. Both of the students were forth year architecture student.

5.3.3 Evaluation and findings

One of the initial findings is that during expression of the design ideas, proportion of the deictic gestures are larger than the previous case study. In some cases the number of metaphoric gesture is bigger than the numbe of iconic gestures. In the structured modeling exercises, the number iconic gestures were the most used gestures in each session.

Secondly, there are clear jumps among three different medium and scales. In other words, there are jumps among one-to-one scale expression (as in the space), expression through scaled models (expression with hand gestures) and abstract space (metaphoric expressions, shift in time and space).

5.3.3.1 Distribution of the gestures

The distribution of the gestures in the verbal analysis can be seen in Table.5.2. As it can be seen from the Table 5.2, the amont of deictic gestures is notably higher than the other types.

Table 5.2 : Distribution of the gestures in students' presentations.

	Iconic	Metaphoric	Deictic	Beats
Student 1, Jury 1	31	17	36	3
Student 1, Jury 2	23	2	43	2
Student 1, Jury 3	10	7	27	0
Student 2, Jury 1	19	18	36	5
Student 2, Jury 2	4	10	16	0
Student 2, Jury 3	2	2	9	0

Another visualistion in respect to the distribution of the type of the gestures can be seen in Figure 5.9. In this figure the characater S1 represents "Student 1" and S2 represents "Student 2". Similarly J1 represents the first jury presentation, J2 the seconde and J3 represents the thisr jury presentation. It can be seen that, in some situations the metaphoric gestures (For example student 2, the second jury presentation). It is observed that different types of the gestures can refer to the same verbal content. Or secondly, the iconic and the deictic gestures can refer not to the same but to the similar verbal content which is explained in the next sub-chapter.

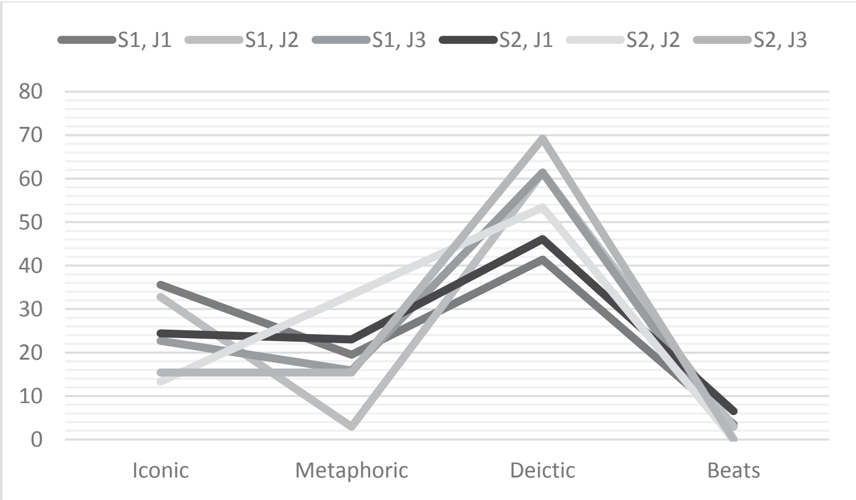


Figure 5.9 : Percentage of the distribution of the gestures in students' presentations.

5.3.3.2 Spatial qualities of the gestures: spatial augmentation

The basic spatial augmentations that we observed are "spatial relations", "orientation", "location", "direction", "circular or spherical shape"of the actions, entities, places or concepts. In Figure 5.10 a sample iconic gesture can be seen. This iconic gesture and the varioations of it was usedf for explaining different concept in the three jury presentation of the student. The student repeated the same gesture in the following verbal content: "Cendere Valley", "different types of buildings", "I am connection with the railway", "connecting two axes". Moreover he also used the same cimulation for describing "a lot of events occur" in a metaphoric way.

Figure 5.10 : An iconic gesture in relatiın with the expression "Cendere Valley".

Therefore, we can say that containement schema was utilized while describing the related concepts and situations with the Cendere Valley.

6. CONCLUSION AND DISCUSSION

In a broader sense this study sought to answer the question, “What is?” This might be the reason why there is a huge gap between the promised potentials of the digital media and its current inadequate reflections on architectural design curricula. Despite the rapid progress in CAD and CAM technologies, conventional methodologies such as sketching and model making are still crucial in architecture education. Given that most of the students tend to use physical media in the earlier phases of the architectural design process, this research should be considered as a preliminary step in understanding why digital media does not necessarily support an architect’s way of generating conceptual ideas during this phase. I argue that the aesthetic dimensions of bodily experience is one of the key concepts in the effort to get a deeper understanding of today’s crisis and gain insight about future directions of digital design environments.

Furthermore, the presence of the physical media for the purpose of drawing and model making as well as for the interactions it facilitates between the hands, which are experienced through hand gestures, plays a crucial role in revealing and generating spatial ideas. The shifting and mismatching between the gestural and the verbal content provided the participants with a degree of flexibility, might be important for the conceptual process of architectural design. Unfortunately, the interface of the digital media as it is used today is inadequate for providing this flexibility; thus, the body schemas are not sufficiently supported. In the current digital epoch, tomorrow’s design environments will be expected to be designer friendly insofar as they promote the body schemas such as source-path-goal and movement and help to facilitate the designer’s spatial thinking process.

In this study, where a modelling application was used, the role of bodily experience, which was complemented by hand gestures and conveyed information that was not verbally expressed, was investigated in the process of expression and creation of spatial thoughts. In the modelling process in a digital environment, the repetitions, patterns and relations in the hand gestures of a participant asked to describe a physical model, were observed. The distribution of the hand gestures according to McNeill's (1992) categories, the relationship between hand gestures and verbal content, the relationship between hand gestures and the medium where the model was explained, and finally, the relationship between Lakoff (1987) and Johnson's (1987) image schemas and the hand gestures, were investigated.

6.1 Body in Design Thinking

Iconic gestures complement the verbal dialogue when the relationship between the components of a physical model and the spatial information is being conveyed. It is sometimes possible to use the same verb for two consecutive sentences and to connect the two sentences to each other through gestures. In addition, we have encountered situations where the kinetic qualities of the physical model were expressed only in gestures, without any verbal expression. The hand gestures do not only convey geometrical qualities of the model, but also the becoming process of an action. In some situations, the gestures, particulary the iconic gestures, were observed to support the source-path-goal schema and the movement schema simultaneously.

When verbal and gestural content is compared, shifting the meaning forward or backward has significance in terms of Lakoff (2008) and Johnson's (2008) source-path-goal schema. While explaining the physical model using a sketch or using hand gestures while sitting face-to-face, iconic gestures were used in "forward" and "backward" offsetting. While the focus was on the computer, the offsets were encountered less often and in the form of deictic gestures (Chart 6). Considering the relationship between iconic gestures and the image schemas (Table 6 and 7), iconic hand gestures can be said to offer stronger support of the source-path-goal schema during communication in a physical environment.

6.2 A Framework Proposal for Evaluating Design Environments

In the current digital epoch, the design environments of the future will expected to be designer friendly through promoting main body schemas such as source-path-goal and movement and encourage designer's spatial thinking process.

● Promoting iconic gestures

- Supporting Lakoff and Johnson's goal-path-action schema
- Providing flexibility in offset in terms of correlation of the gestural and the verbal contents
- Promoting containment schema-spatiality of the environment

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APPENDICES

APPENDIX A: Analysis of the transcript of the modeling exercise 1.

APPENDIX B: Analysis of the transcript of the modeling exercise 2.

APPENDIX C: The transcript of the student presentations during jury meeting.

APPENDIX A: Analysis of the transcript of the modeling exercise 1

Table A.1 : Analysis of the transcript of the modeling exercise 1 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
1	1	"0.00"	So the first one was splitted into sections vertically	iconic	simulation in 3D in the air, verticality, sequentiality	Backwards	None
2	1	"0.06"	So you had only vertical cardboard pieces	iconic	simulation in 3D in the air, verticality, sequentiality	Forward	None
3	1	"0.10"	that were just placed on the stick	iconic	simulation in 3D in the air, verticality, sequentiality	Forward	None
4	1	"0.14"	So it came together as a the head or sphere	metaphoric	simulation in 3D in the air, expanding		None
5	1	"0.20"	So it was like show just like cardboard piece	iconic	simulating 2D, sequentality		Drawing
6	1	"0.24"	and the next one little bit bigger	iconic	simulating 2D, bigger		Drawing
7	1	"0.26"	to get the curve	deictic	pointing through drawing		Drawing
8	1	"0.29"	So to make the sphere it would be only round pieces	iconic		Forward	Drawing
9	1	"0.33"	And than a whole you can add them up all the stick	metaphoric	simulation in 3D in the air	Backwards	None
10	1	"0.47"	Maybe take the sphere and then cut it into sections. I do not know how to to it	iconic	simulation in 3D in the air, sequentiality		None
11	1	"0.59"	Yeah, me neither. Or i could draw one curve the shape of this piece	iconic	simulating 2D		Drawing
12	1	"01.02"	and then extend it	iconic	simulation in 3D in the air, direction		None
13	1	"01.09"	But then it would turn out to a silinder	deictic	pointing		Drawing
14	1	"01.17"	Yeah exactly then I would need to draw smaller ones in different shapes. But it would be easier to have a sphere and then…	metaphoric	simulation in 3D in the air, direction, stowing vertically		None
15	1	"01.26"	Maybe take the sphere and see if we can cut it	deictic			Computer Screen
16	1	"03.22"	We can cut it by the [GESTURE]	iconic	simulation in 3D in the air, horizontality		None
17	1	"04.02"	Or otherwise we could do as if we took the circle	Deictic			Computer Screen

Table A.1 : Analysis of the transcript of the modeling exercise 1 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
18	1	"04.03"	and draw lines	deictic	orientation, sequentality		Computer Screen
18	1	"04.06"	in the thickness of the cardboard	deictic	simulation in 3D in the air, orientation		Computer Screen
20	1	"04.09"	we would have the new diameter of the circles	deictic			Computer Screen
21	1	"04.25"	To draw lines like that	deictic			Computer Screen
22	1	"04.27"	like vertical ones	deictic			Computer Screen
23	1	"04.30"	Than do it the way you thought doing it	iconic	simulating in 3D in the air, circular movement	Forward	Computer Screen
24	1	"04.32"	just drawing all the	iconic	simulating in 3D in the air, circular movement	Forward	Computer Screen
25	1	"05.49"	Extend surface	deictic			Computer Screen
26	1	"07.46"	Draw a circle	iconic	simulating 2D		Drawing
27	1	"07.47"	draw lines (Drawing, simulation in 2D, iconic, augmetation: sequentaility, [action-43])	iconic	simulating 2D, sequentiality		Drawing
28	1	"07.49"	So we have all the diameters in	iconic	simulating 2D, framing		Drawing
29	1	"07.50"	in drawing circles in those type	iconic	simulating 2D		Drawing
30	1	"09.06"	Then we will need [action - 55] a point	deictic			Computer Screen
31	1	"09.58"	And then double those	deictic			Computer Screen
32	2	"12.53"	Second one. If you have a sphere	iconic		Forward	Drawing
33	2	"12.57"	it would be cardboard pieces this way	iconic	simulating 2D, sequentiality, angle, direction	Forward	Drawing
34	2	"13.01"	so 45 degrees angle	deictic			Drawing
35	2	"13.03"	and this way	iconic	angle, direction, spatial relations	Forward	Drawing
36	2	"13.07"	and so here there is a 90 degrees angle	deictic			Drawing
37	2	"13.12"	And its pieces	deictic	simulating 2D		Drawing
38	2	"13.13"	going this way	Iconic	angle, direction, spatial relations, sequentiality		Drawing
39	2	"13.16"	and their cuts	deictic	simulating 2D		Drawing

Table A.1 : Analysis of the transcript of the modeling exercise 1 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
40	2	"13.18"	lets say in the front	deictic	simulating 2D, spatial relations		Drawing
41	2	"13.19"	and the other pieces	deictic	simulating 2D	Forward	Drawing
42	2	"13.28"	its like columns in trees like [GESTURE]	metaphoric	simulation in 3D in the air, angle, connections, , motion	Backward	None
43	2	"13.33"	So these	deictic	simulation in 3D in the air, angle, direction	Forward	None
44	2	"13.34"	are all in that way	iconic	simulation in 3D in the air, angle, direction		None
45	2	"13.37"	and their cuts	iconic	simulation in 3D in the air, sequentiality, spatial relations, angle, direction, motion		None
46	2	"13.39"	like here	deictic	simulation in 3D in the air, direction		None
47	2	"13.40"	And the other one come like this but then	iconic	simulation in 3D in the air, direction, connection, spatial relations		None
48	2	"13.47"	It would be like this	deictic			Computer Screen
49	2	"13.50"	but instead of as many as that	deictic			Computer Screen
50	2	"13.54"	We would only need half of them for this way	iconic	simulating 2D, sequentality, direction, spatial relations		Drawing
51	2	"13.57"	and for the other ones	deictic			Drawing + None
52	2	"13.59"	We would need the same	deictic	simulating 2D		Drawing + None
53	2	"14.03"	and then always cut like if you have a circle	iconic	simulating 2D		Drawing
54	2	"14.06"	that would be always going cut to the middle	iconic	simulating 2D, sequentality, direction, motion, spatial relations,		Drawing
55	2	"14.15"	you need as many cuts as	deictic	Spatial relations, below-above, inside		Drawing + None
56	2	"14.16"	they are cardboards going the other way	metaphoric	simulation in 3D in the air, angle, direction		None
57	2	"14.20"	Lets copy all those	deictic			Computer Screen
58	2	"15.05"	And than one set of those we cut	deictic			Computer Screen
59	2	"15.17"	So nine this way	iconic	simulation in 3D in the air, direction, sequentiality		Computer Screen + None

Table A.1 : Analysis of the transcript of the modeling exercise 1 (continued).

Segmen t	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
60	2	"15.19"	nine the other way	iconic	simulation in 3D in the air, direction, sequentiality		None
61	2	"15.21"	there would be nine cuts (Pointing, screen).	deictic			Computer Screen
62	2	"15.28"	and then even those out right, probably.	iconic	simulating 2D, sequentiality, direction, out		Computer Screen + None
63	2	"15.54"	Well if it should be holding up really good they would need to be the look of the cardboard	metaphoric			Drawing
64	2	"16.17"	Sure. Maybe like even those out a bit. But then should be	metaphoric	Simulating 2D		None
65	2	"17.07"	Lets do one in the middle (Pointing, screen, augmented: middle) so because	deictic	Middle		Computer Screen
66	2	"17.49"	These cuts need to be in all the circles at the same spot, right?	deictic			Computer Screen
67	2	"20.10"	**GESTURE** + **GESTURE**	iconic	Simulation in 3D, direction, spatial relationn, sequentality		None
68	2	"20.18"	I can think of if those cuts,have to be at the same spot	iconic	Simulating 2D, framing	Forwa rd	Drawing
69	2	"20.28"	If there	iconic	Simulation in 3D, direction, spatial relationn, connection		None
70	2	"20.29"	if has a circle right in the middle	iconic	Simulating 2D, middle, direction		Drawing
71	2	"20.34"	but the other one right in the middle	iconic	Simulating 2D, middle, framing		Drawing
72	2	"20.36"	[GESTURE]	iconic	Simulation in 3D, direction, connection, angles		None
73	3	"20.46"	So the third one is similar to this one	deictic			Computer Screen
74	3	"20.49"	but instead of going diagonal	iconic	Simulating 2D, middle, sequentialty, angles, direction		Drawing
75	3	"20.54"	it is more of [**GESTURE]**	metaphoric	Circular, framed	Forwa rd	Drawing
76	3	"21.00"	one set of cardboard pieces its right vertically	iconic	Simulation in 3D, sequentiality, direction, spatial relations		None + Drawing
77	3	"21.05"	and it has also cut like this ,	iconic	Simulating 2D, direction		Drawing
78	3	"21.07"	and the other one is horizontal	iconic	Simulating 2D, direction		Drawing

Table A.1 : Analysis of the transcript of the modeling exercise 1 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
79	3	"21.11"	and has its cut here	deictic			Drawing
80	3	"21.16"	So that piece the other one comes like that	iconic	Simulation in 3D, direction, spatial relations, connnections, angles		None
81	3	"21.19"	and it is probably same	deictic			Computer Screen
82	4	"21.39"	Take a sphere	iconic	Simulating 2D		Drawing
83	4	"21.42"	you abstracted to a i think it is called polyeder}	iconic	Simulating 2D, framing		Drawing
84	4	"21.47"	So all like playing pieces	iconic	Simulation in 3D, motion		None
85	4	"21.49"	on its surface	iconic	Simulating 2D, angle, shape, spatial relations		Drawing
86	4	"21.53"	and it was in triangles	iconic	Simulating 2D, framing		Drawing
87	4	"22.00"	All the triangles were	deictic	Simulating 2D, framing		Drawing
88	4	"22.02"	still like on one piece	deictic	Simulating 2D, framing		Drawing
89	4	"22.16"	It would I do not know **GESTURE**	iconic	Simulation in 3D, spatial relations, searching/recalling		None
90	4	"22.20"	They were frames	deictic	Simulating 2D, framing		Drawing
91	4	"22.22"	in the middle cut out	iconic	Simulating 2D		Drawing
92	4	"22.25"	so that actually we would need to able to start with a pollyader	deictic		Forward	Computer Screen
93	4	"22.34"	and tell them how many pieces of individual surfaces	iconic	Simulating 2D, framing	Forward	Drawing
94	4	"23.58"	Well we could startwith just the regular rectangle that	iconic	Simulating 2D	Forward	Computer Screen
95	4	"00.04"	all the sides are the same length	iconic	Spatial relations, angle, equality	Backward	Drawing
96	4	"01.05"	Just I think eight	iconic	Simulating 2D, sides, direction, spatial relations		Drawing
97	4	"02.34"	Because all those are mixed	deictic			Computer Screen
98	4	"02.42"	But then again that the triangles	iconic	Simulating 2D		Drawing

Table A.1 : Analysis of the transcript of the modeling exercise 1 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
99	4	"03.18"	Can we just draw[action - 90] something like that? (Pointing, screen)	deictic			Computer Screen
100	4	"03.32"	To draw it like if we would, if we flatten the	iconic	Simulation in 3D, direction, horizontality		None
101	4	"03.40"	That would be actually perfect	iconic	Simulating 2D, geometry	Forward	Drawing
102	4	"03.43"	but I dont know how many	iconic	Simulating 2D, geometry		Drawing
103	4	"03.55"	do we need about 2 or one and which ones?	deictic		Forward	Drawing
104	4	"03.58"	like if it starts to spread	metaphoric	Simulation in 3D, horizontality, motion		None
105	4	"04.06"	Maybe we can abstract super super crazy and do just a t..box?	iconic	Simulating 2D	Forward	Drawing
106	4	"04.18"	Then we can just need to draw triangle	iconic	Simulating 2D	Forward	Drawing
107	4	"04.27"	Same size, length of the size	iconic	Simulating 2D, spatial relations, angles		Drawing
108	4	"04.29"	add another one	deictic			Drawing
109	4	"04.30"	and the third one	deictic			Drawing
110	4	"04.33"	and other forth one.	deictic			Drawing
111	4	"04.35"	And we can follow these.	iconic	Simulating 2D		Drawing
112	4	"04.41"	But that is like instead of a sphere, we would hava a pyramid which is.	iconic	Simulating 2D		Drawing
113	4	"05.03"	Or can we just draw a	deictic			Computer Screen
114	4	"05.08"	can we chose how many sides? Like	deictic			Computer Screen
115	4	"06.17"	The	deictic	Object		Computer Screen
116	4	"07.14"	Like what we keep do is the first circles, of first model we could	deictic	Geometry	Forward	Computer Screen
117	4	"07.20"	draw a rectangle hole	iconic	Simulating 2D		Drawing
118	4	"07.22"	like here	Deictic			Computer Screen
119	4	"07.26"	because it had like a stick through it. Maybe we add that.	deictic			Drawing
120	4	"07.38"	Like a really small one like a wooden tiny stick Comment	metaphoric			Computer Screen

APPENDIX B: Analysis of the transcript of the modeling exercise 2

Table B.1 : Analysis of the transcript of the modeling exercise 2 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
1			**Dört** farklı **model** vardı.	Beats	Sayı		None
2			Bunlardan bir tanesi	Beats			None
3			birbirine tamamen paralel levhalardan **oluşuyor** tamam mı	Iconic	Paralel, yanyanalık, doğrultu	Backwards	Drawing
4			Sadece dikey paralel levhaların	Iconic	Düşeylik, paralellik, yanyanalık, doğrultu		None
5			kesitteki farklılıklarıyla	Iconic	Dış yüzey kontörü		None
6			**oluşturuyoruz**	Metaforik	Bir araya getirmek		None
7			İkincisinde hem yatay	Iconic	Düşeylik, yanyanalık, doğrultu		None
8			hem dikey	Iconic	Yataylık, yanyanalık, doğrultu		None
9			birbirine paralel formlar **kullanacağız**	Iconic	Paralelik, yanyanalık, doğrultu		None
10			İç içe geçmiş şekilde. Üçüncüsünde	Beats			None
11			**içi boşluklu** üçgenler ve içi **boşluklu dörtgenler kullanacağız**	Beats			None
12			düzgün **olmayan dörtgenle**r ve üçgenler	Beats			None
13			Sanıyorum kürede ikisiyle de yapılabilen sadece üçgen de kullanabilirsin **sadece dörtgen de**	Beats			None
14			Dördüncüsünde de	Beats			None
15			yine paralel levhalar	Iconic	Paralellik, açısal değer, doğrultu	Forwards	None
16			yatay ve	Iconic	Paralellik, yataylık		None
17			dikey konumda değil	Iconic	Paralellik, düşeylik		None

Table B.1 : Analysis of the transcript of the modeling exercise 2 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
18			diyagonel	Iconic	Paralellik, açısal değer, doğrultu		None
19			İki yana mı diyagonel, birbirine dik geçiyor	Iconic	Paralellik, açısal değer, doğrultu		None
20			Evet, aynen öyle. Önce istersen ilkini yapalım birbirine paralel olanları, dikine paralel olanları	Deictic			None
21			bir kaç **farklı** boyutta	Beats			Computer Screen
22			sadece tek levha ya da kalınlıklar ya da ben tamam	Deictic	Tekillik		Computer Screen
23			biraz böyle. Bu merkez istersen bu büyüklükte bir küre olsun çapı bu olsun sağa ve sola doğru kopyalarak şeyapalım küçültelim	Deictic			Computer Screen
24			hemen yanına **yapıştırabilirsin**	Iconic	Yanyanalık,	Forwards	Computer Screen
25			bu arada boşluk bırakmadan	Iconic	Bitişiklik	Backwards	Computer Screen
26			ilkinde öyleydi yani birbirine yapışık	Iconic	Doğrultu, yön	Forwards	Computer Screen
27			Onu dönüşte istersen sonra **seçeriz** sadece kopyalayalım önce bir	Deictics			Computer Screen
28			[...]	Deictics			Computer Screen
29			Sağ tıklayamıyorum ki. Somut şeyi tekrar yapıyor. Sürekli bunlard kontrole basınca şey yapıyor	Beats			Computer Screen
30			Şuraya bas	Deictics			Computer Screen
31			snap özelliği varsa istersen direk GESTURE	Deictics		Forwards	Computer Screen
32			Tamam bunu da seç istersen dairesel şeyler [..] onu küçült istersen şeyi	Deictics			Computer Screen
33			Bence küçülterek gidelim. Göz kararı değiştir çok problem değil. Azar azar olsun. Çünkü çok küçük farklarla	Deictic			Computer Screen
34			formu çok iyi vermiş bu birinci şeyde. Grasshopper bilmiyorsun değil mi	Beats			Computer Screen + Drawing
35			Şeyi None mu bunun bir küre çizip	Iconic	Dış yüzey kontörü		None
36			O küreyi sıra sıra ayırmak gibi bir şansımız None mu	Iconic	Paralellik, yanyanalık, doğrultu	Forwards	None
37			direk	Iconic	Doğrultu, yön		None

Table B.1 : Analysis of the transcript of the modeling exercise 2 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
38			Mesela şunlar dursun kenarda. Şöyle yapalım.	Deictics			Computer Screen
39			Bir tane büyük plak çizelim	Metaforik			None
40			onları bir sürü kopyalayalım yanyana	Iconic	Doğrultu, yanyana	Forwards	None
41			sonra ortasına bir tane küre çizelim	Iconic	Ortası		None
42			intersection'ı alalım	Iconic	Doğrultu		None
43			ve hazır olsun	Beats			None
44			Şimdi [..] şuraya şeyi çizelim	Deictics			Computer Screen
45			ince ince kenarları olabilir mi. Şuraya şeyi gönderelim	Deictics			Computer Screen
46			Tam olarak	Metaforik	Doğrultu, yön		Computer Screen
47			direk boyutların yazamıyor musun oraya .bu sefer iyice. Nasıl olsa kesişimini alacağız ya.	Deictics		Forwards	Computer Screen
48			Bunu ekleyip direk silebilirsin	Deictics			Computer Screen
49			GESTURE şunu çok ince yap abi fazla kalın olmasın [..]	Deictics		Forwards	Computer Screen
50			GESTURE [..] istersen kopyalayalım bir kaç tane	Deictics			Computer Screen
51			Tamamdır. Önce onu seçelim. Çok geriye gittin. Bunu seçiyorsun	Deictics			Computer Screen
52			[...]	Deictics			Computer Screen
53			İntersection ikisinin de mi kesişimi oluyor	Iconic			Computer Screen
54			Bir tane seçsen, ortadakinin hepsini	Deictics			Computer Screen
55			GESTURE	Deictics			Computer Screen
56			Bak şöyle yapalım. Boş ver abi uzun sürüyor. Bir tane az önceki gibi extrude edilmiş şöyle bir yuvarlak **çizelim**	Iconic	Şeklin dış kontörü, çizim doğrultusu	Forwards	Drawing
57			Tamam mı merkezleri sonra snapleri açık bir şekilde aynı merkezden	Iconic	Merkez		Drawing
58			mesela bunu 50cm çapında çizip	Iconic	Şeklin dış kontörü, çizim doğrultusu	Forwards	Drawing

Table B.1 : Analysis of the transcript of the modeling exercise 2 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
59			ondan sonra 40cm	Iconic	Şeklin dış kontörü, çizim doğrultusu, oran		Drawing
60			30 cm	Iconic	Şeklin dış kontörü, çizim doğrultusu, oran		Drawing
61			20cm	Iconic	Şeklin dış kontörü, çizim doğrultusu, oran		Drawing
62			10 cm	Iconic	Şeklin dış kontörü, çizim doğrultusu, oran		Drawing
63			Öyle yapacağız o zaman				Drawing
64			Zaten form biraz şeydi. Basık bir formdu.	Iconic	Şeklin dış kontörü, çizim doğrultusu		Drawing
65			Kesişimlerini alarak yapmayı deneyecektik ama olmadı. [..] sol görünüşte çalışsan daha rahat edersin orayı merkez olarak kabul edip. Değer girebiliyor musun	Deictics			Drawing
66			Şu şeylerden yap istersen gridlerden git birer tane birer tane azaltarak şeyapalım	Deictics			Computer Screen
67			Sol görünüşte ince olsun kenarları	Deictics			Computer Screen
68			Yeniden komutu alıp bence front görünüşte şu şeyi seçip	Deictics			Computer Screen
69			Şurda istersen tekrar seçip. Yüzeyini oluşturursun sonra tekrar taşımak zorunda kalmasın	Deictics			Computer Screen
70			Sonra şunu seç abi o kadar yakın olmasın	Deictics			Computer Screen
71			Aslında şey zaten makette de öyleydi	Iconic	Şeklin dış kontörü, çizim doğrultusu		Drawing
72			Normal küre formu şuysa	Iconic	Şeklin dış kontörü, çizim doğrultusu		Drawing
73			Gördüğümüz form şöyle bir formdu	Iconic	Şeklin dış kontörü, çizim doğrultusu		Drawing
74			Bastırılmıştı yani	Iconic	Eylemin doğrultusu, geometrinin büyüklüğüne dair oran		Drawing
75			Ama tabi bu kadar değildi	Deictics			Drawing
76			Onları [...]	Deictics			Computer Screen
77			Boşver bu yaptıklarımızı	Deictics			Computer Screen
78			buna göre kopyalayıp rotate edelim	Deictics			Computer Screen
79			Şimdi bak ikinci formda bu yaptığımız şeylerin aynılarını kullanalım. Bir daha yapmaya uğraşmayalım.	Iconic/Deictics	Dairesel seçim		Computer Screen

Table B.1 : Analysis of the transcript of the modeling exercise 2 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
80			Kopyala istersen	Iconic/Deictics	Dairesel seçim		Computer Screen
81			Şimdi bunun aralarını açacağız GESTURE	Iconic	Paralellik, doğrultu, yakınlık		None
82			Bir de bunların aynı şekilde yukarıdan aşağı doğru rotate yapacağız	Iconic	Doğrultu, yön, ardışıklık, açı		None
83			Hem de hem yatay hem dikey rotate ama önce aralarını açmamız lazım	Beats			None
84			Yani bu plakaların aralarını bu sefer pararlel boşluklar olacak	Iconic	Paralellik, doğrultu, yön, ardışıklık,açı		Drawing
85			Daha fazla bırakalım istersen. Daha fazla anlaşılsın ortaya çıksın. Şurda bir tane daha	Deictics			Computer Screen
86			GESTURE	Deictics			Computer Screen
87			Tam hizasına kaydıralım merkezleri çakışsın	Iconic/Deictics	Doğrultu		Computer Screen
88			Rotate kopyala ile rotate edemiyor musun? Bu arada şöyle bir şey yapalım	Beats			Computer Screen
89			bir saniye öncelikle şu sadece ortadaki var ya merkezdeki sadece onu	Deictics			Computer Screen
90			rotate yap abi şöyle çevir kopyalayalım	Iconic	Doğrultu, yön, açı		Computer Screen
91			Şimdi şu en uçtakileri	Iconic/Deictics	Doğrultu, yön, açı		Computer Screen
92			en uca alalım abi. Daha iki şekil daha var	Iconic/Deictics			Computer Screen
93			yatayla dikeyi yaptığımız plakaları diyagonel yapıyorsun	Iconic	Doğrultu, yön, düşeylik ardışıklık, açı		None
94			dolayısıyla bunu sadece kırkbeş drece çevirmen yeticek	Deictics			Computer Screen
95			Küreyi	Iconic	Dış yüzey kontörü		Drawing
96			üçgen şeylere **ayıracağız** yüzeylere ayıracağız	Iconic	Oran, yanyanalık		Drawing
97			Aynen. İçi boş	Iconic	Doluluk/boşluk		Drawing
98			Hacim olarak içerisi boş	Iconic	Dış yüzey, hacim, küresellik, doluluk-boşluk		None

Table B.1 : Analysis of the transcript of the modeling exercise 2 (continued).

Segment	Model	Time	Expression	Type of Gesture	Augmentation	Offset	Medium
99			böyle üçgenler var surfarce'inde	Iconic	Dış yüzey, hacim, küresellik, üçgenler, üçgenlerin yüzeyde konumlanışı		None
100			Yani eğer yapabiliyorsan solid bir küre çizip	Iconic/Deictics	Küresellik		None
101			onu ondan sonra traille gride ayırıp hani yüzeyleri boşaltmak mantıklı olur kısa olur. Bir yüzeye grid atamak gibi bir şansn va mı? Önce istersen küre çiz. Max'te bunun şeyi var ya.	Iconic			None
102			Arttırıyor işte yüzeyleri	Beats			
103			Şurda şöyle bir işaret var	Deictics			

APPENDIX C: The transcript of the student presentations during jury meeting.

Table C.1 : The transcript of the student presentations during jury meeting.

CURRICULUM VITAE

Name Surname:	Sema ALAÇAM
Place and Date of Birth:	Darende, 1981
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EDUCATION:

- **B.Sc.:** Istanbul Technical University, Faculty of Architecture, Department of Architecture, 2005
- **M.Sc.:** Istanbul Technical University, Graduate School of Science Engineering and Technology, Department of Informatics, Architectural Design Computing Graduate Program, 2008

PROFESSIONAL EXPERIENCE AND AWARDS:

2014 :	Best presentation award, runner up, The Association for Computer-Aided Architectural Design Research in Asia 2014, Kyoto, Japan, 14-17 May 2014, Bacınoğlu, Z & **Alaçam, S.**: "A Context Based Approach to Digital Architectural Modeling Education". http://www.caadria.org/man/recipient.html
2013-2014.:	ETH Zürich, Faculty of Architecture, Department of Architecture, Chair of Structural Design, Academic Guest**.**
2007-2014.:	Istanbul Technical University, Graduate School of Science Engineeringand Technology, Department of Informatics, Research Assistant.

GRANTS AND SCHOLARSHIPS:

▪ TÜBİTAK (The Scientific and Technical Research Council of Turkey), 2214/A Graduate Scholarship for PhD students, 6 months within PhD research at ETH Zürich.

▪ TEI 2014, 8th International Conference on Tangible, Embedded and Embodied Interaction, "Graduate Student Consortium" (Grant for conference fee, travel and accommodation expenses), Ludwig-Maximilians University 16-19th February 2014, Munich.

▪ MMM 2014, The 20th Anniversary International Conference on MultiMedia Modeling, “Conference fee, travel and accommodation expenses” were supported by LinkedTV within “Special Session of Mediadrom: Artful post-TV Scenarios”.

▪ TÜBİTAK (The Scientific and Technical Research Council of Turkey), 2211 Graduate Scholarship for PhD students.

▪ İTÜ Rectorate, Scientific Research Project Foundation, “Analysis of the Effects of Haptic and Body-Spatial Perception during Architectural Modelling Process” (No: 34547) Supervisor: Prof. Gülen Çağdaş.

▪ TÜBİTAK (The Scientific and Technical Research Council of Turkey), 2210 Graduate Scholarship for Master students.

▪ İTÜ Rectorate, Scientific Research Project Foundation, “An Interface Proposal for Architectural Design Collaboration Process” (No: 32428) Supervisor: Prof. Gülen Çağdaş.

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

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▪ **Alaçam S.**, Çağdaş, G., Gürbüz, E., Hirschberg, U., Sökmenoğlu, A. (2013). Architectural Design Education Through a Workshop: Experimenting With Digital Media in B. Bolak Hisarlıgil, S. Lokce & O. Turan (Eds.), *MIMED Forum IV: Flexibility in Architectural Education*, (Chapter 20, pp. 298-314), Cambridge Scholars Publications, ISBN13: 978-1-4438-4265-5

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