GESTURE AND LANGUAGE USE IN TODDLERS:

THE ROLE OF VERBAL AND NON-VERBAL WORKING MEMORY

IN LANGUAGE DEVELOPMENT AND GESTURE PRODUCTION PROCESS

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DECLARATION OF ORIGINALITY

I, Naziye Güneş Acar, certify that

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ABSTRACT

Gesture and Language Use in Toddlers: The Role of Verbal and Non-Verbal Working Memory in Language Development and Gesture Production Process

Gestures constitute an inseparable part of communication system and from very early years onward children use speech accompanying gestures. Importance of gestures in communication processes lead researchers to investigate cognitive underpinnings of gestures. In a limited number of studies conducted with adults, working memory capacity has been speculated to play a central role in gesture use. However, only a few studies investigated cognitive underpinnings of gesture use in very young children. The purpose of the current study is to investigate the role of verbal and non-verbal working memory for gesture production in toddlers. As a secondary aim and to understand the connection between language and cognitive processes from a holistic point of view, relations of the verbal and non-verbal memory systems to expressive and receptive language parameters are also examined. Results indicated that there is a close association between childrens's receptive language ability and their non-verbal working memory capacity when the effect of age was controlled. Considering gesture use, although partially supported, findings suggested that children produce gestures with no accompanying speech when their low verbal working memory capacity is coupled with a high non-verbal working memory capacity. Moreover, children who scored higher on both verbal and non-verbal working memory were found to be producing more gesture-speech combinations than other children whose verbal and non-verbal working memory capacities were below average. Thus, results of the present study suggested that many aspects of language development including gesture use are influenced by memory abilities.

ÖZET

Küçük Yaştaki Çocuklarda Dil ve Mimik Kullanımı: Sözel ve Sözel Olmayan Çalışan Belleğin Dil Gelişimi ve Mimik Kullanımı Üzerindeki Etkisi

Dil araştırmacılarının yaptığı son çalışmalar, mimiklerin iletişim sisteminin ayrılmaz bir parçası olduğuna işaret etmiş ve aynı çalışmalar çocukların 9 ila 10 ay itibari ile mimik kullanmaya başladığını göstermiştir. Mimik kullanımının dil ediniminde önemli bir yer tutması araştırmacıları mimik kullanımının bilişsel alt yapısını incelemeye itmiştir ve yetişkinler ile yapılan sınırlı sayıdaki çalışmalarda mimik kullanımını destekleyen en temel mekanizmanın çalışma belleği olabileceği ortaya atılmıştır. Ancak bu yetinin çocuklardaki bilişsel temellerine dair çok az şey biliyoruz. Alanyazındaki bu eksikliği gidermek için, önerilen bu çalışma aracılığı ile 24-36 aylık çocuklarda mimik kullanımının sözel ve sözel olmayan çalışma belleği ile olan ilişkisi araştırılmıştır. İkincil olarak ise, dil gelişimi ve bilişsel süreçler arasındaki bağlantıyı bütüncül bir açıdan ele almak amacıyla önerilen iki bellek kapasitesi ile alıcı ve ifade edici dil yetisinin arasındaki bağlantı da incelenmiştir. Sonuçlar, yaşın etkisi kontrol edildiğinde, alıcı dil yetisi ve sözel olmayan bellek kapasitesinin birbirleri ile önemli derecede ilişkili olduğunu göstermiştir. Mimik kullanımı ile ilgili olarak ise, kısmen desteklense de, mimikleri tek başına yanında herhangi bir sözcük olmadan kullanan çocukların sözel olmayan çalışan bellek kapasitelerinin iyi olmasına karşın düşük sözel çalışan bellek kapasitesine sahip oldukları gözlemlenmiştir. Buna ek olarak, mimiklerin sözcükler ile beraber kombinasyon şeklinde kullanılmasının daha fazla bilişsel kaynak gerektirdiği ve bunu sadece hem sözel çalışan bellek kapasitesi hem de sözel olmayan çalışan bellek kapasitesi iyi olan çocukların yapabildiği sonucuna varılmıştır. Sonuç olarak bu

çalışma, farklı bellek kapasitelerinin ve aralarındaki etkileşimin, mimik kullanımı da dahil olmak üzere, dil becerisinin bir çok yönünü etkilediğine işaret etmiştir.

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CHAPTER 1

INTRODUCTION

Gesture use is a robust phenomenon, spontaneously used by people across varying languages, ages and cultures. It is so robust that even congenitally blind people who did not see any one gesturing and people who communicate through sign language use speech accompanying gestures (Özyürek, 2010). Gesture use has recently been an issue of great interest for research and this interest in studying gesture results from its being a component of the communication system, its tight relationship with cognition, cognitive advantages it provides and its potential use in the identification of language delay.

Until quite recently, research on gesture use has focused on its facilitative communicative functions for listeners, but later, attention has been drawn to the cognitive advantages it provides and the mechanisms that underlie individual differences in gesture use. Most outstanding of the proposed mechanisms is cognitive capacity, specifically working memory capacity. Especially verbal working memory is increasingly recognised as a contributing factor to excessive gesture use in some populations whose verbal working memory is impaired. Furthermore, using gesture combinatorially with speech requires execution and coordination of gesture and speech modalities along with continuous updating and retainment of information (Cocks, Morgan & Kita, 2011). That is, if individuals have poor working memory capacity, then while using speech and gesture in combination they rely dominantly on one modality and consequently their full grasp of the meaning fails (Cocks et al., 2011). Although working memory involvement in gesture use is commonly emphasized, studies specificially testing this relationship in very young children are lacking and studies exploring this link in older adults have a number of limitations in the measurement of working memory (Chu, Foulkes, Meyer & Kita, 2014; Cocks et al., 2011).

Considering these issues and limitations, the focus of the present study was the link between working memory and gesture use in early years of life. In particular, the investigation was about the role of verbal and non-verbal working memory in gesture use. To understand the connection between language ability and cognitive processes more precisely from a holistic point of view, the connection between expressive and receptive language abilities and these two memory systems was also investigated.

The introduction is composed of three sections. The first section covers the link between language and working memory. Then, the focus shifts to the connection between two communicative units: gesture and language. Lastly, working memory and gesture relationship is reviewed with an emphasis on theoretical accounts.

CHAPTER 2

LITERATURE REVIEW

2.1 Working memory and its role in language use

As a dynamic component of memory system, in the literature, working memory has come to be defined as the ability to hold and manipulate representations in the face of concurrent mental operations, distraction and attentional shifts (Conway et al., 2002; Engel de Abreu, Conway & Gathercole, 2010). Although researchers agree on the function and importance of working memory for both general memory system and everyday cognitive functions, the structure of working memory and its relations with STM and LTM remain an issue of controversy.

A variety of models are proposed to explain the nature and structure of working memory (Shah & Miyake, 1999). Earliest models of working memory come from the studies of Broadbent and from another team whose members are Atkinson and Shiffrin. In these models sensory information is transferred into short-term memory which is later fed into long-term memory (Shah & Miyake, 1999). Central executive processes are a key to the transmission of information form one type of memory to the other, at least in the model proposed by Atkinson and Shiffrin (Shah & Miyake, 1999). One serious weakness with these earlier models, however, is that there is only one store for all kinds of information regardless of the modality from which the information comes (Cowan, 2011). This weakness is addressed by later models.

A compartmentalized view of working memory was provided by Baddeley and Hitch (1974). According to their influential three-component model, verbal-phonological and visual-spatial information are maintained separately in different stores called phonological loop and visuo-spatial sketchpad and later all the information across two stores are managed or manipulated by an attention related construct called central executive (Cowan, 2008). In the following years another component called episodic buffer was also added to the model in order to represent cross-domain associations and features that are not stored in any relevant slave system of the model (Cowan, 2008). Episodic buffer is thought to connect the information coming from the two stores with the information coming from long-term memory and new information coming from the environment (Cowan, 2008).

Continuity between working memory and long-term memory gained popularity after the postulation of Cowan's Embedded-Processes Model. In Cowan's model, attention processes have a profound effect on storage and in sharp contrast to multi-component working memory model of Baddeley and Hitch (1974), in Cowan's model, working memory is a part of long-term memory not a separate system (Kane, Conway, Hambrick & Engle, 2007). According to this model, when a subset of representations in long-term memory comes into a heightened state of activation, they comprise the representations of working memory (Kane et al., 2007).

In the literature, there is a major distinction between the conceptualization of working memory as consisting of multiple domain specific components and conceptualization of working memory as a domain general system that controls the focus of attention. However, the role of working memory in high-level cognitive activities such as language, comprehension, reasoning and problem solving is unquestionable. What underlies the connection between working memory and high-level cognition is supposed to be its capacity to control attention, its capacity to coordinate multiple system functioning and its connection with fluid intelligence (Kane et al., 2007; Lepine, Barrouillet & Camos, 2005). In addition, some existing accounts argue that what derives the relation between working memory and high level cognitive tasks are strategy use and knowledge such that people with high working memory spans are the ones who are better in strategically planning and monitoring their activity in complex situations requiring high level cognitive activity (McNamara & Scott, 2001). Among other high-level cognitive activities, working memory's function in language development at both productive and receptive levels is especially evident because language processing requires storage and processing of a sequence of symbols. Language processing requires a coherent and meaningful representation of the discourse which in turn requires an ability to compute semantic and syntactic relations among successively encountered words, phrases and sentences (Daneman & Merikle, 1996). Because working memory incorporates both storage and processing capacities, it seems to play a more comprehensive role in language processing than any other memory mechanism such as short term memory which is associated only with passive storage capacity (Daneman & Merikle, 1996).

There have been a number of theoretical approaches to explain individual differences in language proficiency. These theoretical approaches can be grouped in two kinds: capacity-limit theories and experience-based explanations (MacDonald & Christiansen, 2002; Kidd, 2013). Central mechanism in capacity-limit theories is working memory capacity and in the literature two models are proposed under capacity-limit theories; one by Just and Carpenter (1992) and another by Waters and Caplan (1996). Although these two theories differ from one another in a number of ways, basically they suggest that variation in the working memory capacity is a primary source of individual differences in language proficiency (Kidd 2013; Just & Carpenter, 1992). Nevertheless, the capacity-limit theories are not without controversy and experience-based accounts posit that individual variation in language processing stems from differential experience with different components of language and biological differences that affect learning and processing (Kidd, 2013). These accounts are described in greater detail next.

Capacity-limit theories adopt a working memory model which incorporates a storage space and a workspace necessary for syntactic and semantic computations of language processing. People vary in the amount of working memory capacity available for storage and processing demands of language processing and this situation leads to qualitative and quantitative differences among individuals in language proficiency (Just & Carpenter, 1992). In Just and Carpenter's capacity-limit theory, language comprehension is a nonmodular process and, in line with this argument, their view posits that working memory is analogous to Baddeley's central executive. However, in Waters and Caplan's capacity-limit account linguistic knowledge is modularized and, in line with this idea, working memory includes two components: one dedicated to controlled processes and another one dedicated to unconscious psycholinguistic processes (Kidd, 2013). What is common in both capacity-limit accounts is that when task demands exceed working memory capacity, individuals with lower levels of working memory capacity will be less able to perform semantic or syntactic computations or store the products of discourse, thus have problems with language processing (Kidd, 2013; Just & Carpenter, 1992). In both capacity-limit theories, improvement in language proficiency is tied to increments in working memory capacity in contrast to experience-based account which suggest that linguistic gain is only possible with linguistic experience (Kidd, 2013).

Phonological loop, one of the subcomponents of working memory, has been the subject of many studies in language literature and its role in language development can be aligned with the propositions of capacity-limit theories.

According to the Phonological Loop Hypothesis, the primary purpose of pholonogical loop is keeping unfamiliar phonological forms temporarily active while more permanent memory representations are being constructed (Baddeley, Gathercole & Papagno, 1998). In the model, phonological loop is conceived to have evolved to facilitate language acquisition. Traditionally, phonological loop function has been assessed by measuring non-word repetition performance which is sensitive to phonological loop function more than other conventional span measures (Baddeley et al., 1998). So far, a number of studies were set out to investigate the usefulness of phonological loop hypothesis in both native and second language acquisition across different age groups, across varying language groups and across a range of disordered populations (SLI, William syndrome and Down syndrome etc). Results from these studies testing phonological loop model fits neatly into the capacity-limit theories suggesting that individuals who have a greater phonological loop capacity tend to outperform those who have a lower capacity in many aspects of language ability, including syntax acquisition, vocabulary size, foreign vocabulary learning, ability to learn unfamiliar phonological material, sentence length, amount of detail provided in a narrative; and language complexity (Baddeley et al., 1998; Kohonen, 1995; Baddeley & Gathercole, 1993; Adams & Gathercole, 1996; Blake et al., 1994; Papagno & Vallar, 1995; Wang & Bellugi, 1994).

In sharp contrast to the capacity-limit account, experience-based theories argue that substantial amount of individual differences in langauge processing ability originates from linguistic experience, biological-architectural factors such as processing speed that can possibly change the nature of phonological representations and lastly the interaction of these two factors (MacDonald & Christiansen, 2002). In this model, working memory is not a separate entity that governs language processing independent from experience and structural factors, rather it is an emergent property of the network itself. (Kidd, 2013; MacDonald & Christiansen, 2002).

Although extensive research has been carried out on individual variation in language processing and different theories have been proposed, it is still unclear whether capacity-based and experience-based accounts are mutually exclusive. According to Kidd (2013), in order to solve this issue and to understand individual variation in language proficieny, longitudinal studies that test relevance of both capacity and experience are required because at different stages of language acquisition, capacity and experience may be exerting different influences.

Due to the dominance of the Phonological Loop Hypothesis, the research to date has tended to focus on the role of verbal working memory in language ability; only a few studies have investigated the effect of non-verbal representations on language processing. The human communication system extends beyond the realm of verbal medium and it is supported by a range of nonverbal tools such as intonation, stress, pitch, rhythm, bodily movements and gestures (Anderson, 2006). This raises some questions related to the cognitive underpinnings of these nonverbal tools such as how these non-verbal tools are represented, processed and integrated into the speech production process. More importantly, are non-verbal representations constrained by working memory capacity as it is the case for verbal representations? Additionally, the presence of both verbal and non-verbal components in the discourse highlights the dynamic nature of language processing system which may require moment-to-moment modulation of resources as well as the interaction of different modules through which different representations are stored. In parallel to this argument, capacity-limit theories assert that degree of interaction between different modules of language processing is also dependent on capacity and in the absence of available resource the interaction between varying subsystems is limited (Just & Carpenter, 1992).

As was pointed out earlier, much of the current literature and theories on the link between working memory and language development pay particular attention to verbal working memory. However, as shown originally by Viterbori, Alp, Scopesi, Zanobini and Usai (unpublished data) non-verbal working memory capacity and morphological ability, another component of language development, may also be related, at least in the case of very young children. In their study, twelve typically developing and twelve language delayed Italian 28-month-olds' non-verbal IQ, non-verbal working memory capacity, expressive and receptive language abilities were assessed. Results indicated that children who had higher nonverbal working memory scores were at relatively lower risk for language delay and, in particular, morphological ability, was the ability which was significantly associated with nonverbal working memory scores. Moreover, when children with a non-verbal working memory span of 2 or 3 (n = 19) were compared with those whose spans were higher (n = 5), high non-verbal working memory group also had higher scores on Expressive Language measures (expressive vocabulary, use of sentences with function words, and use of sentences with pronouns). Although the difference between the two groups failed to reach statistical significance on Receptive Language measures, the results were in the predicted direction such that those children who had an IST score of 3 or less, scored lower on Receptive Vocabulary (M = 15.4, SD = 3.2 vs. M = 18.0, SD = 1.2) and Receptive Grammar (M = 11.1, SD = 6.4 vs. M = 14.6, SD = 2.9). That these differences failed to reach statistical significance might be due to the rather small sample size. In general, then, the results of the study suggest that nonverbal WM may be related to both expressive and receptive aspects of language development.

Moreover, differential relationship of verbal and non-verbal working memory has recently been investigated by a study as a part of master's thesis project in Turkish speaking children (Feldman, 2012); however, only expressive language ability of very young children was assessed in the mentioned study. Specifically, results showed that verbal WM is a predictor of several subcomponents of language development such as vocabulary size, mean length of utterance and morphosyntactic knowledge. However, in the same study, non-verbal WM was not a strong predictor of language subcomponents, despite its moderate correlations with all the language outcomes. In a way, these results are consistent with those of the Italian study. Yet, it is not clear whether the observed superiority of verbal WM in predicting language outcomes is related to the use of expressive language measures only.

Because of difficulties some toddlers experience with articulation, a gap between expressive and receptive language competence may be observed in such children. Thus, their expressive language competence may lag behind their receptive language competence, but their communicative competence may be at the same level as the latter. The same difficulty would constrain their performance on verbal WM tasks such as the Non-word Repetition task. Therefore, Feldman's (2012) results may not be generalized to receptive language competence.

Therefore, a replication of that study where receptive language ability is also assessed along with expressive language ability together with both verbal and non-verbal WM assessments, seems to be in order. The hypothesis that verbal and nonverbal WM differentially predict expressive and receptive language, respectively, is tested in the present study. Consistent with the results of the two earlier studies, both WM capacities were predicted to be related to both language modalities, but (1) verbal WM-productive language relation was expected to be stronger than nonverbal WM-productive language relation and, similarly, (2) nonverbal WM-receptive language relation was expected to be stronger than verbal WM-receptive language relation.

2.2 Language and gesture as integrated communication systems

Human communication system extends beyond the realm of verbal medium and it is supported by a range of nonverbal tools such as intonation, stress, pitch, rhythm, bodily movements, interpersonal spatial positioning and gesture (Anderson, 2006). Facial and bodily gestures constitute an integral part of everyday communication; their effects are so robust that across different cultures and age groups, including infants, individuals use gestures in combination with their speech (Özyürek, 2010). Apart from its impact on face-to-face interaction even people congenitally blind, people talking on the phone and people who communicate via sign language rely on gestures to convey their intended messages to other parties (Özyürek, 2010). Speakers benefit from multimodality enormously because through different modalities it is possible to convey messages more effectively. For instance, our hands are better at representing shapes and our faces are better at representing emotions and attitudes, thus saving our energy which may otherwise be put into use for producing precise verbal descriptions of these dimensions (Wagner, 2014).

Gestures are visible actions produced by hand, body and face during speaking in place of an utterance or as a part of an utterance (Wagner, 2014). Gestures can be classified according to their form, the semantic and pragmatic functions they perform, their temporal congruity with speech and their connection to the dialogue context (Wagner, 2014). Generally, it is reasonable to use a categorization system like the one proposed by McNeill (1992) which is based on the semantic function of gestures. In McNeill's classification system, gestures are divided into four main categories: iconic gestures, metaphoric gestures, deictic gestures and beat gestures. Iconic gestures represent physical features of concrete entities or actions; metaphoric gestures are similar to iconic gestures but differently they picture more abstract entities; deictic gestures are simple pointing actions and they may include both abstract and concrete pointing; and, lastly, beats are defined as fast hand movements that are in close synchrony with the prosody of speech in turn contributing to the prominence of speech rather than its meaning (Wagner, 2014; McNeill, 1992). In the developmental trajectory, gesturing begins between 8 and 12 months before children turn into fluent speakers (Iverson & Goldin-Meadow, 2005). In the developmental sequence, deictic gestures are the first to appear as these groups of gestures are closely tied to the context, later children develop more complex forms of gestures such as iconic gestures which are not strongly tied to the context and make extensive demands on attentional processes (Iverson & Goldin-Meadow, 2005; Liszkowski & Furman, 2014). Early in development, gestures play a central role in language learning. To illustrate, lexical items enter into a child's vocabulary after they are expressed in gestures, similarly two-word utterances produced by a child come into the stage only after the child's first gesture-word combinations (Iverson & Goldin-Meadow, 2005). Collectively, these findings outline a critical role for gesturing and it is clear that, before turning into truly fluent speakers, gestures provide children with the possibility to convey meanings they are incapable of expressing verbally.

Although there is consensus on the importance of gesturing on language development at multiple levels from word acquisition to narrative development, different accounts exist on whether gesture and speech interact and form an integrated system during language production or the two streams of communication are separated but parallel systems. Proponents of the integrated communication system approach maintain that gesture and speech come from different representational formats; however, they convey the speaker's meaning as a composite signal through semantic and temporal coordination (Özyürek, 2010). On the other hand, independent systems account maintains that gestures derive from spatial and motoric representations while speech originates from propositional representations and these two representations do not interact but are processed in a parallel fashion during language production (Özyürek, 2010). In the latter account, gestures are not assumed to have a communicative function and according to these models gestures are for keeping representations active in the memory and facilitate the retrieval of lexicons through cross modal priming from gesture to speech (Özyürek, 2010). A considerable amount of literature has been published on this debate and recent neuro-imaging, neuropsychological, cross-linguistic and experimental research supported the claims of interaction models over independent and sequential models. The remaining part of this section gives a brief overview of these empirical efforts.

First counter evidence for the independent models comes from a study by Wagner, Nusbaum and Goldin-Meadow (2004). Using a dual-task paradigm, authors tried to decide which system, visuospatial working memory or verbal working memory, mediated gesture production process. Participants were asked to perform two tasks simultaneously: (1) to explain the solution of math problems they were presented and (2) to perform a working memory task. Working memory task was also manipulated across participants, while one group of participants remembered a list of letters (verbal working memory task), the other group was assigned an array of dots on a grid (visuospatial working memory task) to remember. Moreover, on some lists, participants were allowed to move their hands freely while on others gesturing was forbidden. Underlying assumption of the study was that if gestures derive from visuospatial representations then gesturing during the math explanation task should interfere with performance in visuospatial working memory task, but if the reverse is true, that is, if gestures do have a propostitional basis then gesturing should facilitate performance in both working memory tasks. Results of the study confirmed the underlying assumptions and it was shown that gesturing during the explanation of math problem does not interfere with the recollection of visual patterns and more importantly participants remembered more items from both lists when they were allowed to gesture than they were not allowed to gesture. More interestingly, the number of items remembered varied according to the semantic relatedness between gesture and speech; that is, when speech and gesture conveyed the same message, participants remembered more items than when gesture and speech conveyed mismatching information (Wagner et al., 2004). From these results authors concluded that gestures originate from propositional representations rather than visuospatial representations.

According to the integrated communication system view, linguistic framing specific to each language changes the way how gestures are structured. In this respect, cross linguistic studies comparing languages which have different typologies, lexical, constructional and expressive resources provide a suitable test ground for determining the relationship between gesture and speech. Each language packages the to-be-expressed message differently and linguistic formulation possibilities existing in each language determine how gestures will be constructed (Kita & Özyürek, 2003). Data for this set of claims were collected by several gesture researchers and one of these studies was conducted by Kita and Özyürek (2003) who compared a number of languages including American English, Turkish and Japanese. In their study, using videos in which certain action events are depicted, they compared the way how speakers of three languages construct their gestures for these action events, each of which have a different verbal representation across proposed languages. Their results showed that when a specific feature of an event is lacking in the lexicon of a certain language then this feature is not represented in the gestures produced, in a similar vein, if a particular language conveys path and manner information through different words then manner and path information are very likely to be represented via two distinct gestures during the discourse (Kita & Özyürek, 2003).

Extension of language specific semantic and syntactic encodings to gesture use was also established in very young children. In a longitudinal study, Furman, Küntay and Özyürek (2014) explored whether language specific features are present in early gestures of Turkish speaking young children. Researchers specifically focused on caused motion expressions due to several reasons: (1) Turkish is a verb-framed language where verb acquisition precedes noun acquisition; (2) in Turkish action and path components of caused motion can be expressed solely in verbs in contrast to satellite-framed languages like English where each component of caused motion is expressed by a different unit; and lastly (3) Turkish is a language open to argument omissions. Their results showed that language-specificity is evident in gesture use. Strikingly, Turkish speaking children were found to be using iconic gestures earlier and in a greater extent than children of other languages, here early verb acquisition of Turkish speaking children was assumed to lead this early onset. Additionally, findings highlighted that Turkish speaking children used gesture as supplementary to the meaning conveyed by speech even after a certain age at which children from other languages used speech as a sole medium of communication. Sustained use of supplementary gestures in Turkish was attributed to argument omissions in Turkish. That is to say, arguments are easily dropped in Turkish because these arguments are deducible from either verb semantics or discourse context. At this point, according to the authors, gestures may be signaling these omitted arguments by referring to visual context, thus serving a pragmatic function.

Gesture serves a beneficial function for both speakers and listeners. On the part of listeners, it is possible to glean specific meanings via spontaneous gestures otherwise difficult to deduce from verbal expressions. For speakers, gestures confer a number of profits from increasing fluency, use of fewer non-juncture filled pauses during speaking, resolving tip of the tongue states easily to reducing the demand on working memory when resources are exhausted (Cook, Yip & Goldin-Meadow, 2011). Having agreed upon the beneficial effects of gesturing, researchers have drawn attention to the question of whether it is the mere presence of gestures or the semantic relation of gesture to speech that makes gesturing both communicatively and cognitively advantageous (Cook et al., 2011). In the study carried out by Cook et al. (2011), participants were asked to remember letters while explaining their solutions to math problems across three conditions, namely; meaningful gesturing, meaningless gesturing and no gesture. Results indicated that participants who were asked to gesture in a meaningful way recalled more items in the working memory task in comparison to others who produced meaningless hand movements or no hand movements at all. The cognitive advantage gesturing confers on working memory thus seems to stem from its properties as a vehicle for transmitting meaning and its synchronization with the meaning conveyed through speech rather than its mere motoric presence (Cook et al., 2011).

Neural circuitry underlying speech and gesture integration also accords with the idea that speech and gesture are the components of the same communication system. Brain regions responsible for language processing are accepted as Broca's area and adjacent areas including BA 45/47 from anterior part of the left inferior frontal cortex, BA 6 from the premotor cortex and inferior part of parietal cortex (Willems et al., 2007). Among these areas it is the frontal left inferior cortex, known as unification site, which shows increased activation when information from different modalities or information from memory is integrated into a sentence level semantic representation (Willems et al., 2007). Gesture and speech integration is not an exception to this finding and their integration is also carried out by the activations observed in this unification site (Willems et al., 2007). Importance of Broca's area as a unification cite for gesture and speech integration is also evident in the case of aphasic patients. In a study carried out by Cocks et al. (2009) a patient with severe Broca's aphasia was compared to control participants in speech and gesture integration performance and it was shown that aphasics have an impaired capacity to integrate speech and gesture. Moreover, following error analyses indicated that when patients with aphasia fail to integrate speech and gesture, they mostly rely on gestural information to decode the meaning similar to individuals who have low comprehension abilities (Cocks et al., 2009). Overall, it is clear that when decoding a meaning, brain utilizes the information carried via both channels, speech and gesture, and while integrating the information coming from different channels unification cite gets activated as it is the case in language processing in which different linguistic units are integrated.

Gestures' role in communication of language-impaired groups also supports the claims of interaction models. When language abilities fail to reach a certain level of proficiency, gestures seem to provide a compensatory mechanism for the language difficulties. Blake et al. (2008) pointed to the compensatory role of gesture, comparing children with SLI to age matched and verbal IQ matched peers on a narrative retelling and classroom description task. Results did show that use of iconic gestures by children with SLI is greater than the use of others, children with SLI replace words with gestures more often than comparison groups do (Blake et al., 2008).

Speech and gesture form an integrated communication system in which gesture puts listeners and speakers in a cognitively and communicatively advantageous position. Before becoming fully fluent speakers, children rely on gestures and in early childhood gesture use is a strong predictor of both vocabulary acquisition and the emergence of multiword constructions (Iverson & Goldin-Meadow, 2005). Apart from contributing to the efficiency of messages, in the face of impaired or delayed language development gestures serve a compensatory function (Blake et al, 2008). It is clear that at different levels of verbal competency, gestures are present but they serve different functions and this functional difference is linked to varying cognitive processes.

Low verbal competency is known to be associated with greater gesture use in several cases like specific language impairment, aphasia and low comprehension ability (Cocks et al., 2009). Based on this finding, it can be further maintained that low verbal working memory, a construct at the root of language development, may be a leading factor in gesture production. However, here it is important not to assume that the relation between verbal working memory and gesture use is a linear one, because other cognitive constructs, such as non-verbal working memory, may be interacting with verbal working memory to ease the gesture production process. For example, Hostetter and Alibali (2007) argued that verbal working memory interacts with visual working memory to ease the gesture production process. However, as discussed before, gestures are more than visual representations and they do have a propositional representational base so it is highly reasonable to expect that verbal working memory interacts with a modality free attentional component. Therefore, in the present study, it was expected that high non-verbal working memory capacity would facilitate the gesture production process resulting in higher number of gestures produced, but only when the ability to construct messages verbally was deficient; that is, when verbal working memory capacity is low.

2.3 Working memory and gesture

People gesture spontaneously as they speak; however, large individual variation in gesture use has been highlighted by empirical research. As an illustration; in general women are more inclined to gesture than men do, young women rely more on gesturing in comparison to older women and, lastly, people who are said to be more extraverted produce more gestures than introverts (Chu, Foulkes, Meyer & Kita, 2014). Recent developments in gesture literature have led to a renewed interest in functions gesture serve beyond its obvious communicative function and cognitive mechanisms underlying individual differences in gesture use.

One of the accounts that explored the cognitive advantages of gesturing and undelying mechanisms of gesture use is named ‘lightening cognitive load hypothesis’ (Goldin-Meadow, Nusbaum, Kelly & Wagner, 2001). Proponents of this view basicly suggest that gesture and speech work synergistically and form an integrated communication system in which active involvement of one modality in discourse lightens the load on the system as a whole (Goldin-Meadow et al., 2001). Alternatively, according to reserachers, gesturing may be playing a role in shifting some of the load on verbal working memory to other components of the cognitive system, consequently reducing the overall load in the system (Goldin-Meadow et al., 2001). This alternative approach strengthens the view accepted in this study which argues that gesture and speech may be making demands on different memory stores such that while non-verbal working memory is addressing the demands of gestures, demands of speech are met excessively by verbal working memory store. The central thesis of this paper is that individual differences in verbal and non-verbal working memory stores and the interaction of these differences have an influence on gesturing behavior of children whose memory stores are still under development.

How gesturing can increase available cognitive resources, how gestures help speaking, and more importantly, do gestures have cognitive functions other than their communicative functions? These are all important questions that deserve attention and in the literature several explanations have been proposed to address these questions. More precisely, communicative functions of gestures are assessed by Lexical Retrieval Hypothesis and Image Activation Hypothesis while Information Packaging Hypothesis appeared to explain cognitive functions of gesturing. As all these hypotheses are somehow connected with working memory, the key construct of present study, in the forthcoming sections they are summarized.

Information Packaging Hypothesis is the central account that assigns a cognitive function to gestures beyond its established communicative functions (Alibali, Kita & Young, 2000). The main idea in the hypothesis is that spatio-motoric thinking which constitutes the very basis of representational gestures shapes speech production by providing an alternative organizational framework which is not available to analytical thinking, a default way of organizing information in speech production (Alibali et al., 2000). Although spatio-motoric thinking and analytic thinking differ from one another with respect to informational organization, in the course of speaking the two modes of thinking work collaboratively with each other to organize to-be-verbalized message in a compatible way with the linear nature of speech without exhausting the limited capacity of language system (Kita, 2000; Alibali et al., 2000). In the collaboration process, the degree of match between the representations of spatio-motoric and analytic thinking are constantly checked and the contents of two thinking modes are updated via translations from one mode to the other mode as far as cognitive resources of thinking modes allow (Kita, 2000; Alibali et al., 2000). Once a certain level of convergence between two modes of thinking is achieved and all organization possibilities are reviewed, the to-be-conveyed information is organized into a series of packages that can be verbalized (Kita, 2000). Overall, Information Packaging Hypothesis offers some important insights into how gesturing along with language constitute thought (Kita, 2000). More importantly, the insights of Information Packaging Hypothesis have a lot in common with the propositions of integrated systems view, as both accounts rely on the synchrony between gesture and language. Additionally, going one step further, Information Packaging Hypothesis and capacity-limit theory of language development can be aligned, because the limited nature of cognitive resources in speech production lies in the center of both views.

Considering communicative functions of gestures, two major views are offered, namely, Lexical Retrieval Hypothesis and Image Activation Hypothesis. In the speech production process, gestures have been argued to support speaking by accelerating the access to elusive lexical items which in turn reduces the demand of the speaking process (Krauss, 1998). This argument was termed as Lexical Retrieval Hypothesis (LRH) by Krauss (1998). LRH assumes that in formulating speech, speakers benefit from gestures because gestures aid the retrieval of inaccessible lexical items from the lexicon (Krauss, 1998). The logic behind this hypothesis is that gestures maintain the conceptual properties of the inaccessible word active during lexical search (Krauss, 1998; Kita, 2000). On the other side, according to Image Activation Hypothesis, when people gesture, they create specific images and these images get connected to the words, in this way language processes encode spatial features more efficiently during speech formulation (Kita, 2000).

Claims of Lexical Retrieval Hypothesis are not without controversy and they have been challenged in a number of studies. One of these studies is very recent and compared the arguments of given theories: (1) gesture reduces cognitive load on working memory; and (2) gestures facilitate lexical retrieval process. Gillespie, James, Federmeier and Watson (2014) administered a battery including tasks on verbal working memory and lexical retrieval to a sample of 50 undergraduates along with a gesture elicitation task in which gesture production rate was recorded. Results revealed that a greater gesture production rate is associated with lower verbal working memory capacity, but not with lexical retrieval difficulty as indexed by lower scores in vocabulary, semantic and phonetic fluency.

In another study by Alibali et al. (2000) the claims of the Lexical Retrieval Hypothesis were contrasted with the claims of Information Packaging Hypothesis. Equating lexical access and manipulating conceptualization load across two tasks, researchers tried to determine whether gesture plays an active role in lexical access or whether gesture is involved in conceptual organization of the message. One of the tasks was an explanation task in which Piagetian conservation problems were solved and conservation judgments were explained by participants and the other one was a description task in which participants described the difference between two items (e.g., a glass of sand and a bowl of sand). Because the explanation task requires a more complex conceptualization process, researchers predicted that explanation task would elicit more gestures than description task. The results of the study supported this prediction. One more time, cognitive functions of gestures and the effect of gesturing in conceptual planning of speech production and thought processes surfaced.

In addition to these accounts, alternatively, gestures may help speakers to concentrate their attention on the task at hand and in this way not only irrelevant information is blocked out, but also the demand on working memory is decreased (Cook et al., 2011). Given that there is a relation between working memory and attention processes, this possibility sounds reasonable. According to Engle (2002) greater working memory capacity is not solely a result of larger memory store but also a result of greater ability to execute attention. In a number of attention tasks such as antisaccade task, Stroop task and dichoting-listening task in which mental work is done in the face of distracting information, people with greater working memory span have been found to outperform people with lower working memory span (Engle, 2002). Moreover, as indicated before, it is executive attention component of working memory which derives the relationship between working memory and many other higher order cognitive tasks including language processing (Engle, 2002).

Gesture may also serve an externalizing function for the internal representations in order to decrease the cognitive load. To put it more clearly, through gestures, speakers may be creating some environmental affordances that coordinate their internal representations with external world or they may be filling the gaps of internal representations with the information present in the external world through gestures especially in the face of novel, difficult, spatial and abstract concepts (Cook et al., 2011). Surely, this externalization alleviates the need to represent all the material internally, which in turn reduces the overall demand on the speech production system (Cook et al., 2011).

The second line of attempts to disentangle the link between cognitive processes and gesturing comprises studies that directly explore the sources of individual variation in gesture production and others that particularly explore the cognitive underpinnings of gestures.

In one of these studies, empathy level, cognitive ability (as indexed by visual, spatial and verbal working memory capacity), conceptualization ability, spatial transformation ability and lexical retrieval ability of participants were regarded as variables effecting gesture frequency and gesture saliency which refers to the size and height of a gesture (Chu, Foulkes, Meyer & Kita, 2014). Empathy level was found to be a strong predictor of gesture saliency, that is, individuals who are more empathetic and care about the quality of their interactions or understanding of others use more salient gestures than individuals who are less empathetic. Similarly, people with high level of empathy were found to be using some gestures like conduit and palm revealing gestures, which are accepted as increasing the interaction between a speaker and listener, to a larger extent (Chu et al., 2014). On the cognitive side, the results revealed that gesture frequency, but not gesture saliency, was negatively correlated with visual-spatial working memory, spatial transformation ability and conceptualization ability (Chu et al., 2014). However, of particular interest to the study, verbal working memory did not show any connection with gesture frequency and gesture saliency (Chu et al., 2014). Perhaps because verbal working memory was measured by digit span task, researchers could not find any significant relationship between this construct and gesturing. Instead of digit span, other span tasks such as reading span might be more appropriate.

In another study, Hostetter and Alibali (2007) argued that hard evidence for a straightforward relationship between verbal skills and gesture production is lacking. According to them, source of these mixed results stem from two reasons: (1) the absence of specific verbal skill tasks relevant to gesture production, and (2) the expectancy that there is a linear relation between gesture production and verbal skill. Speculating on the second claim, researchers reasoned that at each end of the verbal skill spectrum people may have different reasons (e.g., compensating verbal impairments or making speech more enriched and communicatively efficient) to use gestures. Hence, verbal skills must be considered in combination with other cognitive skills like spatial abilities. At different levels of verbal skill, level of proficiency in other cognitive skills may contribute to the amount of gestures produced. Their results have supported this reasoning because people with lower verbal ability combined with high spatial visualization skill showed the greatest gesture production rate (Hostetter & Alibali, 2007). Here it may be possible that although people may have the necessary spatial images in their mind, they might have failed either (1) to organize them into packages to verbalize or (2) to find the affiliate lexical item for the expression (Hostetter & Alibali, 2007). Another important result from this study is that, among verbal ability tasks, it was the phonemic fluency task, but not semantic fluency task, which turned out to be a strong predictor of gesture production rate. What makes this result important is phonemic fluency's connection with executive control and attention. Phonemic fluency task is assumed to tap organizational efficiency, in doing this, the task relies on frontal lobe abilities like switching, effortful planning and strategic search because throughout this task participants need large amount of executive control to organize their lexicon around new subcategories (Hostetter & Alibali, 2007). As indicated by Information Packaging Hypothesis, gestures serve a facilitative function in these organizational processes, this overlapping function between gesture and phonemic fluency might be reflective of a common underlying cognitive ability namely working memory whose connection to executive functions have been well established.

Executive functions are a subset of cognitive abilities carrying out the control and coordination of information in the service of goal directed behavior (Kuhn, Willoughby, Vernon-Feagans, Wilbourn & Blair, 2014). Mostly agreed executive functions in the literature are inhibition, shifting and updating (Miyake, Friedman, Emerson, Witzki, & Howerte, 2000). Language development may be a precursor for executive functioning and one such view belongs to Zelazo and his colleagues (as cited in Kuhn et al., 2014) who proposed a theory called cognitive complexity and control theory. In view of this theory, language is useful both for the process of constructing the mental representation of a problem to-be-resolved and for forming/using rule structures necessary for the resolution of a problem or conflict. An indirect relationship from gesture use to executive functioning is also observed in a longitudinal study by Kuhn et al. (2014) which demonstrated that gesture use at 15 months predicted language development in 2 to 3 years which, in turn, predicted executive functioning at the age of 4. The authors concluded that symbolic understanding children develop through gesture use is later transferred into language and lastly in the sequence this ability lends itself to managing multiple representations which is central to executive functioning (Kuhn et al., 2014).

Intertwined relation between working memory and gesture use finds also support from aging literature. Older adults produce less speech accompanying gestures, they are slower in gesture imitation, they fail to name and categorize pantomime gestures and they are less likely to use gestures as a tool for enriching their verbal communication (Cocks et al., 2011). One reason behind this impairment is thought to be cognitive impairments associated with aging, especially reduced working memory capacity. For older adults, in language context, reduced working memory capacity means allocating most of this resource to verbal processing and leaving fewer resources for gesture processing (Cocks et al., 2011). In a similar vein, older adults' difficulty with remembering the context, in a framework where gestures provide a context for verbal processing and language provides a context for gesturing, is assumed to be a second problem leading to impairment in their gesture use (Cocks et al., 2011). Comparing younger and older adults Cocks et al. (2011) emphasized the role of working memory in speech and gesture integration in which different but related information coming from these two channels need to be integrated for deducing the exact meaning. Semantic and temporal integration of speech and gesture appears around 14 to 22 months and even when children enter into the two-word stage they continue to use these two modalities combinatorially (Özçalışkan & Goldin-Meadow, 2009). In old age, impairments are observed in the integration process as also indicated by Cocks et al. (2011) who observed that speech and gesture integration is impaired in older adults in comparison to younger adults. Older adults predominantly rely on speech which can be interpreted unambiguously without gestures when the integration process fails. In the same study, although working memory was not assessed, researchers proposed a specific role to working memory in the integration process. Speech and gesture provide a context for each other and flow of information between these distinct modalities needs to be retained and updated continuously. Surely, the retention and updating work falls on the shoulders of working memory, when it fails so does the integration process.

Similar to elderly population, very young children also have a very limited working memory capacity. Low working memory capacity may lead to impaired use of speech-gesture combinations also in very young children. This possibility was tested in the present study. In order to combine speech and gesture in an efficient way, children need to be capable of representing more items in their working memory because integration process requires the representation of complimentary meanings separately across two modalities as well as the integration and coordination of these modalities. Considering the requirements of the integration process, in the current study it was expected that children who have higher non-verbal working memory abilities combined with better verbal working memory skills would produce significantly higher number of speech-gesture combinations than other children whose verbal and/or non-verbal working memory stores fall short.

2.4 The present study

In the light of the above literature review, the aim of the present study was to investigate the connections among language development, gesture use and working memory. Central questions in this study were: (1) Do the use of gesture and gesture-speech combinations relate differentially to verbal and non-verbal working memory capacity and (2) How do receptive and productive language development relate to these two memory systems separately.

The three general hypotheses of the current study were that (1) verbal working memory and non-verbal working memory have close connections with attentional executive processes and memory abilities (i.e., they are related systems),

(2) they both have an influence on both language development and gesture use, and (3) receptive and expressive language are differentially related to verbal and non-verbal working memory.

The specific hypotheses were as follows:

1. The amount of gestures produced by children depend on their working memory capacity such that low verbal working memory is associated with greater gesture production, but only when it is accompanied by high non-verbal working memory capacity.
2. Use of gesture-speech combinations is related to both verbal and non-verbal WM capacity, such that children who are better in verbal and non-verbal WM capacity produce a greater number of gesture-speech combinations than other children who are worse in either or both of the two memory systems.
3. Verbal WM is a stronger predictor of productive language than non-verbal WM. Conversely, non-verbal WM is a stronger predictor of receptive language than verbal WM.
4. Verbal and non-verbal WM are closely associated.

CHAPTER 3

METHODOLOGY

3.1 Participants

Participants were 50 children aged 22-42 months (*M* = 33.6, *SD* = 4.42), they were recruited by convinence sampling from five private day-care centers located in İstanbul. All children came from middle-to-high SES families and also all of them were native Turkish speakers with no history of any language or developmental delay. One child was excluded from the sample because she did not want to complete one of the working memory tasks, and another child was also excluded from the sample due to experimental failure. Thus, the final sample consisted of 48 children (20 female, 28 male) with an average age of 33.5 months (*SD* = 4.49). The distrubution of children across age groups is represented in Table 1.

Table 1. Child Gender by Age Period.

	22-28 months	29-35 months	36-42 months	Total
Male	4	16	8	28
Female	1	9	10	20
Total	5	25	18	48

3.2 Measures

Children were tested on three main dimensions: working memory, gesture use and language skill. A total of four measures were employed to assess working memory (Imitation Sorting Task and The Non-Word Repetition Task), gesture use (Gesture Elicitation Task) and receptive language development (Turkish Test of Early

Language Development; Topbaş & Güven, 2011). In addition to these tasks, the parents were given a parent report form for assessing productive language skills of children (Turkish Communicative Development Inventory; Aksu-Koç, Küntay, Acarlar, Maviş, Sofu, Topbaş & Turan, 2011) and a demographic form (see Appendix C)

3.2.1 Working memory tasks

3.2.1.1 Imitation Sorting Task (IST; Alp, 1994)

Imitation Sorting Task (IST) is a measure for assessing the size of nonverbal working memory in very young children (Alp, 1994). Across eight levels of difficulty and with three sets of toys (e.g., eating utensils, animals, vehicles, fruits and furniture) to be sorted at each level, children are required to imitate the experimenter as he/she sorts small toys into two separate transparent canisters. The number of toys in each set is designated according to the level of difficulty by adding one more toy at each succeding level. In an attempt to make sure that children understand the task procedure and they are capable of dropping the toys into canisters, a warm-up trial with one toy is introduced at the first level.

In the present study, test trials began with the second level. Before each trial children were allowed to explore objects for a few seconds and later the experimenter demonstrated the sorting in the prescribed order. Upon completing demonstration, children were requested to sort the objects in the same way as the experimenter demonstrated. In order to achieve the pass criterion, children were required to imitate sorting the toys into the same groups of two rather than dropping the sorted toys exactly in the same canisters as the experimenter. If the child failed on the first trial, one more chance was provided after the experimenter demonstrated correct sorting one more time. In order to successfully complete a level, children needed to pass two out of the three sets of toys. Failure at two consecutive levels resulted in the termination of testing. Highest level passed during the administration was converted into a numerical score for IST such that high scores reflecting high working memory capacity. Scores ranged between 1 to 8 and if only one set out of three sets could be sorted correctly then an extra half point was given to children.

IST was found to possess adequate psychometric properties. The measure was found to have a high interobserver reliability as high as 100%, and also it was found to have a very high retest reliability (r = 0.75). IST, as an experimental tool, is both senstive to age differentiation in the size of working memory and immune to learning effects. In an earlier study, upon retesting within a few weeks childrens'original score and rank remained similar suggesting that this instrument reflects an underlying capacity rather than learned responses. In a similar vein, administration of the task six months later revealed an increase in childrens'working memory score reflecting age differentiation specific to working memory capacity. Another contribution to construct validity of IST came from an unpublished study, Myers, Perlmutter, and Cohen (as cited in Alp, 1994) which adopted another task similar to IST. In this task, children were required to reproduce a 2x4 visual array comprised of small toys as similar to imitation procedure in IST. What was striking in these two tasks was the similarity between the scores taken from each measure by children of three years old (for details, see Alp, 1994).

3.2.1.2 Nonword Repetition Task (NWR; Gathercole & Baddeley, 1989)

The Non-Word Repetition Task which was constructed by Gathercole and Baddeley in 1989, based on the assumptions of phonological loop model, is frequently used for assesing phonological memory abilities. A number of other cognitive processes are also tapped by non-word repetition ability and they include speech perception, motor planning, articulation, lexical and phonological knowledge, phonological segmentation and assembly of articulatory instructions (Baird, Dworzynski, Slonims & Simonoff, 2009; Snowling, Chiat & Hulme, 1991). Moreover, NWR task was qualified as a psychometrically sound measure with its acceptable test-retest reliability (Archibald, 2008). NWR task is also very practical to implement and it has several advantages over traditional language measures. Unlike traditional knowledge-based language measures it is free from bias by experience as it is less culturally biased. One last advantage of NWR task is its being independent of IQ (Archibald, 2008).

In the original version of the task, children are presented with a set of 40 non-words whose length changes from two to five syllables. Following the presentation of words verbally, children are asked to repeat the nonwords. Performance is scored as the total number of correctly repeated non-words (Adams, 2010).

In Turkey, in an attempt to measure reading achievement of school aged children education researchers compiled non-words that represented grammatical and phonetic characteristics of Turkish (Babür, Haznedar, Erçetin, Özerman & Çekerek, 2013). In the identification process of words, numerous story and textbooks were scanned by authors and the number of words were reduced from 453.000 to 53.688 on the basis of frequency of words (Babür et al., 2013). Completing word identification process, authors derived non-words from the frequency list at hand by taking the phonological and morphological structure of Turkish into account. In the end, the process ended up with a list of 126 non-words (Babür et al., 2013). In the current study, within the context of non-word repetition task, a set of 29 non-words from this list and another 11 non-words used in an unpublished study (Feldman, 2012) were used to assess children's verbal working memory capacity (for the total list of non-words see Appendix A).

The non-words used in the present study varied in syllable length ranging from two to five, at each syllable length 10 nonwords were presented to children. Before the presentation of non-words to be assured that the procedure was fully understood by the children, a trial word like "daddy" *(baba)* which was most likely familiar to the child was introduced. As it is the case in the original version of the task, children were expected to repeat back the non-word after it was spoken by the experimenter. Five consecutive failures resulted in the termination of the task and childrens' verbal working memory score was determined by the number of correctly repeated non-words. Scores varied between 0 and 40, any refusal to repeat the non-words were accepted as missing while immediate self-corrections were treated as a correct response.

3.2.2 Gesture elicitation task (Liszkowski & Furman, 2014)

Gesture elicitation task is a novel tool for assessing the nonverbal aspect of communication, namely, iconic gesture production. Recently, researchers have shown an increased interest in the question of when and why children use representational gestures. Studies such as that conducted by Liszkowski and Furman (2014) showed that young children produce representational gestures when they want to convey their requests to other people and when they want to correct others' erroneous actions. Relying upon these findings, Liszkowski and Furman (2014) constructed a new gesture elicitation paradigm. In the given paradigm, children are presented with correcting situations in which one puppet erroneously acts on known everyday objects such as hammer, shovel, cup etc and in turn children are expected to protest these erroneous acts and correct them by producing only speech, only gesture or producing gesture and speech in combination. For each child, the amount of only-gesture, only-speech and gesture-speech combination produced across six experimental trials were calculated.

In the administration of the task, two stuffed toy puppets (a dog and a bear) were used to demonstrate two different actions on objects (for objects and actions see Appendix B). Across participants, each puppet was randomly assigned to demonstrate either a correct or a wrong action. Amount of only-gesture, only-speech or gesture-speech combination produced by children in response to either toy did not differ significantly (Gesture: t (46) = -.994, p = .325; Speech: t (46) = -.777, p = .441; Gesture-Speech Combination: t (46) = .635, p = .528). Each testing session consisted of 1 warm-up trial and 6 test trials. A different object was used for each of the 7 trials. The object for the warm up trial was always a toy rattle and the order of test objects were randomized across children. In randomizing test trial objects, half of the children were presented first with the objects that afforded actions on the body (hairbrush, toothbrush and cup) while other half was presented first with the objects that afforded actions on the neutral space (hammer, shovel and knife). Across two set of toys, children's responses in the form of gesture, speech or gesture-speech combination did not differ significantly (all ps > .05).

3.2.2.1 Coding

A coding system was developed specifically for gesture elicitation task and this system consisted of formal criteria for identifying (1) only-gesture acts were gestures that were not accompanied by speech, (2) only-speech acts were words produced without gesture and lastly (3) gesture–speech combinations were acts containing both gesture and speech which are semantically and temporally synchronised. Only-gesture, only-speech and gesture-speech combination counts were coded by two primary coders from the video recordings. To determine reliability, the author coded a subset of the data coming from 18 participants (33% of the sample) on the gesture elicitation task.

In order to decide whether a hand movement was a gesture unit or not coders assessed any hand movement on the basis of three criteria: (1) movement, which means any hand movement that has a sufficient amplitude and speed so that it could be easily perceived, (2) location, according to this criteria a hand movement should be counted as gesture if it was produced in the visual field of its perceiver and lastly (3) configuration that is a hand movement should reflect a clear action with a precise hand shape and well-marked motion trajectory (for more details see Colletta, Pellenq & Guidetti, 2010). Hand movements that were produced without any speech and that met these criteria were identified as only-gesture. Cohen's κ was run to determine if there was agreement between each of primary coders and reliability coder on gesture only count. There was a substantial agreement between the judgements of first primary coder and reliability coder, $\kappa = .735$, $p < .01$ while the agreement between second primary coder and reliability coder was almost perfect, $\kappa = .921$, $p < .01$ (Landis & Koch, 1977).

Speech produced by children without any accompanying gesture was also coded. Children’s speech was transcribed and it was classified as only-speech if hands were at resting potential that is there was no change in hand shape or motion during speech. The interrater reliability calculated between first primary coder and the reliability coder was found to be κ = 0.538 (p <.0.01), and with the second primary coder it was found to be perfect, κ = 1 (p <.0.01).

Gesture speech pairs were accepted as gesture-speech combinations if there was both a semantic and temporal relation between gesture and speech (Özçalışkan & Goldin-Meadow, 2009; Blake, Myszczyszyn, Jokel & Bebiroglu, 2008). Semantic relationship between gesture and speech were categorized into three types: (1) a reinforcing relation was coded when gesture conveyed the same information with speech (e.g. "brushing our teeth"+using finger or hand as a toothbrush), (2) a disambiguating relation was identified when gesture clarified the referent of speech (e.g. "like this, like this"+using finger or hand as a toothbrush) and (3) a supplementary relation was accepted when gesture added semantic information to the message conveyed in speech (e.g. "our tooth"+using finger or hand as a toothbrush). Furthermore, three types of temporal relation between gesture and speech were also coded. Timing of gesture to speech was classified as: (1) gesture precedes the speech, (2) gesture and speech occurs simultaneously and (3) gesture follows the concept expressed in speech. With both primary coders the observed reliability coefficient calculated on gesture-speech combination count was almost perfect (κ = .909, p <.0.01 and κ = .916, p <.0.01 respectively). Agreement was also excellent for identifying the semantic relation between gesture and speech pairs, kappas were calculated to be .821 and .841 across two primary coders. On the other hand, the reliability coefficients for identifying the temporal relation between gesture and speech pairs stayed at moderate levels, with the first primary coder kappa was found to be .472 and with the second primary coder kappa was calculated to be .528.

3.2.3 Language measures

3.2.3.1 Turkish Communicative Development Inventory (TİGE; Aksu-Koç, Küntay, Acarlar, Maviş, Sofu, Topbaş & Turan, 2011)

TİGE (Türkçe İletişim Davranışları Gelişimi Envanteri) is a parent report form for assessing language and communication abilities of young children ages 8 to 36 months. It was adapted from MacArthur-Bates Communicative Development Inventories (CDI) which has been originally developed for English language and which is still being adapted into many other languages (Dale & Penfold, 2011). Turkish adaptation of the instrument was made in 2011 by a group of language researchers, reliability and validity evidence of the adapted form is also established (Turan & Ökçün-Akçamuş, 2013; Aktürk, 2012).

TİGE is composed of two versions whose target age group differs: while TİGE-I is for 8 to 16-month old children, age range of the latter version is restricted to 16 to 36 months. The instrument is administered to the primary caretaker of the child, for the most part to the mother. In the current study, TİGE-II was implemented to assess language and communication competence of children as the target age group of the present study and TİGE-II overlaps perfectly.

TİGE-II comprises two parts: former one is for assessing vocabulary size and early pragmatic skills and the second part is for evaluating children’s knowledge of sentence structure and grammar.

In the first part of TİGE-II, vocabulary size of the children is determined via a checklist containing 711 words coming from 21 different categories like animals, vehicles, toys, foods, body parts, furnitures etc. For the current study, vocabulary size of participating children was derived from the number of words the child could produce out of 711 words placed in vocabulary checklist. Early pragmatic skills of the children were also assessed by questions on children's understanding of past/future events and their reasoning on non-present objects or people.

Second part of TİGE-II is devoted to assessment of morphosyntactic development of children. For this end, children's use of basic elements forming Turkish sentence structure such as tenses, nominal case markings, negation and question endings is measured. In the present study, a morphosyntactic development score was obtained by summing up each answer given to the questions located in second part of TİGE-II. Moreover for the same aim, TİGE-II request from parents to convey three longest sentences that the child has ever produced and the degree of complexity of the sentences that the child uses. In the present study, a mean length of utterance score was computed by dividing total number of smallest meaningful units to the total number of words the child used in the sentences reported by the caregiver.

In the current study, primary caregivers of children were asked to complete TİGE-II in order to derive proposed productive language parameters. However, return rate of inventories appeared to be very low as parents of only ten children completed the forms. For this reason, parameters from TİGE inventory were not included into the main analyses.

3.2.3.2 Turkish Test of Early Language Development (TEDİL; Topbaş & Güven, 2011)

TEDİL is a Turkish adaptation of Test of Early Language Development-Third Edition (Hresko, Reid & Hammill, 1999) and its adaptation study was carried out by Topbaş and Güven (2011). It has been introduced to measure receptive and expressive language skills of children between the ages of 2 to 8 years. Out of five main language components, TEDİL covers three of them and they can be listed as follows: semantics, morphology and syntax. Across two parallel forms named Form A and Form B, mentioned language components are evaluated. Each parallel form, containing 76 items, consists of two parts; one measuring expressive language and other evaluating productive language. In the current study only receptive language component of the test was administered to children and two parallel forms, Form A and Form B, were randomized such that half of the children received Form A and other half received Form B. Between two groups who received Form A and Form B, there was no difference with respect to receptive language scores, t (46) = 1.89, p = .064.

In the administration process, children were individually tested and they were presented with a booklet of colorful pictures and some objects like cubes, small coins, and some toys. What was expected from children in response to these items was to describe or show pictures or asked to follow verbal instructions or give verbal responses to questions asked. According to the age of each child, items were chosen and testing process was commenced. At the end, for each child a raw score of receptive language was calculated according to the guidelines presented in Topbaş and Güven (2011).

3.3 Procedure

After Institutional Review Board for Research with Human Subjects (İNAREK) of Boğaziçi University approved the tasks and testing procedure, the data collection process started. Informed consent was acquired from the parents of all participating children.

All testing sessions were conducted in day-care centers which agreed to cooperate and each child was tested individually in a quite room of the center. The entire battery was administered in one session and the tasks were administered to all participants in the following order: Gesture Elicitation Task, Imitation Sorting Task, Non-Word Repetition Task and Turkish Test of Early Language Development. At the end of the session, each child was thanked and presented with a small gift.

CHAPTER 4

RESULTS

The results are presented in two main sections. In the first section, results of the preliminary analyses are reported. In the second section, results of the analyses carried out to test the hypotheses are reported.

4.1 Preliminary analyses

Descriptive statistics for the key variables of the study are shown in Table 2.

Table 2. Descriptive Statistics of the Key Variables

Variable	N	Min	Max	Mean	SD
Age	48	22	42	33.50	4.48
Non-verbal WM	48	1	8	4.15	1.75
Verbal WM	48	0	38	18.46	11.89
Receptive Language	48	5	26	15.54	5.09
Vocabulary Size	10	201	702	522.70	186.89
Mean Length of Utterance	9	5.33	16.33	9.57	3.48
Morphological Knowledge	10	23	56	43.60	11.07
Only-Gesture Amount	48	0	6	0.75	1.45
Only-Speech Amount	48	0	3	0.23	0.55
Gesture-Speech Combination Amount	48	0	6	2.48	2.48

Note: WM = Working Memory.

Prior to the main analyses, all study variables were checked for normality: skewness ranged from a low of -.081 to a high of .382 while kurtosis values ranged from .004

to -1.82. All skewness and kurtosis values were within the acceptable limits offered for social sciences. The only exception was the amount of only-gesture produced by children in gesture elicitation task with a skewness of 2.37 (*SE* = .34) and a kurtosis of 5.21 (*SE* = .67); thus a log transformation was applied for this variable and log transformed scores were used in the main analyses.

Zero-order correlations among the study variables are presented in Table 3. The following variables increased with age: non-verbal working memory, r (46) = .410, $p < .01$; verbal working memory, r (46) = .457, $p < .01$; receptive language, r (46) = .583, $p < .01$; and number of gesture-speech combinations produced in the gesture elicitation task, r (46) = .295, $p < .05$. Moreover, to check whether there were any sex differences, a series of t-tests were carried out. The results indicated that girls' scores were higher than that of boys on non-verbal working memory task, t (46) = 2.34, $p = .024$ and verbal working memory task, t (46) = 2.22, $p = .031$. No other sex differences were observed.

To provide the necessary background for testing the hypotheses, the following analyses were caried out. First, the relations between the two WM scores and gesture use was examined. The results showed that number of both only-gesture and gesture-speech combination produced by children are positively related with their non-verbal working memory score, r (46) = .367, $p < .05$, and r (46) = .408, $p < .01$, respectively; however, the verbal working memory score was significantly associated *only* with the amount of gesture-speech combination produced, r (46) = .373, $p < .01$. Thus, although verbal WM predicts only the amount of gesture-speech combinations produced, non-verbal WM predicts *both*, the amount of only-gesture *and* the amount of gesture-speech combinations produced. When the effect of age

Table 3. Zero-order Correlations among Study Variables

Study Variables	1	2	3	4	5	6	7
1. Age	-	.410**	.457**	.583**	.203	-.064	.295*
2. Non-verbal WM		-	.519**	.471**	.367*	.105	.408**
3. Verbal WM			-	.471**	.193	-.016	.373**
4. Receptive Language				-	.401**	-.060	.359*
5. Only-Gesture Amount					-	-.007	-.196
6. Only-Speech Amount						-	-.128
7. Gesture-Speech Combination Amount							-

Note: WM = Working Memory. All tests two-tailed.

* $p < .05$. **$p < .01$.

was partialed out, it was observed that the strong association of non-verbal working memory with the amount of only-gesture and the amount of gesture-speech combination remained significant, r (45) = .318, p = .029, and r (45) = .329, p = .024, respectively; however, the association between verbal working memory and gesture-speech combination amount turned into a marginally significant one, r (45) = .280, p = .057.

Across the children, 13 did not produce no response in the form of only-gesture, only-speech or gesture-speech combination on the gesture elicitation task. Those children were compared with the remaining children by a series of t-tests. The results showed that, although these children were not different from the others with respect to age, t (46) = -.977, $p > .05$, they performed more poorly on the non-verbal working memory task, t (46) = -3.52, p = .001, and on the verbal working memory task, t (46) = -2.53, p = .015, and also more poorly in the receptive language test, t (46) = -2.64, p = .011.

Of the remaining children; three produced solely only-gesture responses across the test trials, two produced solely only-speech responses and 13 children produced solely gesture-speech combination responses. Aside from these cases whose response form did not change from one experimental trial to another, 17 children produced more than one response form across the trials. Among these seventeen children, only one child was found to be using all possible forms of response in gesture elicitation task while others used two different response types on the task. In general, then, the use of gesture or speech in isolation seems to be rarer than the use of gesture-speech combinations for this age-range. Age information, memory scores and receptive language ability of these different groups of children are summarized in Table 4.

Lastly, the relations between receptive language and gesture use were examined. These analyses showed that receptive language scores are positively correlated with only-gesture and gesture-speech combination scores, r (46) = .401, $p < .01$, and r (46) = .359, $p < .05$, respectively. Moreover, with partial correlation analyses, the effect of age was controlled and same associations were checked. Results from these partial correlation analyses revealed that when the effect of age was controlled, receptive language ability was still associated with only-gesture production, r (45) = .356, p = .014; however, its relation with the amount of gesture-speech combination did not reach significance, r (45) = .241, $p > .05$. Thus, these results showed that gesture use without no accompanying speech is related to receptive language competence, the more advanced the child is in language development, the more s/he uses gestures in isolation. Nevertheless, the ability to produce gestures in combination with speech is related more closely with age rather than receptive language ability.

Table 4. Distribution of Age, Memory and Receptive Language Scores according to Gesture Elicitation Task Performance

Gesture Elicitation Task Performance	Min	Max	Mean	SD
1. No Response (*N* = 13)				
Age	22	42	32.46	5.39
Non-verbal WM	2	4	2.84	.851
Verbal WM	0	24	11.69	8.93
Receptive Language	7	19	12.54	4.27
2. Solely Only-Gesture Response (*N* = 3)				
Age	30	36	32.33	3.21
Non-verbal WM	4	6	5	1
Verbal WM	8	13	11	2.64
Receptive Language	12	20	14.67	4.61
3. Solely Only-Speech Response (*N* = 2)				
Age	29	30	29.50	.707
Non-verbal WM	2	2.5	2.25	.353
Verbal WM	0	30	15	21.21
Receptive Language	5	9	7	2.82
4. Solely Gesture-Speech Combination Response (*N* = 13)				
Age	28	40	33.77	4
Non-verbal WM	2	6.5	3.92	1.44
Verbal WM	0	36	19.69	11.25
Receptive Language	10	23	16.38	3.40
5. Versatile Response (*N* = 17)				
Age	23	42	34.76	4.36
Non-verbal WM	1	8	5.41	1.75
Verbal WM	0	38	24.41	11.97
Receptive Language	9	26	18.35	5.01

Note: WM = Working Memory

4.2 Main analyses

The present study aimed to address three questions: (1) how does only-gesture production relate to verbal and non-verbal working memory in very young children, (2) whether the capacity to produce gesture-speech combinations represents an ability which is highly related with both verbal and non-verbal working memory capacity, and (3) how do verbal and non-verbal working memory separately relate to receptive and productive language development? Moreover, a strong association between verbal and non-verbal working memory stores was also anticipated. In the following, the analyses addressing these questions are presented.

4.2.1 The link between verbal and non-verbal WM

One of the hypotheses was that verbal working memory and non-verbal working memory are related systems and this relatedness comes from their close connection with attentional executive processes. The highly significant correlation between non-verbal working memory and verbal working memory, r (46) = .519, $p < .01$, supported the hypothesis. Even when the effect of age was partialed out, this association between the two memory stores remained significant, r (45) = .409, $p < .01$.

4.2.2 The link between only-gesture production and working memory

In order to test whether there is a difference in the amount of only-gesture acts produced by children across six test trials in gesture elicitation task depending on their competence in representing and manipulating verbal and non-verbal representations, a hierarchical regression analysis was performed. Specifically, it was predicted that low verbal working memory would result in greater only-gesture production, but only when it was accompanied by high non-verbal working memory capacity. The amount of only-gesture reponses produced by the children was regressed on age, verbal working memory capacity, non-verbal working memory capacity and the interaction term of these two memory systems, in specified order.

As shown in Table 5, the overall regression model was marginally significant, *F* (4, 43) = 2.57, *p* = .051, and accounted for approximately 19% of the variance in only-gesture production scores. However, the predicted interaction between verbal and non-verbal working memory could not be confirmed, β = -.143, *t* (44) = -.275, *p* = .784. Although the overall model approached significance, none of the individual predictors turned out to be significant in the presence of other variables. Thus, the hypothesis that low verbal working memory would result in greater gesture production, but only when it was accompanied by high non-verbal working memory capacity was not supported.

Table 5. Hierarchical Regression Model for the Interaction Effect

Step	Predictors	R2	DF	F	p	B	SE	β
1.		.039	1, 46	1.87	.178			
	Age					.011	.008	.198
2.		.193	4, 43	2.57	.051			
	Age					.001	.009	.017
	Verbal WM					.002	.008	.088
	Non-verbal WM					.071	.043	.500
	Interaction Term					.000	.002	-.143

Note: WM = Working Memory.

In order to further our understanding on only-gesture production, memory profile of a group of children whose sole response to experimental trials in gesture elicitaton task was only-gesture was investigated. A one-sample t-test was run to determine whether verbal working memory capacity and non-verbal working memory scores of this small subgroup were different than the average verbal and non-verbal working memory scores of the entire sample. Results indicated that the average non-verbal working memory capacity of 4.10 was comparable to that of this subgroup who solely used only-gestures, $t\ (2) = 1.55$, $p > .05$. On the other hand, their verbal working memory score was lower than the sample average, $t\ (2) = -5.21$, $p = .035$. Thus, these last two analyses provided some support for the hypothesis. It seems that children who are at least of average non-verbal working memory but of low verbal working memory, resort to using only-gesture without accompanying speech in their communicative attempts.

4.2.3 How gesture-speech combination use relates to working memory capacity

Considering gesture-speech combinations, in the current study it was predicted that early ability to use gesture-speech combinations would be associated with both verbal and non-verbal working memory capacity. More precisely, it was hypothesized that children with better verbal and non-verbal working memory capacities would produce a higher number of gesture-speech combinations than other children with relatively low performance at both or either of the two memory systems. In order to test this hypothesis, children were divided into three groups on the basis of their scores on each memory task. Those who scored higher on both verbal working memory and non-verbal working memory task were classified as "equally good", those who scored below the group mean of both verbal and non-verbal working memory task were classified as "equally poor", and lastly those whose performance in one of the memory tasks was above the mean while the other one was below the mean were classified as “inequable”. Furthermore, as age of children was found to be positively correlated with gesture-speech combination produced (see Table 3), a one-way ANCOVA was conducted to determine whether there was a statistically significant difference among three memory profile groups on gesture-speech combination produced controlling for the effect of age.

The results of the analysis are summarized in Table 6. There was a significant effect of memory profile on the amount of gesture-speech combinations produced by children after controlling for the effect of age, F (2, 44) = 3.77, p = .031. Planned contrasts indicated that children who outperformed others both on verbal working memory and non-verbal working memory capacity (equally good) produced significantly more gesture-speech combinations (M = 4.07, SD = 1.73) than other children whose non-verbal and verbal working memory scores fell below the average values (M = 1.28, SD = 2.24) after controlling for the effect of age, t (45) = 2.74, p < .05. However, contrary to the study hypothesis, no significant difference was found between equally good children (M = 4.07, SD = 1.73) and children who were good at either of working memory tasks (inequable; M = 2.44, SD = 2.63) with respect to amount of gesture-speech combination produced, t (45) = 1.64, p > .05. Result of the last pairwise comparison involving the inequable group should be interpreted with caution because within such a small data set a fine distinction between those children who are only good at verbal working memory and others who are only good at non-verbal working memory could not be drawn.

Table 6. ANCOVA for Memory Profile Groups on Gesture-Speech Combination Produced with Age as Covariate

Source	SS	df	MS	F	p
Memory Profile	38.756	2	19.378	3.77	.031
Age	2.487	1	2.487	.484	.490
Error	225.991	44			
Total	585.000	48			

4.2.4 The link between working memory and language development

The last set of analyses aimed to examine the relationship between working memory capacity and language development at both receptive and productive levels. In order to determine the differential relations of expressive language to verbal working memory and nonverbal working memory, hierarchical regression analyses for each expressive language subcomponent like vocabulary size, mean length of utterance and morphological knowledge were planned such that age, non-verbal working memory and verbal working memory were meant to be carried out. However, as indicated before, only ten parents completed and returned the inventory that assessed children's expressive language ability. Thus, with 10 valid cases and 3 independent variables, the ratio for this analysis is 3.33 to 1, which does not satisfy the minimum requirement for hierarchical regression. As the minimum ratio of valid cases to independent variables for multiple regression is 5 to 1 (Tabachnick & Fidell, 2007), the proposed connection between verbal working memory and expressive language could not be tested.

The second part of the hypothesis considered whether receptive language ability was linked differentially with verbal and nonverbal working memory. To investigate this question, a hierarchical regression analysis was carried out. In the hierarchical regression analysis; receptive language was regressed on age, verbal working memory and nonverbal working memory, in this order. As shown in Table 7, on the final step, 42 % of the variance in receptive language ability was predicted by age, verbal working memory and non-verbal working memory, F (3, 44) = 10. 76, $p < .01$. As children's age, and their scores from verbal and nonverbal working memory increased receptive language scores also increased. On the final step, neither verbal working memory (β = 0.169, $p = .237$) nor non-verbal working memory (β = 0.212, $p = .131$) predicted receptive language ability; however, the additional explained variance accounted by both memory systems showed a strong trend toward significance, 8.4%, *F-change* (2, 44) = 3.19, $p = 0.051$, $\Delta R^2 = 0.084$.

Table 7. Hierarchical Regression Analyses for Receptive Language as Dependent Variable

Step	Predictors	R2	DF	F	p	B	SE	β
1		0.340	1, 46	23.65	.000			
	Age					0.662	0.136	0.583
2		0.423	3, 44	10.76	.000			
	Age					0.475	0.150	0.419
	Non-verbal WM					0.616	0.400	0.212
	Verbal WM					0.073	0.060	0.169

Note: WM = Working Memory.

To further our understanding related to verbal and nonverbal working memory and their relation with receptive language, a series of partial correlation analyses were carried out. Pearson correlation coefficients computed in descriptive analyses section revealed that the four variables of receptive language, age, verbal working memory and non-verbal working memory were all positively correlated with one another (all *p*s $< .01$). Among these bivariate correlations, the largest correlation coefficient was found for the association between age and receptive language (see Table 3). This suggests that age might be the underlying reason of this relationship between two memory systems and receptive language. Upon conrolling for the effect of age, verbal working memory was shown to be approaching but not reaching significance, $r\ (45) = .282$, $p = .055$, whereas non-verbal working memory was still associated with receptive language significantly, $r\ (45) = .313$, $p = .032$. Although far from being conclusive, it can be argued that irrespective of the age effect, non-verbal working memory capacity is more strongly associated with receptive language ability than verbal working memory capacity.

CHAPTER 5

DISCUSSION

The findings from the current study on the interdependence among language development, working memory capacity and gesture use suggest that possessing relatively larger or smaller verbal and non-verbal working memory capacities leads to differences in receptive language ability, production of gesture without accompanying speech and use of gesture-speech combinations.

5.1 Differential relations of only-gesture production to verbal and non-verbal working memory stores

One goal of the current study was to understand whether individual variation in gesture production with no accompanying speech was linked to working memory capacity. Specifically, it was predicted that low verbal working memory would result in greater only-gesture production, but only when it was accompanied by high non-verbal working memory capacity. This hypothesis was not confirmed because no evidence for the predicted interaction was found. However, the results of further analyses carried out with a subset of children who solely used gestures in the absence of speech during gesture elicitation task, provided some evidence for the hypothesis. This subgroup comprised three children who solely produced only-gesture. When they were compared with the remaining children with respect to the performance across both memory tasks, it was observed that this small group was not different from the remaining children in non-verbal working memory capacity but their verbal working memory capacity was found to be very low. Because there were only a few such children, the results can only be viewed as suggestive.

This said, these results are encouraging because they are in line with the propositions of Information Packaging Hypothesis. According to Information

Packaging Hypothesis, speaking and gesturing are supported by different modes of thinking: spatio-motoric thinking and analytic thinking and these two modes interact with each other during communication process in order to achieve the most efficient and economic way of organizing to be conveyed information (Kita, 2000; Alibali, Kita & Young, 2000). Moreover, two modes of thinking are considered to be resource limited; however, in the model the nature of this resource(s) is not addressed (Kita, 2000). It is conceivable that representations of analytical thinking and spatio-motoric thinking might exploit verbal and non-verbal working memory stores, respectively. In that case, the Information Packaging Hypothesis would suggest that the final organization of a message is determined by an interaction between the capacities of these two memory stores which keep analytical and spatio-motoric representations active. Depending on the amount available in the two stores, the final organization may take the form of only-gesture, only-speech or gesture-speech combination.

Three children who used solely gestures in the gesture elicitation task seem to have organized their protest to the puppet performing inappropriate actions with the objects, via gestures in the absence of speech perhaps because they had to rely mostly on their non-verbal working memory in the absence of a large enough verbal working memory capacity. Therefore, partial evidence offered by these results and propositions of Information Packaging Hypothesis seem to complement each other in explaining informational organization of to be conveyed messages.

These results also seem to be in agreement with the conclusions of Hostetter and Alibali (2007). According to them, the relation between gesturing and verbal ability should not be regarded as linear, because the connection of gesturing to other cognitive systems may also be a leading factor in the gesture production rate.

Results of their study showed that low verbal ability results in greater gesture production rate only when spatial visualization skill is relatively higher. In a way, the present results suggest the presence of a possible continuity of the interaction between verbal and spatial mechanisms in the gesture production process from very young ages into young adulthood.

In the literature, many special populations with verbal deficits such as children with SLI were found to be compensating for their verbal deficits with gesturing. These results are also consistent with the compensation idea (Blake et al., 2008). Participating children who used solely gestures without accompanying speech in their communicative attempts had problems with verbal repetition and this difficulty seems to be resolved by producing gestures because full or partial verbalization of the entire message is possibly harder for these children. As Hostetter and Alibali (2007) indicated, at different levels of verbal competency gestures serve different functions from compensation to enrichment of the message and in the case of these children, gestures seem to be playing a compensation role.

At one end of the continuum, there may be no communicative attempt at all. In the present study, for example, 13 children did not produce any response in gesture elicitation task. Although those children were not younger than the remaining children, their verbal and non-verbal working memory spans were significantly smaller. It may be that in the case of these children, neither of the resources was sufficiently large enough to produce any response. At the other end of the continuum, there are children who solely use gestures in combination with speech and other children who use gesture either in isolation or in combination with speech flexibly. These two groups of children outperformed other children both in verbal and non-verbal working memory capacity. Again in line with the interaction argument of

Hostetter and Alibali (2007), it seems that for such children, gestures serve for enriching the message through continuous exchanges between verbal and non-verbal competence. Thus, gesture production varies both quantitatively and qualitatively across different levels of verbal ability; however, this production difference can not be explained solely on the basis of verbal ability rather its interaction with another mechanism like non-verbal working memory capacity should be taken into consideration.

5.2 Gesture-speech combination use relates to both working memory stores

Another important finding from the current study is that children who outperform their peers both in verbal and nonverbal working memory capacity produce more gesture-speech combinations than other children who have smaller verbal and/or non-verbal working memory capacity. This finding lends support to the argument that gesture-speech combinations are complex constructions which require more extensive cognitive processing than gestures or speech alone.

Prior studies have noted that gestures precede their lexical counterparts and gesture-speech combinations precede two-word utterances (Iverson & Goldin-Meadow, 2005). As two-word utterances appear later in developmental sequence and they are more complicated constructions, their antecedents should also be more complicated and require more cognitive resource than the antecedents of individual words do. More complex processing definitely requires a larger cognitive capacity and children who have large enough verbal and non-verbal working memory capacity can afford using gesture-speech combinations. This is exactly what the results of the present study showed.

In one of the previous studies evaluating gesture-speech integration performance in elderly people, it was observed that in comparison to young adults, older adults were not good at integrating speech and gesture when the message deduction required such kind of integration although they were able to fully comprehend gestures and speech in isolation (Cocks et al., 2011). According to the authors, a possible explanation for this result may be the reduced working memory capacity associated with aging because in this process what is required is constant maintanence and updating of intermediate products of integration (Cocks et al., 2011). However, this explanation was a speculative one because in that study, working memory capacity of elderly people was not measured. By assessing working memory capacity, the present study lent some credibility to this speculation. However a note of caution is necessary here, in the present study integration of gesture and speech was assessed within the scope of productive language in comparison to Cocks et al. (2011) study which evaluated gesture speech integration within the scope of receptive level. Despite this distinction, it appears that, in comparison to adults, both children and elderly people have limited capacities for gesture-speech integration and, in the case of young children, the ability to produce gesture-speech combinations relies on both verbal and non-verbal working memory capacity.

Contrary to expectations, this study did not find a significant difference in production rate of gesture-speech combination between children who are good at both working memory tasks and the inequable group composed of children who are either good at verbal working memory or non-verbal working memory. Even though the difference was in the expected direction ('equally good' ones had a higher score than the 'inequable'ones), the difference failed to reach significance. However, the rather small sample size of the study may have been the reason.

5.3 Receptive language ability and working memory capacity

Another important finding is that verbal working memory and non-verbal working memory capacities together account for differential receptive language abilities of children along with the effect of age. However, when the effect of age was partialed out, the association of receptive language with non-verbal working memory capacity was stronger than its association with verbal working memory.

This result is consistent with those of Viterbori et al. (unpublished data), who suggested that children who have larger non-verbal working memory stores scored higher on receptive language measures such as receptive vocabulary and receptive grammar in comparison to children having smaller non-verbal working memory stores.

Moreover, current results together with the results of a recent unpublished study by Feldman (2012) support the differential influence of verbal and non-verbal representations and their maintainence on receptive and productive levels of language processing. In Feldman's study (2012), only productive language ability of children was assessed and it was found that verbal working memory rather than non-verbal working memory predicted productive language. In the current study, receptive language ability of a comparable group of children was measured and it was shown that this time not verbal working memory but non-verbal working memory was more strongly associated with receptive language ability.

The results from the two studies are consistent with the idea that the two language modalities, receptive and productive, are differentially linked with verbal and non-verbal working memory systems. Whereas, non-verbal working memory supports receptive language processing verbal WM supports productive language processing. Although it is rather difficult to explain these results holistically from a single theoretical perspective, at least the observed link between verbal working memory and productive language is consistent with results of prior studies that support the claims of Phonological Loop Hypothesis. Verbal working memory, as measured by non-word repetition, has been repeatedly found to be a significant predictor of many language parameters like vocabulary size, length of sentences, language complexity (Baddeley et al., 1998).

The connection between non-verbal working memory and receptive language may partly be explained by the processing requirements of the tasks that are employed to assess them. In both kinds of tasks, measuring non-verbal working memory and receptive language ability, no verbal output is required on the part of children. This explanation seems to be appropriate especially in the case of very young children. It is not uncommon in this age range that the child's expressive language lags behind his/her receptive language. Because (1) verbal WM assessment involves articulation of words and (2) such children have trouble articulating them, their verbal WM score would be poorer than their non-verbal WM. In older ages, however, this would be true only in the case of special populations. Therefore, further theoretical and empirical work on the issue is in order.

5.4 Limitations, future directions and conclusions

The major limitation of this study is the inability to collect data on participating childen's productive language measures due to parents's low motivation to complete inventories. If these data could be collected, then the picture on the link between each of memory stores and both modalities of language processing would be more meaningful. Another weakness related to sample size is age range of children, in the beginning an age range of 24 to 36 months was proposed; however, later it was observed that the representation of children younger than 30 months within the sample is very low. In order to grasp fully the connection between working memory and language processing in early years, this period of development should not be ignored so further research with younger children seem to be in order.

A potential source of weakness in this study came from one of the tasks used. Children's verbal working memory capacity was assessed by non-word repetition task and in the literature it is accepted as a reliable measure to assess verbal working memory as it is sensitive to phonological loop function and it taps many other cognitive processes (Baddeley et al., 1998). However, a few children (n = 2) who did not have any problems conversing with the experimenter, actually refused to repeat the items of the non-word repetition task, presumably because those words did not make sense. Here it seems that their high level of language awareness rather than their inability to repeat non-words resulted in lower performance on non-word repetition task. Because the number of such children was not large enough to affect the results in a substantial way, the presented results may still stand. In future research, this point must be taken into consideration. For example, other tasks may be employed along with, or in place of, the non-word repetition task. If indeed it is employed, in the case of such participants, the experimenter may try to elicit response from them by introducing the task as "Now, we're going to play a silly game" to counteract the difficulty.

Another possible weakness of the current study might come from the fact that children's extraversion level was not assessed. A few children, who appeared to be very shy, started responding after the first few trials of the gesture elicitation task. It is likely that their scores would have been higher than the ones recorded. In fact, there is evidence that some of the individual variation in gesture use is related to people's extraversion level (Chu et al., 2014). Therefore, in future research aiming to explore individual variation in gesture use, the noise introduced by extraversion level should be taken into account.

Despite these limitations, this investigation complements the gaps of earlier studies by both assessing two different memory stores and dealing with language development over a wider spectrum from productive and receptive language to non-verbal communication. The most obvious finding to emerge from this study is that many aspects of language development including non-verbal communication is closely related with cognitive abilities especially memory abilities. Taken together, current study suggests that the way how children organize their to be externalized messages relies on the cognitive resources available and since discourse processes have a dynamic nature in which there are continuous exchanges between different aspects of language processing, the overall system also calls for exchanges between different cognitive mechanisms like working memory. The findings of this study may have important implications for future clinical practices. In clinical settings, gesture use appears to be a marker of language delay of some disordered groups such as children with focal brain injury and a sign of autism, thus if the connection of working memory and gesture use can be established clearly then the assessment of these neuropsychological conditions can be strengthened along with working memory assessment (Goldin-Meadow & Alibali, 2013).

APPENDIX A

STIMULUS FOR NON-WORD REPETITION TASK

Practice item: Baba

2 syllable-words	4 syllable-words
Desa	Manapartak
Moru	Usulbakta
Pedi	Güntülümde
Lerte	Yaşıpalam
Kotav	Kirseneti
Meşni	Nikanita
Darkat	Keleyordu
Bortu	Horsulamak
Tarkas	Şekirlemiş
Niğden	Çoralacak
3 syllable-words	**5 syllable-words**
Atardan	Yörtümlerecek
Feriden	Subuntalyordu
Yalkoma	Çöpatlımıyız
Atnasın	Başıltanmasın
Siltarsa	Tümsütülmüş
Remzeldi	Ikışyanaylı
Tabardak	Kılıflomata
Velerden	İkirinvedi
Mazında	Menindenlikte
Gimizde	Urgatosyordu

Note: Stimulus used in Non-word Repetition Task. Adapted from “The Relation Between Working Memory and Language Development in 21 to 36-month-old Native Learners of Turkish,” by E. A. Feldman, unpublished master’s thesis. Adapted with permission.

APPENDIX B

STIMULUS FOR GESTURE ELICITATION TASK

Object	Demonstration Phase Action	Test Phase Action
Toy hammer	Hammer on table with toy hammer	Rotate hammer in the air
Toy shovel	Shovel with toy shovel	Place shovel on head
Cup	Drink from cup	Stick hand in cup
Toy knife	Cut with toy knife	Spin toy knife on table
Toothbrush	Brush teeth with toothbrush	Jump on toothbrush
Hair brush	Brush hair with hair brush	Use hair brush as cane to walk with

Note: Stimulus used in gesture elicitation task. Adapted from “The Emergence of Non-Verbal Representational Communication,” by U. Liszkowski and R. Furman, 2014. Adapted with permission.

APPENDIX C

DEMOGRAPHIC FORM

Çocuğun adı, soyadı:
Çocuğun cinsiyeti: KIZ………….. ERKEK…………
Çocuğun doğum tarihi:
Toplam kaç tane çocuğunuz var?
Eğitim durumunuz nedir? İlkokul………….. Ünivesite…………….. Ortaokul………… Yüksek Lisans…………… Lise………………. Doktora………………….
Eşinizin eğitim durumu nedir? İlkokul………….. Ünivesite…………….. Ortaokul………… Yüksek Lisans…………… Lise………………. Doktora………………….
Çalışıyor musunuz? EVET……………. HAYIR…………..

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