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Cognitive systems struggling for word order

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ABSTRACT

We argue that the grammatical diversity observed among the world's languages emerges from the struggle between individual cognitive systems trying to impose their preferred structure on human language. We investigate the cognitive bases of the two most common word orders in the world's languages: SOV (Subject–Object–Verb) and SVO. Evidence from language change, grammaticalization, stability of order, and theoretical arguments, indicates a syntactic preference for SVO. The reason for the prominence of SOV languages is not as clear. In two gesture-production experiments and one gesture comprehension experiment, we show that SOV emerges as the preferred constituent configuration in participants whose native languages (Italian and Turkish) have different word orders. We propose that improvised communication does not rely on the computational system of grammar. The results of a fourth experiment, where participants comprehended strings of prosodically flat words in their native language, shows that the computational system of grammar prefers the orthogonal Verb–Object orders.

1. Introduction

We investigate the cognitive bases of the two most common word orders found in the languages of the world: Subject–Object–Verb (SOV) and Subject–Verb–Object (SVO). The way languages change over long periods of time, the analysis of the syntactic structures attested in the world's languages, the relative stability in word order, and how new languages, known as Creoles, emerge in situations of atypical language acquisition, suggest a syntactic preference for SVO. There is, however no parallel

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evidence that would account for the existence of at least as many SOV languages. We propose that it is possible to dissociate communication from grammar and hypothesize that the prominence of the SOV order among the world's languages lies in the cognitive mechanisms responsible for prelinguistic communication. The dominance of the two most common word orders in the world's languages would thus result from the struggle between the preferences of the computational system of grammar and the forces that govern prelinguistic communication.

We rely on the proposal that the human faculty of language is modular and that it is possible to identify different cognitive systems responsible for specific linguistic tasks (Chomsky, 2000; Fodor, 1983). The production and comprehension of language (either spoken or signed) require at least three task-specific cognitive systems: the conceptual system (semantics) that provides and interprets the meaning of linguistic utterances; the sensory-motor system (phonology and phonetics) that produces and perceives the actual sounds and signs of language; and the computational system of grammar (syntax) that links meaning with sounds (or signs) by generating the structure of sentences (Hauser, Chomsky, & Fitch, 2002; Pinker & Jackendoff, 2005).

While the grammars of individual languages make use of all the three cognitive systems, it is generally believed that the structural regularities related to signaling the grammatical relations within a sentence, i.e. those expressing the relations of 'who did what to whom', emerge from the computational system of grammar, i.e. syntax (Chomsky, 1957; Jackendoff, 1997; Pinker & Jackendoff, 2005). For instance, within the principles and parameters framework of grammar (Chomsky, 1980), the universally shared aspects of syntactic structure are known as principles and the structural variation is represented by parameters within the computational system of grammar. An example of a principle is that a sentence must always have a Subject, even if it is not overtly expressed. An example of a parameter concerns the choice of the basic structure of sentences responsible for the linear order of words. For example, while in an SVO language like English an unmarked sentence would be a girl catches a fish, in a SOV language like Turkish the same sentence would be expressed as kız balık yakaladığına (the equivalent of English the girl the fish catches).

We take a new look at word order variation, and argue that the structural diversity observed among the world's languages does not emerge solely from the computational system of grammar but rather from the ways in which the three aforementioned cognitive systems interact with each other. There are six logically possible ways of arranging words in sentences according to their basic grammatical functions of Subject, Object and Verb (OSV, OVS, SOV, SVO, VOS, VSO). Of these six, SVO and SOV characterize the basic orders of the great majority of the world's languages (76%: SOV% and SVO%) (Dryer, 2005). There is thus a clear preference for word orders where the Subject precedes the Object and where the Verb–Object constituent is preserved (as in both S–OV and S–VO) (Greenberg, 1963; Greenberg, 1978).

There are, however, reasons to believe that SVO is the preferred structure for syntax. Studies in historical and comparative linguistics suggest that the computational system of grammar has one single preferred word order. Indeed, analyzes of how languages change over time, report that, when word order changes independently of language contact, it is unidirectional from SOV to SVO (cf. Newmeyer, 2000).[1]

[1] Word order change has extensively been studied in the Indo-European language family. Romance languages, such as French, have changed from SOV to SVO (Bauer, 1995), the same is true for Germanic languages such as English (Kiparsky, 1996), Swedish (Holmberg & Platzack, 1995) and Icelandic (Hróarsdóttir, 2000), as well as Slavic languages such as Russian (Leinonen, 1980). Also the Indo-European ancestor languages, such as Sanskrit (Staal, 1967) and Ancient Greek (Taylor, 1994) were SOV, suggesting that Proto-Indo-European had the SOV order. While the evidence for the unidirectional change from SOV to SVO is largely based on research on Indo-European languages, languages such as Finnish (Leinonen, 1980) and Austronesian languages such as Seediq (Aldridge, in press), that are not part of the Indo-European family, have undergone the same direction of change. In fact, if we look at the ancestor languages in Dryer (2005), it is clear that the SOV order was the dominant configuration among most of the sampled languages.Unfortunately, descriptions of historical change are only available for a restricted (though substantial) number of linguistic families. Of these, the only putative exception to the unidirectional change from SOV to SVO that occurs independently of language contact concerns Mandarin Chinese (Li, 1977). Li and Thomson (1974) have suggested that Mandarin has been undergoing a change from SVO to SOV through grammaticalization of serial-verb constructions. However, in contemporary Mandarin the SOV constructions are heavily marked and VO constructions vastly outnumber OV constructions, showing that SVO is the basic word order (Li, 1990). In fact, Sun and Givón (1985) have shown on the basis of written and spoken analyses that in contemporary Mandarin OV constructions only appear in about 10% of the cases. They further argue that there is no evidence either from their corpus or from the acquisition of Mandarin by native children that would suggest a drift toward the SOV order. Light (1979) comes largely to the same conclusion.

Thus, indirectly, historical and comparative linguistics suggest that when the word order of a language changes for language internal reasons, the computational system of grammar drives it towards the SVO order. Interestingly, SVO languages are more stable in word order than other languages, that usually have several additional alternative orderings of Subject, Verb and Object (Steele, 1978). This stability of SVO languages is an additional reason to consider SVO syntactically preferred.

Though there are alternative proposals (cf. Haider, 2000 based on German), convergent evidence in theoretical linguistics points to the universality of SVO as the basic word order for the computational system of grammar (Chomsky, 1995). It has been argued that there is a universal underlying structure, from which the surface syntactic forms of all languages are derived (2004; Kayne, 1994; Moro, 2000). In this basic structure, the heads of phrases universally precede their associated complements: for example, verbs precede their objects, prepositions precede nouns and main clauses precede subordinate clauses. In addition, specifiers – syntactic categories that specify the heads, as for instance 'some' in some apples – universally precede the head they are associated with. This specifier-head-complement configuration corresponds to the SVO order (Chomsky, 1995).

Interestingly, there are reasons to believe that the SOV order predominant in the world's languages is not particularly well suited for syntactic computations, whose task is to unambiguously map meaning to sound or signs (Hawkins, 1994). For example, verbs define the arguments they take, i.e. when one hears a verb like give, one is primed to expect two internal arguments pertaining to the object to be received, and to the recipient. However, in SOV languages the complements precede the heads – thus both direct and indirect object precede the verb. Given that the role of the arguments is defined by the verb, it is useful to use extra cues, i.e. morphological marking of case, to identify their semantic roles (Hawkins, 1994; Newmeyer, 2000). This suggests that the SOV order should be dispreferred by the computational system of grammar.

If we accept that the computational system of grammar has one single underlying order, it remains to be explained why grammatical diversity emerges in the first place – in particular, which cognitive mechanisms are responsible for the origin of the SOV word order, and why the SOV and SVO orders are equally prominent among the world languages. Hauser et al. (2002), argue that everything but the underlying SVO order is generated outside the computational system of grammar. However, to the best of our knowledge, neither theoretical proposals nor experimental evidence have clarified why and where in the language faculty the alternative configurations emerge.

Interestingly, a dichotomy between SVO and SOV has been found in two specific cases of atypical language acquisition. Creoles, new fully-fledged languages that arise in communities where children are exposed to a pidgin – a rudimentary jargon created by people who must communicate without sharing a native language (Bickerton, 1981) – use this jargon to develop a systematic SVO order in a single generation (Bickerton, 1984). In contrast, homesigners – deaf children not exposed to any sign language – create their own gestural vocabulary (Goldin-Meadow & Feldman, 1977) and use the Object–Verb order,[2] which parallels the SOV order, in their gestural expressions (Goldin-Meadow, 2005; Goldin-Meadow & Mylander, 1998).

While Creoles are syntactically fully-fledged languages (Bickerton, 1984; Muysken, 1988), the nature of the gesture systems of homesigning children is less clear. The SOV order that is dominant in homesign is also attested in the gestural utterances produced by normally hearing English (SVO), Chinese (SVO), Spanish (SVO) and Turkish (SOV) speaking adults, instructed to use only gestures to describe simple scenarios (Goldin-Meadow, So, Özyürek, & Mylander 2008). The structural similarities between the gesture systems of homesigning children and the improvised gestures of normally hearing adults suggest a strong predisposition for the SOV order in simple improvised communication (Goldin-Meadow et al., 2008).

[2] It is generally agreed that it is more appropriate to describe the gesture systems of homesigners, as well as normally hearing adults asked to gesture, in terms of semantic roles (e.g. Actor, Patient, Action) rather than grammatical roles (e.g. Subject, Object, Verb). However, because the present paper directly compares word order in spoken language to the gesture order of normally hearing adults, and because in our experiments the semantic roles of words unanimously correspond to the same grammatical roles (e.g. the Actor is always the Subject, the Patient the Object, and the Action the Verb), for the sake of clarity we will use the terms of Subject, Object and Verb.

We expand the hypothesis that SOV characterizes improvised communication and suggest that the SOV order in gestures is prelinguistic in nature because it results from a direct interaction between the sensory-motor and the conceptual systems. We argue that unlike in language where the mapping between signal and meaning has to necessarily be mediated by syntax, in improvised gestural communication the mapping between the signal (the gestures) and its meaning is achieved without the intervening syntactic computations responsible for phrase structure. Several studies with adult speakers learning a new language show that they do not abandon their native grammar (Odlin, 1989). For example, immigrant workers learning Dutch – a language with SOV order in subordinate clauses and SVO order in main clauses – tend to use the SVO order when their native language is Moroccan Arabic (SVO), and the SOV order when their native language is Turkish (SOV) (Jansen, Lalleman, & Muysken, 1981). The fact that normally hearing English (SVO), Chinese (SVO) and Spanish (SVO) speaking adults in Goldin-Meadow et al. (2008) produced gesture strings in the SOV order and failed to transfer their native SVO order to gestures, suggests that they bypassed their native linguistic structures. This may mean that it is possible to communicate simple events in a prelinguistic way, i.e. without relying on the computational system of grammar, a necessary ingredient of language.

The picture so far thus suggests that there is a general faculty of language that includes the sensory-motor system, the conceptual system and the computational system of grammar. The world languages emerge from the interaction of these three systems only when the computational system of grammar links meaning (the conceptual system) to sounds or signs (the sensory-motor system). However, language-like structures also emerge in improvised gestural communication that does not appear to rely on the computational system of grammar. We propose that these structures offer evidence that the different word orders observed in the world's languages are not uniquely defined by the computational system of grammar – were it so, we would expect the grammatical structures to exhibit much less variation than is attested among the world's languages.

In order to investigate whether the structural regularities in improvised gestures are grammatical in nature, we tested normally hearing Italian and Turkish-speaking adults, whose native languages use different word orders, SVO for the former and SOV for the latter. In Experiment 1, we tested whether normally hearing Italian and Turkish-speaking adults introduce the structural regularities of their native grammars into their gesture strings. Our intention was to replicate the results of Goldin-Meadow et al. (2008), though with a set of stimuli that could be systematically modified, in subsequent experiments, as to their complexity. In Experiment 2, we used more complex stimuli in order to investigate whether the structural regularities in improvised gestures rely on the computational system of grammar, that is, whether there is evidence for phrase structure. In Experiment 3, we investigated whether the preferences found in gesture production emerge also in gesture comprehension. In Experiment 4, we investigated the preferences of the computational system of grammar by testing the order preferences for prosodically flat sequences of words in participants' native language.

2. Experiment 1: gestural descriptions of simple scenarios

Normally hearing adult speakers of English (SVO), Turkish (SOV), Spanish (SVO) and Chinese (SVO) asked to gesture instead of using their native language, have been found to order their gestures in the SOV order (Goldin-Meadow et al., 2008). In Experiment 1, we tried to establish whether we find the same gesture regularities (i.e. the SOV order) with stimuli that can be systematically manipulated in complexity for subsequent experiments that can disentangle the cognitive origin of the SOV order. We thus asked native speakers of Italian and Turkish to describe simple scenarios depicted on drawn vignettes by using either only gestures or their native language. We tested Italian (SVO) and Turkish (SOV) speaking adults because their native languages use orthogonal word orders. On the basis of Goldin-Meadow et al.'s (2008) results, we predict that Italian and Turkish-speaking adults structure their gesture strings identically in the SOV order. Any deviance from the participants' native order would suggest that the structural regularities in gestural communication are independent of participants' native syntax.

2.1. Method

2.1.1. Participants

Twenty eight Italian native-speaking volunteers (15 females, 13 males, mean age 23.8, range 19–27 years) recruited from the subject pool of the International School of Advanced Studies in Trieste (Italy) and 28 Turkish native-speaking volunteers (14 females, 14 males, mean age 21.4, range 19–24 years) recruited from the subject pool of the Boğaziçi University in Istanbul (Turkey). Participants reported no auditory or language related problems and did not know any sign language. Participants received a monetary compensation.

2.1.2. Stimuli

The stimuli of Experiment 1 consisted of 32 simple drawn vignettes that depicted someone doing something to someone or something else (e.g., a girl catches a fish) (for the full list of vignettes see Appendix A). In all the vignettes, each of the three constituents unambiguously matched the category of the Subject, the Object or the Verb (e.g., the fish cannot catch the girl). In order to avoid possible frequency biases induced by different occurrences of individual constituents, in this and subsequent experiments, the depicted scenarios consisted of four different Subjects, Objects and Verbs that were distributed across the vignettes in a combinatorial manner. All constituents were thus equally frequent ($N = 8$) and participants saw them during the experiment in different combinations with other constituents an equal number of times. In order to avoid possible biases induced by certain constituents appearing either on the left or the right side of the vignettes, we created mirror images of each vignette and counterbalanced their appearance across participants.

2.1.3. Procedure

Participants were presented with the vignettes one by one in random order on a computer screen. After seeing each vignette, half of the participants in each linguistic group were instructed to describe it as clearly as possibly by using only gestures. Participants were asked not to speak. We allowed participants to take as much time for describing each vignette as they thought it was necessary and to proceed to the following vignette when they thought they had accomplished the task. Participant's responses were videotaped and consequently coded for the order of individual gestures by two independent coders. The other half of the participants in each linguistic group was asked to describe the vignettes in their native language (Italian or Turkish). Their responses were audio recorded and coded for the order of words by two independent coders.

2.2. Results

Participants' responses were coded by two independent coders who had to determine the order of the gestures in participants' descriptions of the vignettes. Because we were interested in the order in which participants organized their gestures, rather than in how well and clearly they could gesture individual constituents, the coders could rely on the vignettes to determine the grammatical role of the gestures. This resulted in a confidence rating of 93% for coder 1 and 91% for coder 2 (the responses coded as 'uncertain' were eliminated from the analysis). Because participants sometimes made repeated attempts to gesture scenarios, we asked the coders to analyze the gesture-string that was produced last and ignore the failed attempts. Because participants sometimes described a scenario with several 2-gesture strings rather than with one 3-gesture string, we asked the coders to analyze the 2-gesture strings separately. The agreement of the two raters' observations on coding gestures was measured with Cohen's kappa coefficient, which resulted in a kappa value of 0.79 for Turkish (substantial agreement) and 0.83 for Italian (perfect agreement).

While we instructed participants to describe vignettes with 3-gestures, when we look at the gesture strings of Italian as well as Turkish-speaking adults, we see that the gesture strings contained either two or three constituents. Participants thus sometimes omitted constituents and described a scenario with two 2-gesture strings. The gesture strings of Italian-speaking participants contained all three constituents on average in 58.6% ($SD = 12.4$) of the cases. For Turkish-speaking participants the three-constituent gesture strings made up on average 63.2% ($SD = 10.4$) of all the gesture strings.

In 2-gesture strings, Italian-speaking participants always gestured the Verb, and, additionally, gestured the Subject on average of 42.3% (*SD* = 10.3) and the Object on average of 57.7% of the cases. Similarly, Turkish-speaking participants always gestured the Verb, but gestured the Subject on average of 45.8% and the Object on average of 54.2% (*SD* = 9.5) of the cases. We carried out an ANOVA with two fixed factors (Constituent omission: Subject vs. Object omission) and (Participants' native language: Turkish vs. Italian). We found a main effect for constituent omission ($F(1, 26) = 12.455$, $P = .032$), but neither interaction with native language ($F(1, 26) = 20.233$, $P = .211$), nor a main effect of native language ($F(1, 26) = 10.167$, $P = .097$). This shows that participants omitted gestures Subjects more than for Object regardless of their native language.

To see whether the 2-gesture strings were consistently organized within and across linguistic groups we carried out a ANOVA with one within-subjects factor (gesture order: SV, VS, OV, VO, SO, and OS) and one between-subjects factor (participants' native language: Turkish vs. Italian). For the distribution of the constituents in 2-gesture strings, see Fig. 1. We found a main effect for gesture order ($F(5, 26) = 83.586$, $P < .0001$) but no interaction with participants' native language ($F(1, 26) = 90.456$, $P = .867$). Pair-wise Bonferroni-corrected comparisons show that Italian speakers were more likely to gesture Objects before, rather than after, Verbs ($P < .0001$); Subjects before Objects ($P < .0001$) and Subjects before Verbs ($P = .032$). The same tendency emerged for Turkish-speaking participants, who gestured Objects before Verbs ($P < .0001$); Subjects before Objects ($P < .0001$); and Subjects before Verbs ($P = .023$). Both Italian and Turkish-speaking participants were more likely to gesture Object–Verb than Subject–Verb ($P < .0001$) or Subject–Object ($P < .0001$) in their 2-gesture strings.

Among the 3-gesture strings, the most dominant order was Subject–Object–Verb (SOV) both for Italian (77.6%; *SD* = 8.9) as well as for Turkish (89.4%; *SD* = 10.6%) speaking adults (see Fig. 2). In order to determine whether this ordering of constituents in 3-gesture strings was consistent between the two groups, we carried out an ANOVA with one within-subjects factor (gesture order: OSV, OVS, SOV, SVO, VOS and VSO) and one between-subjects factor (participants' native language: Turkish vs. Italian). We found a main effect of gesture order ($F(5, 26) = 140.634$, $P < 0.0001$), but again no interaction with participants' native language ($F(1, 26) = 17.409$, $P < 0.543$), and no main effect of native language ($F(1, 26) = 33.232$, $P < 0.522$). Pair-wise Bonferroni-corrected comparisons show that Turkish speakers ordered their gesture strings predominantly in the SOV order ($P < .0001$). The SOV order was also the most dominant one for Italian participants ($P < .001$).

In order to determine whether participants were bypassing their native grammars, we compared the order of constituents in participants' verbal descriptions with the constituent orders found in participants' gestural descriptions of the same vignettes. The participants of both linguistic groups, when

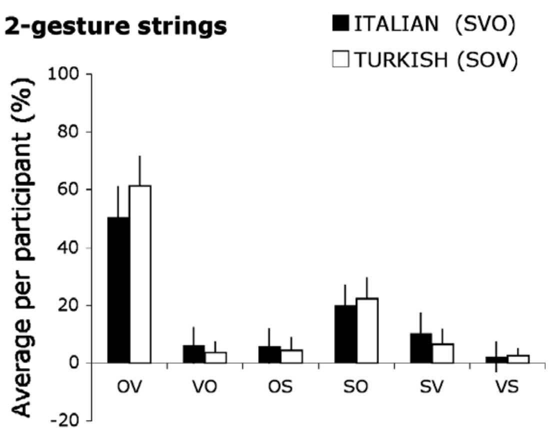

Fig. 1. Italian and Turkish speakers' 2-gesture strings for describing simple scenarios: distribution of constituent orders for Subject, Object and Verb.

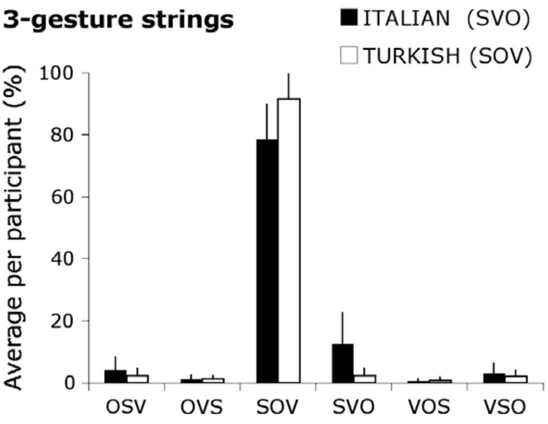

Fig. 2. Italian and Turkish speakers' 3-gesture strings for describing simple scenarios: distribution of constituent orders for Subject, Object and Verb.

asked to use their native language, always described the simple scenarios with sentences that contained the Subject, the Object and the Verb. Without exceptions, Italian speakers' spoken sentences were in the SVO and Turkish speakers' sentences in the SOV order, that is, for all participants, in the basic order of their native language.

To compare the 3-gesture strings to the verbal descriptions of the vignettes we performed an ANOVA with one dependent variable (percentage of SOV) and two fixed factors (modality: speech vs. gestures; and participants' native language: Turkish vs. Italian). We found a main effect for modality ($F(1, 52) = 128.834$, $P < .0001$) and native language ($F(1, 52) = 98.234$, $P < .0001$) and an interaction between modality and native language ($F(1, 52) = 90.233$, $P < .0001$). Bonferroni-corrected post-hoc tests ($P < .05$) show that Italian participants 3-gesture strings had significantly more SOV order than their verbal descriptions ($P < .0001$). The differences between Turkish speaking participants' 3-gesture utterances and their verbal descriptions failed to reach significance ($P < .309$). Italian and Turkish-speaking participants verbal descriptions differed significantly ($P < .0001$), but the differences between their gestural utterances failed to reach significance ($P = 0.655$). This shows that at least Italian-speaking participants were bypassing their native grammar.

2.3. Discussion

These results show that, while in the speech test, Italian and Turkish participants used orthogonal word orders, both Italian and Turkish speakers produced gesture strings predominantly in the SOV order. Because Italian (SVO) and Turkish (SOV) have orthogonal word orders, our results, like those of Goldin-Meadow et al. (2008), show that when asked to gesture, speakers of different languages introduce the same SOV order into their gesture strings. Because the SOV order is ungrammatical in SVO languages like Italian (Experiment 1) as well as in English, Chinese and Spanish (Goldin-Meadow et al., 2008), it has been suggested that SOV is a natural order – possibly semantic in origin – for describing simple events (Gershkoff-Stowe & Goldin-Meadow, 2002; Goldin-Meadow et al., 2008). Furthermore, it has been suggested that the fixed order of gestures may represent the seed of grammar, since also homesigning children introduce the Object–Verb order into their gesture strings (Goldin-Meadow, 2005; Goldin-Meadow & Mylander, 1998), and since new sign languages that emerged from homesigners in Nicaragua (Senghas, Coppola, Newport, & Supalla, 1997) and Israel (Sandler, Meir, Padden, & Aronoff, 2005) also appear to be organized in the SOV order. This interpretation has some plausibility, since the SOV order in gestures is indistinguishable from the canonical SOV order of simple clauses in Turkish.

However, a second interpretation of our results, as well as those of Goldin-Meadow et al.'s (2008), is also possible. When gesturing, participants must use the sensory-motor system for executing the physical gestures and rely on the conceptual knowledge stored in the conceptual system to convey the meaning of the vignettes with individual gestures. However, there is no reason to believe that the computational system of grammar is necessarily involved in producing these simple gesture strings. For example, on the basis of simple gesture-strings it is impossible to determine whether the gestural utterances have any internal language-like hierarchical organization of constituents such as specifiers, heads and complements. To decide between these two interpretations regarding the origin of the SOV order in gestures – whether or not it is grammatical in nature – we carried out a second experiment.

3. Experiment 2: gestural descriptions of complex scenarios

One possible way to investigate whether the computational system of grammar is used when normally hearing adults are asked to gesture, is to increase the complexity of the scenarios that the participants are asked to describe. We thus asked speakers of Italian and Turkish to describe more complex scenarios depicted on drawn vignettes by using either their native language or only gestures. In natural language, the complex vignettes we used, would be described with complex sentences containing a main clause and an embedded clause (as in English [the man tells the child [that the girl catches a fish]]).

If the SOV order that emerged in the description of simple scenarios (Experiment 1) is grammatical for Turkish-speaking adults, it should also extend to more complex SOV like structures typical of Turkish (SOV). Participants should thus gesture the subordinate clauses in the same position as the Object of simple clauses, i.e. before the Verb of the main clauses, as in Turkish [Adam çocuğa [kızın balık yakaladığını] anlatır] (equivalent in English to [man child-to [girl fish catches] tells]). Furthermore, if gestural communication triggers SOV language-like constructions in the computational system of grammar, we would expect also Italian-speaking participants to produce complex gesture strings that follow the SOV language-like structures that are typical of Turkish, as well as other SOV languages.

3.1. Method

3.1.1. Participants

Twenty eight Italian native-speaking volunteers (14 females, 14 males, mean age 25.6, range 20–29 years) recruited from the subject pool of the International School of Advanced Studies in Trieste (Italy) and 28 Turkish native-speaking volunteers (16 females, 12 males, mean age 20.1, range 18–23 years) recruited from the subject pool of the Boğaziçi University in Istanbul (Turkey). Participants reported no auditory or language related problems, did not know any sign language and had not participated in Experiment 1. Participants received a monetary compensation.

3.1.2. Stimuli

The stimuli of Experiment 2 consisted of drawn vignettes more complex than those of Experiment 1. The 32 complex vignettes were created by randomly embedding the 32 simple drawings from Experiment 1 in a speech bubble in eight different scenarios (for an example of how the complex vignettes were created and a full list of the complex frames see Appendix B).[3] In natural languages, vignettes like these would be described with complex sentences containing a main clause (e.g. *the man tells the child*) and an embedded clause (e.g. that the girl catches a fish), as in English the man tells the child that the girl catches a fish. In order to avoid possible biases induced by certain constituents appearing either on the left or the right side of the vignettes, we created mirror images of each vignette and counterbalanced their appearance across participants.

3.1.3. Procedure

The procedure of Experiment 2 was identical to that used in Experiment 1. Participants were presented with the vignettes one by one in random order on a computer screen. After seeing each

[3] Some of the verbs of the main clauses required a direct object and some did not. However, this is not relevant to our experiment.

vignette, half of the participants in each linguistic group were instructed to describe it as clearly as possible by using only gestures. Participants were asked not to speak. We allowed participants to take as much time for describing each vignette as they thought it was necessary, and to proceed to the following vignette when they thought they had accomplished the task. Participant's responses were videotaped and consequently coded for the order of individual gestures by two independent coders. The other half of the participants in each linguistic group was asked to describe the vignettes in their native language (Italian or Turkish). Their responses were audio recorded and coded for the order of words by two independent coders.

3.2. Results

Participants' responses were coded by two independent coders who had to determine the order of the gestures in participants' descriptions of the vignettes. Because we were interested in the order in which participants organized their gestures, rather than in how well and clearly they could gesture individual constituents, the coders could rely on the vignettes to determine the grammatical role of the gestures. This resulted in a confidence rating of 98% for coder 1 and 96% for coder 2 (the responses coded as 'uncertain' were eliminated from the analysis). Because participants sometimes made repeated attempts to gesture scenarios, we asked the coders to analyze the gesture-string that was produced last and ignore the failed attempts. The agreement of the two raters' observations on coding word order was measured with Cohen's kappa coefficient, which resulted in a kappa value of 0.93 for Italian and 0.85 for Turkish (perfect agreement).

When we look at the gestural descriptions of complex scenarios, it becomes evident that among the responses of the Italian and Turkish-speaking participants, there was not a single gesture string adhering to the syntactic structure typical of SOV languages. Italian speakers gestured the main clause before the subordinate clause in 87.5% ($SD = 10.2$) of the cases. The same order was also evident in Turkish speakers, who gestured the main clause before the subordinate clause in 96.7% ($SD = 3.3$) of the cases. We carried out an ANOVA with one within-subject factor (order of clauses: main clause before subordinate clause vs. subordinate clause before main clause) and one between-subjects factor (participants' native language). We found a main effect of order ($F(5, 26) = 118.345$, $P < .0001$), but no interaction with participants' native language ($F(1, 26) = 34.324$, $P < .534$), and no main effect of native language ($F(1, 26) = 23.564$, $P < .690$). This shows that participants gestured the main clauses before the subordinate clauses regardless of their linguistic background.

In order to determine whether participants were bypassing their native grammar, we compared the order of clauses in participants' verbal descriptions to the order of clauses in participants' gestural descriptions of the same vignettes. To discover the most natural native syntactic constructions for describing the complex scenarios, we first analyzed the verbal descriptions of both Italian and Turkish-speaking adults. Without exceptions, in Italian speakers' sentences the main clause preceded the subordinate clause. In contrast, in Turkish speakers' sentences, the subordinate clause always preceded the verb of the main clause.

To compare the gestural descriptions to the verbal descriptions of the complex vignettes we performed an ANOVA with one dependent variable (percentage of main clause followed by subordinate clause gesture strings) and two fixed factors (modality: speech vs. gestures; and participants' native language: Turkish vs. Italian). We found a main effect for both modality ($F(1, 50) = 78.435$, $P < .0001$) and native language ($F(1, 50) = 67.564$, $P < .0001$), and a significant interaction between modality and native language ($F(1, 50) = 69.573$, $P < .0001$). Bonferroni-corrected post-hoc tests ($P < .05$) show that Turkish-speaking participants' gestured scenarios had significantly more 'subordinate clause following main clause' than their verbal descriptions of complex scenarios ($P < .0001$). The differences between the same 'main clause following subordinate clause' constructions in Italian participants' gestured and verbal descriptions failed to reach significance ($P < .204$). Italian-speaking participants verbal descriptions had significantly more 'main clause followed by subordinate clause' constructions than Turkish speakers' verbal descriptions ($P < .0001$), but the differences between Italian and Turkish gestural descriptions failed to reach significance ($P = .096$). This shows that at least Turkish-speaking participants were bypassing their native grammar.

3.3. Discussion

While in the speech task Italian speakers always described complex vignettes with sentences typical of SVO languages and Turkish speakers always described the same vignettes with sentences typical of SOV languages, when gesturing, neither Italian- nor Turkish-speaking adults produced even a single gesture-string that conformed to the structure of complex sentences typical of SOV languages, like Turkish. Turkish-speaking participants failure to gesture the subordinate clause before the verb of the main clause, that was common among the Turkish-speaking participants when using their native language, demonstrates that gestural communication does not follow the grammar of Turkish. Thus Experiments 1 and 2 taken together show that, when gesturing, both Italian and Turkish-speaking adults bypassed their native linguistic structures.

In the computational system of grammar, the majority of SOV languages are syntactically left-branching, thus the subordinate clauses usually precede the verb of the main clause, and the majority of SVO languages are syntactically right-branching, thus subordinate clauses usually follow the main clauses (Chomsky, 1957). This is clearly not the case in our results, where for both Italian and Turkish speakers the main clauses were gestured before the subordinate clauses – a construction typical of SVO but not of SOV languages. This shows that the SOV order in improvised gesturing does not generalize to more complex SOV language-like constructions: it thus does not instantiate the typical linguistic hierarchical organization of constituents. Our results thus indicate that participants were not using the computational system of grammar and that improvised gesture communication is the product of a direct link between the conceptual and the sensory-motor systems.

4. Experiment 3: gesture comprehension

If gesturing does not utilize the computational system of grammar and relies instead on a direct link between the conceptual and the sensory-motor systems, the preference for the SOV order should not only prevail in gesture production, but also be observable in gesture comprehension. In Experiment 3, we therefore investigated the gesture order preferences in comprehension by using the same simple scenarios that participants described in Experiment 1.

4.1. Method

4.1.1. Participants

Thirty six Italian native-speaking volunteers (18 females, 18 males, mean age 21.2, range 18–28 years) recruited from the subject pool of the International School of Advanced Studies in Trieste (Italy) and 36 Turkish native-speaking volunteers (20 females, 16 males, ages 19–22) recruited from the subject pool of the Boğaziçi University in Istanbul (Turkey). Participants reported no auditory or language related problems, did not know any sign language and had not participated in Experiments 1 and 2. Participants received a monetary compensation.

4.1.2. Stimuli

The stimuli of Experiment 3 consisted of the 32 simple vignettes used in Experiment 1 (see Appendix A), and 32 video clips where a person described each of these vignettes by using only gestures. Like in Experiments 1 and 2, each vignette was counterbalanced with its mirror image across participants. In order to determine whether there is a preference for a specific constituent order in gesture comprehension, we constructed the video clips digitally in all the possible six orders of Subject, Object and Verb (SOV, SVO, OSV, OVS, VSO and VOS). To avoid possible biases for gesture order introduced by the gesturer, we asked her to produce individual gestures for each of the four Subjects, Objects and Verbs that were depicted on the simple scenarios. We then digitally edited the individual gestures so that they all were equal in length (2000 ms) and then combined them into all the logically possible six orders of Subject, Object and Verb (6000 ms). Following this procedure, the video-clips describing the same vignette thus only differed in the order of the constituents (for an example see Video 1).

4.1.3. Procedure

Participants were seated in front of a computer screen. They were first told that they would see video clips of someone describing simple situations with gestures. They were then instructed to choose as quickly as possible, immediately after each gesture clip, between two drawn vignettes (used in Experiment 1), the one that depicted the content of the gesture clip they just saw (dual forced choice task).

In the dual forced choice task one of the vignettes corresponded to the gesture clip and the other one did not by semi-randomly deviating in either one of the three constituents (of Subject, Object or Verb) (for an example see Appendix C). As the vignettes were created according to a combinatorial design, the distracting vignette of one trial was the correct vignette of another trial. Each participant saw each of the scenarios gestured in the video clip once in each of the six logically possible orders (192 trials). Each participant saw each of the vignettes six times as the correct target and six times as the distracter. Participants had 1500 ms to choose before the next trial began. We measured Reaction Times (RTs) from the onset of the dual forced choice task (i.e. from the moment when the two vignettes appeared on the screen).

To determine whether there is a gesture order preference, all participant saw each of the 32 different scenarios once in each of the six logically possible orders of Subject, Object and Verb. The experiment thus had 192 trials and was divided into six experimental blocks: in each block participants saw each of the 32 scenarios only once in semi-randomly determined gesture order. Between experimental blocks participants could take a break for as long as they wished.

4.2. Results

Participants' responses show that they were not having difficulties with the task, as Italian-speaking participants only failed to give an answer on average in 7.6% ($SD = 2.3$) and Turkish-speaking participants on average in 6.3% ($SD = 1.5$) of the trials. Similarly, the percentage of correct answers was on average 91.1% ($SD = 8.9$) of all the answered trials for Italian- and 94.3% ($SD = 5.7$) of the answered trials for Turkish-speaking adults.

In order to investigate order preferences in gestures, we first compared participants' performance on individual constituent orders. The ANOVA between all constituent orders in Turkish speakers' responses shows that gesture order influenced their RTs ($F(5, 31) = 10.23$, $P < .01$). Post-hoc tests show that the SOV order elicited fastest RTs for Turkish-speaking adults (Bonferroni-corrected $P < .04$) (see Fig. 3). Also the ANOVA between all constituent orders in Italian speakers' responses shows that constituent order influenced their RTs ($F(5, 30) = 12.7$, $P < .01$). Post-hoc tests show that the SOV order elicited the fastest RTs also for Italian-speaking participants (Bonferroni-corrected $P = .045$) (see Fig. 3). To see whether we find these differences also when taking items, rather than subjects, as random variables, we also carried out ANOVAs with the vignettes as random variables for Turkish ($F(5, 30) = 30.48$, $P = .037$) and Italian ($F(5, 30) = 25.21$, $P = .048$) participants. Post-hoc tests show that the SOV order elicited the fastest RTs for both groups in the item based analysis as well (Bonferroni-corrected Turkish: $P = .033$; Italian: $P = .041$). Italian speakers' shorter RTs with SOV than with their native SVO order with gestures suggests that the same preference – non-grammatical in nature – we observe in the production of improvised gestures, also prevails in comprehension.

We observe consistent preferences between Italian and Turkish speaking participants' performance also when we look at all the six logically possible orders. For Italians Object–Verb orders (OSV, OVS, SOV) elicited on average significantly shorter RTs than Verb–Object orders (SVO, VOS, VSO) (2-tailed t-test between Object–Verb and Verb–Object orders: $t(35) = 2.969$, $P < 0.01$). Exactly the same preference for Object–Verb orders over Verb–Object orders emerged also in Turkish-speaking participants' RTs (2-tailed t-test between Object–Verb and Verb–Object orders: $t(35) = 3.696$, $P < 0.01$) (see Fig. 5). Because Italian is a Verb–Object order language, the preference for Object–Verb orders in Italian-speaking participants' RTs must be independent of participants' native language.

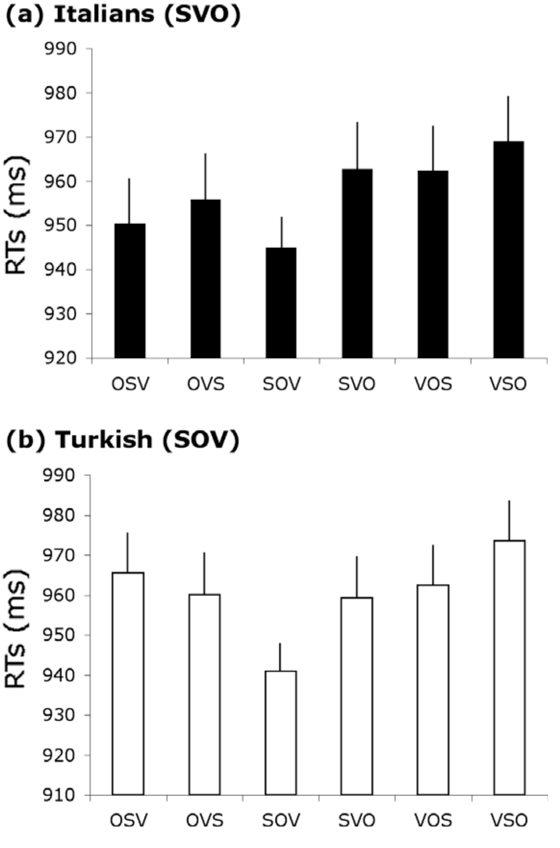

Fig. 3. Participants's average RTs in gesture comprehension: (a) Italian-speaking participants and (b) Turkish-speaking participants.

4.3. Discussion

Italians' faster reaction times with SOV than with their native SVO order suggests that the same preference – non-grammatical in nature – we observe in gesture production (Experiment 1), prevails also in gesture comprehension. While participants neglecting their native syntactic structures in gesture production and comprehension is clearly caused by the fact that they had to either produce or interpret gestures instead of sentences in their native language, it is unclear why the SOV order should prevail as the preferred configuration.

One possibility is that we are observing a simple modality effect, with this particular order of constituents emerging as a by-product of gesturing and with no consequence for the word order distribution in world's languages. Alternatively, it is possible that the SOV order prevails in gestures because gesturing relies on the direct interaction between the sensory-motor and the conceptual system. While we are not aware of any particular reason why SOV would be good for the sensory-motor system, SOV might be preferred by the conceptual system. It has been argued that semantic relations (e.g. verbs) require the presence of the entities (e.g. nouns) they link (Gentner & Boroditsky, 2009). The two word orders that satisfy this requirement are SOV and OSV. The latter is, however, extremely rare among world languages because the Object precedes the Subject (Greenberg, 1963; Greenberg, 1978). The SOV order thus satisfies the condition that the entities (the Subject and the Object) precede the relations (the Verb) in the most optimal way.

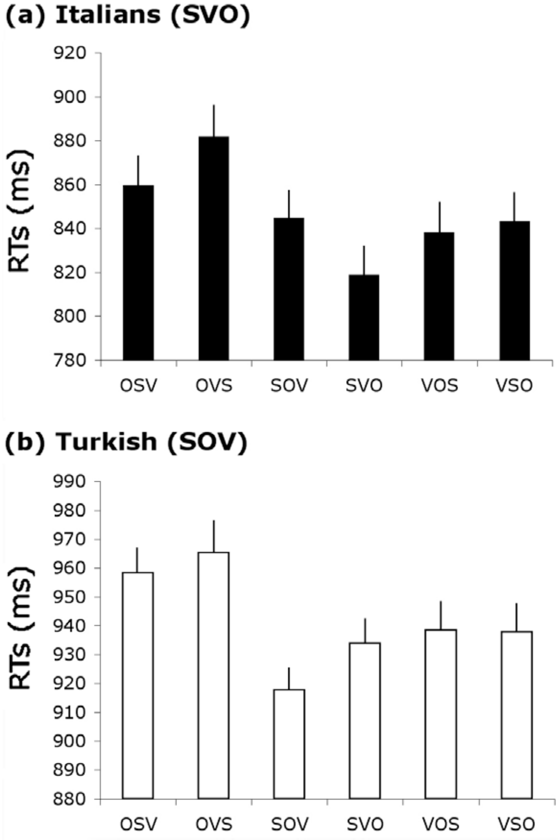

Fig. 4. Participants's average RTs in the comprehension of artificially synthesized strings of words in their native language: (a) Italian-speaking participants, and (b) Turkish-speaking participants.

According to this view, participants bypass their native linguistic structures and prefer a non-grammatical gesture order because they are not using the computational system of grammar. This view becomes plausible when considering how resistant adult speakers of a language are in abandoning the linguistic structures of their native language when using a foreign language (Muysken, 1988, cf. Odlin, 1989). Evidence in favor of this view comes also from American sign language, which has undergone a change from SOV to SVO (Kegl, 2008). In order to provide experimental evidence in favor of either one of the two alternatives, namely whether the SOV order in gestures is a simple modality effect or whether it reflects a preference of a cognitive system other than the computational system of grammar, we carried out Experiment 4.

5. Experiment 4: speech comprehension

In Experiment 4, we investigated whether also the computational system of grammar has word order preferences, and whether these preferences differ from the constituent order preferences we found for communication in the absence of the computational system of grammar. Evidence from Creole languages suggests that when children have a pidgin's vocabulary at their disposal during language acquisition, they grammaticalize the input by engaging the computational system of grammar (Bickerton, 1984). It may therefore be that when normally hearing adult speakers of a language hear word strings in their native language, they may also make use of the computational system

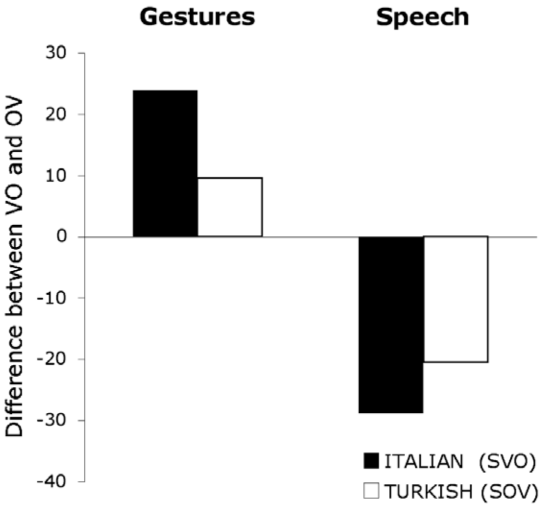

Fig. 5. Participants' average RTs to Object–Verb and Verb–Object orders in the comprehension of gestures and artificially synthesized strings of words in their native language.

of grammar to organize them. We therefore tested the comprehension of artificially synthesized and prosodically flat word strings in participants' native language. If the computational system of grammar is involved in the comprehension of these word strings, we would expect participants to perform fastest on their native word orders: Italian speakers with the SVO and Turkish speakers with the SOV orders.

While there are many reasons, both theoretical and based on language change, that suggest a preference for the SVO order in the computational system of grammar, there is no direct evidence for this preference (Newmeyer, 2000). The reason for the lack of clear evidence may lay in the fact that it is difficult to determine whether a non-native word order is computationally better for speakers of a language that has an alternative canonical word order: participants are simply always better on their native order.

A direct comparison between Italian and Turkish speakers is thus not possible. It may, however, be possible to determine more general word order preferences even in adult speakers of a language. For example, it has been proposed that there is a clear preference for orders where the Subject is in first (SOV and SVO) rather than in medial (OSV and VSO) or final (OVS and VOS) position (Greenberg, 1963; Greenberg, 1978). It has also been argued that world's languages can be classified roughly into Object–Verb (OVS, OSV, SOV) and Verb–Object (SVO, VOS, VSO) languages, because the languages in each of these two groups of act syntactically alike in many ways (Lehmann, 1973, 1978; Vennemann, 1974, 1976). We thus predict, that when exposed to artificially synthesized prosodically flat strings of words in their native language, both Italian and Turkish-speaking participants would on average be faster on orders where the Subject is in the initial position and where the Verb precedes the Object. Because Turkish (SOV) is an Object–Verb language, Turkish-speaking adults performing better on Verb–Object orders and thus overcoming the native Object–Verb constituent, would be especially strong evidence for order preferences in the computational system of grammar.

5.1. Method

5.1.1. Participants

Thirty six Italian native-speaking volunteers (19 females, 17 males, mean age 25.4, range 23–29 years) recruited from the subject pool of the International School of Advanced Studies in Trieste (Italy) and 36 Turkish native-speaking volunteers (22 females, 14 males, ages 20–24) recruited from the subject pool of the Boğaziçi University in Istanbul (Turkey). Participants reported no auditory or language related problems, did not know any sign language and had not participated in Experiments 1, 2 and 3. Participants received a monetary compensation.

5.1.2. Stimuli

The stimuli of Experiment 4 consisted of the 32 simple vignettes used in Experiment 1 (see Appendix A), and artificially synthesized audio clips describing each of these vignettes with a sentence consisting of a prosodically flat sequence of three words in both Italian and Turkish (see Appendix D). Like in Experiments 1–3, each vignette was counterbalanced with its mirror image across participants. To determine whether there is a preference for a specific constituent order in speech comprehension, we constructed the audio clips in all the possible six orders of Subject, Object and Verb (SOV, SVO, OSV, OVS, VSO and VOS). To avoid a bias for certain orders through prosodic and phonological cues, we synthesized the Italian (exemplified in Audio 1) and Turkish (exemplified in Audio 2) words by using MBROLA (Dutoit, 1997) and PRAAT (Boersma, 2001). We constructed phoneme files for each sentence with a phoneme length of 80 ms, pauses between the words of 80 ms and a constant pitch of 200 Hz. To obtain different word orders of the same sentence we changed the order of the words in the phoneme files before synthesizing the sentences. For Italian we used the It4 voice and for Turkish the Tr1 voice. The artificially synthesized sentences were prosodically flat and the sentences describing the same vignette only differed in the order of words. Four native speakers of Italian and four native speakers of Turkish verified that all the audio clips could be clearly understood.

Importantly, Italian is a language that uses Verb-agreement and the verbs of each sentence are marked for the Subject of the sentence. In general, speech perception studies have demonstrated that in Italian there is a clear preference for Subject initial position and the SVO order. Verb agreement, however, also plays a role in parsing (Bates, Devescovi, & D'Amico, 1999). The synthesized sequences of words therefore preserved the inflectional markings in Italian, even though, in the present task they could not be used to disambiguate between the two nouns, given they were both singular. Turkish is additionally a case-marking language where Objects are marked for case. Despite varying the order of words, the auditory sentences used in Experiment 4 preserved verb-agreement in Italian and both verb-agreement and case-markings in Turkish (see Appendix D). This was not only important because Object initial sentences without case marking are ungrammatical in Turkish (Erguvanli, 1984), but also because the marking of case in Turkish could liberate listeners from relying on the linear order of words. In fact, MacWhinney, Osmán-Sági, and Slobin (1991) found that when Turkish participants had to act out sentences with a Verb and two Nouns, of which the Object was clearly case-marked, they had the same accuracy with all word orders and could interpret all the sequence on the basis of case-marking alone. Based on these findings, we believe that any possible preference for one of the logically six possible word orders among Turkish-speaking participants in our reaction-times experiment would be especially strong evidence for one of the orders being more natural for the computational system of grammar.

5.1.3. Procedure

The procedure of Experiment 4 was identical to the procedure of Experiment 3. Participants were seated in front of a computer screen. The participants were given instructions where they were told that they would hear a sentence in their native language (Italian or Turkish). Immediately after each audio clip, participants were instructed to choose as quickly as possible between two drawn vignettes (used in Experiment 1) the one that depicted the content of the sentence they just heard (dual forced choice task).

In the dual forced choice task, one of the vignettes corresponded to the audio clip and the other one did not by randomly deviating in either one of the three constituents (of Subject, Object or Verb) (for an example see Appendix C). As the vignettes were created according to a combinatorial design, the distracting vignette of one trial was the correct vignette of another trial. Each participant listened to each of the scenarios once in each of the six logically possible orders (192 trials). Each participant saw each of the vignettes six times as the correct target and six times as the distracter. Participants had 1500 ms to make a choice before the next trial would begin. We measured Reaction Times

(RTs) from the onset of the dual forced choice task (from the moment when the two vignettes appeared on the screen).

To determine whether there is a word order preference, each participant saw each of the 32 different scenarios once in each of the six logically possible orders of Subject, Object and Verb. The experiment thus had 192 trials and was divided into six experimental blocks: in each block participants saw each of the 32 scenarios only once in semi-randomly determined gesture order. Between experimental blocks participants could take a break for as long as they wished.

5.2. Results

Like in gesture comprehension, participants' responses to the artificial synthesized prosodically flat strings of words in their native language show that they were not having difficulties with the task, as Italian-speaking participants only failed to give an answer on average in 5.3% ($SD = 1.6$), and Turkish-speaking participants on average in 5.9% ($SD = 1.2$) of the trials. Similarly, the percentage of correct answers was on average 95.3% ($SD = 4.7$) of all the answered trials by Italian- and 91.2% ($SD = 8.2$) of the answered trials by Turkish-speaking adults.

In order to determine whether the computational system of grammar is involved, we first compared participants' performance on individual word orders. The ANOVA between all word orders in Turkish speakers' responses shows that word order influenced their RTs ($F(5, 31) = 6.8$, $P < 0.01$). Post-hoc tests show that the native SOV order elicited fastest RTs for Turkish-speaking adults (Bonferroni-corrected $P < 0.01$) (see Fig. 4). Also the ANOVA between all constituent orders in Italian speakers' responses shows that word order influenced their RTs ($F(5, 31) = 7.436$, $P < 0.01$). Post-hoc tests show that the native SVO order elicited the fastest RTs for Italian-speaking participants (Bonferroni-corrected $P < 0.02$) (see Fig. 4). To see whether we find these differences also when taking items, rather than subjects, as random variables, we also carried out ANOVAs with the vignettes as random variables for Turkish ($F(5, 30) = 21.22$, $P = .029$) and Italian ($F(5, 30) = 40.56$, $P = .031$) participants. Post-hoc tests show that the SOV order elicited the fastest RTs for Turkish (Bonferroni-corrected $P = .048$) and SVO for Italian (Bonferroni-corrected $P = .028$) participants in the item based analysis as well. To comprehend artificially synthesized prosodically flat strings of words in their native language, both groups were using the computational system of grammar because they performed fastest on their native word orders: Italians on SVO and Turkish on SOV.

When we look at all the six logically possible orders, however, we observe consistent preferences across Italian and Turkish speaking participants' performance. For Italians, word orders where the Subject is in initial position (SVO and SOV) elicited significantly shorter RTs than orders where the Subject is in either second (OSV, VSO: 2-tailed t-test: $t(35) = 2.391$, $P < .01$) or third position (OVS and VOS: 2-tailed t-test: $t(35) = 2.201$, $P < .01$). Importantly the comparison between Subject in second and third positions failed to reach significance (2-tailed t-test: $t(35) = 9.392$, $P = .39$). The same tendency to prefer Subject initial word orders was evident also for Turkish-speaking adults (2-tailed t-test between S-initial and S-second position: $t(35) = 2.670$, $P < 0.01$; 2-tailed t-test between S-initial and S-third position: $t(35) = 1.976$, $P < 0.01$; 2-tailed t-test between S-second and S-third position: $t(35) = 4.392$, $P = .231$). There is thus a clear preference for word orders where the Subject is in the initial position (as in SVO and SOV), but no significant difference whether it occurs in second or third position.

Importantly, because both Italian and Turkish are Subject initial languages, we also looked at the positions of Objects and Verbs. For Italians, Verb–Object orders (SVO, VOS, VSO) elicited on average significantly shorter RTs than Object–Verb orders (OSV, OVS, SOV) (2-tailed t-test between Verb–Object and Object–Verb orders: $t(35) = 2.591$, $P < 0.01$). Exactly the same preference for Verb–Object orders over Object–Verb orders emerged also in Turkish-speaking participants' RTs (2-tailed t-test between Object–Verb and Verb–Object orders: $t(35) = 4.202$, $P < 0.01$) (see Fig. 5).

One possible explanation for the VO preference could be that among the VO orders there are more cases where the Subject precedes the Object (SVO, VSO) than there are among the OV orders (SOV). However, there is a significant preference for the Subject only in the initial position, but no significant difference between Subject in second and third positions (see above). This allows us to compare orders where the Subject is in a non-initial position – either Subject-second (OSV; VSO) or Subject-third (OVS; VOS) – because in these orders the position of the Subject does not matter. Comparing OV (OSV; OVS) to VO (VSO; VOS) orders, we still find a significant preference for VO orders for both Turkish (2-tailed *t*-test between OV (OSV; OVS) and VO (VOS; VSO) orders: $t(35) = 8.736$, $P < 0.001$) and Italian participants (2-tailed *t*-test between OV (OSV; OVS) and VO (VOS; VSO) orders: $t(35) = 9.143$, $P < 0.001$). Because Turkish is an Object–Verb order language, the preference for Verb–Object orders in Turkish-speaking participants' RTs must be independent of participants' native language.

5.3. Discussion

While expectedly, in speech comprehension, both groups of subjects were faster on their native order, when we consider all six orders together, both Italian and Turkish-speaking adults show on average shorter RTs with word orders where the Subject is in the initial position (SVO and SOV) as opposed to when it is in the medial or final position, and with word orders where the Verb precedes the Object as opposed to where the Verb follows the Object. While the preference for the Subject in the initial position is clearly interesting, it must be noted that both Italian (SVO) and Turkish (SOV) are Subject initial languages. The overall preference for Subject initial orders may thus be due to the fact that participants were simply fastest on their native order.

This cannot be the case for the preference for Verb–Object orders over Object–Verb orders, because both Italian and Turkish-speaking adults were on average faster with word orders where the Object follows the Verb. Because Turkish (SOV) is an OV language and because the shortest RTs emerged for the native SOV order, participants' general preference for the VO orders (SVO, VOS, VSO) is especially compelling – on average Turkish-speaking adults prefer word orders that violate their native language's Object–Verb directionality. Because Italian and Turkish-speaking participants prefer the same Verb–Object orders, our findings show that the computational system of grammar does have specific preferences for arranging words in sentences. These preferences are independent of participants' native language.

Importantly, when comparing the findings of speech comprehension (Experiment 4) to the findings of gesture comprehension (Experiment 3), we see that improvised gesture and speech have complementary word order preferences: when perceiving sequences of unknown gestures, both Italian and Turkish-speaking adults prefer Object–Verb orders, when perceiving sequences of known words both Italian and Turkish-speaking adults prefer Verb–Object orders. While to our knowledge this is the first experimental evidence showing that the computational system of grammar privileges the Verb–Object orders, it also enforces the idea that the SOV order in gestures arises from the direct interaction between the sensory-motor and conceptual system.

Importantly, the complementary order preferences in gesture (OV) and speech (VO) comprehension parallel the word order distribution among the world's languages where the SOV and SVO orders are distributed almost equally (Dryer, 2005). This suggests that the SOV order in improvised gestures is not simply a modality effect, but could very well emerge for the same reason the SOV order prevails among world languages as one of the dominant configurations. Because improvised gesturing bypasses participants' native grammar both in production as well as in comprehension, and fails to show the internal language-like organization of constituents, it is likely that it emerges as the preferred constituent configuration in the direct interaction between the conceptual and sensory-motor systems.

6. General discussion

In the present paper, we have proposed that the prominence of the SOV and the SVO orders among the world's languages originates from different cognitive systems: SOV is the preferred constituent order in the direct interaction between the sensory-motor and the conceptual system; the SVO order is preferred by the computational system of grammar.

Our results show that when participants are asked to gesture, they prefer the SOV order in the production of simple clauses, independently of whether their native language is SOV or SVO (see also

Gershkoff-Stowe & Goldin-Meadow, 2002; Goldin-Meadow et al., 2008). These results indicate that gesture production is independent of the participants' native grammar. In order to decide whether the SOV strings produced by our participants have the structural properties that characterize the hierarchical constituent structure of SOV languages, or are just a flat sequence of individual gestures, we tested the production of more complex sentences that require a main and a subordinate clause. If grammar were responsible for the SOV order observed in Experiment 1, then subordinate clauses should occupy the position immediately before the verb, as in SOV languages, and in our Turkish-speaking participants' verbal descriptions of the same complex vignettes. Our results show that when gesturing complex scenarios, neither Italian nor Turkish participants respect the structure of SOV languages. Gesture production thus does not appear to be governed by the computational system of grammar.

Experiments 1 and 2 taken together show that SOV is the preferred order in gesture production for the description of simple scenarios, and that it is not language-like in nature, since the SOV structure breaks down as soon as participants have to describe more complex scenarios. These findings confirm our hypothesis that simple improvised communication is the result of a direct interaction between the sensory-motor and the conceptual systems. Human language, in contrast, must necessarily also make use of the computational system of grammar (Chomsky & Lasnik, 1977).

To test whether the SOV order preferred in gesture production emerges also in gesture comprehension, we carried out Experiment 3. We showed that Turkish as well as Italian speaking adults were fastest in choosing the correct vignette after seeing the gestured videos in the SOV order, even though in Italian the SOV order is ungrammatical. Furthermore, on average, both linguistic groups showed a preference for orders where the Object precedes the Verb (OSV, OVS, SOV) over orders where the Object follows the Verb (SVO, VOS, VSO). Because Italian is a Verb–Object language, this preference for orders where the linear order of Verb and Object is reversed, is especially strong evidence for the SOV preference in simple gestural communication.

Why do improvised communication (SOV) and language (SVO) prefer different word orders? While the SOV order in improvised gestural communication parallels the Object–Verb orders found in homesigning children (Goldin-Meadow, 2005), the SVO order proposed for language can be found in children who grammaticalize the pidgin input into Creole languages (Bickerton, 1981; Bickerton, 1984). The difference between these two atypical language acquisition situations – the former having to create a vocabulary and the latter already having the pidgin lexicon – suggests that lexical input may be sufficient to trigger the computational system of grammar. While our experiments on gesture production and comprehension mimic the situation of homesigners, in Experiment 4 we aimed at creating a task that parallels the situation of children exposed to a pidgin.

In Experiment 4, we therefore tested the comprehension of artificially synthesized prosodically flat word strings in participants' native language – thus guaranteeing an existing lexicon – and varied the order of the words within the strings. While Italian (SVO) and Turkish (SOV) speaking participants were fastest in choosing the correct vignette after hearing strings in which the words appeared in the order of their respective native language, when comparing participants performance on all the six logically possible word orders, we found that both linguistic groups prefer word orders where the Object follows the Verb (SVO, VOS, VSO) over orders where the Object precedes the Verb (OSV, OVS, SOV). Because Turkish is an Object–Verb language, the findings of Experiment 4 provide strong evidence for the Verb–Object order preference in the computational system of grammar. The asymmetry in our results of the organization of unknown gestures and of known words, strengthens our hypothesis that improvised gesture production, as well as comprehension, is not mediated by the computational system of grammar.

Taken together, Experiments 3 and 4 provide the first cross-linguistic evidence for word order preferences in comprehension. Italian-speaking participants bypassing their native linguistic structures in comprehending improvised gestures, demonstrates that a direct link between the sensory-motor and the conceptual systems that prevails in gesture production, is discernable also in gesture comprehension. The fact that participants chose the correct vignettes faster after seeing gestured videos in the Object–Verb than in Verb–Object orders, shows that this link – unmediated by the computational system of grammar – prefers word orders where the Objects precede the Verbs. In comprehending artificially synthesized words in their native languages, participants were fastest in choosing the correct vignette after hearing sequences of words in their native word orders, showing that the computational system of grammar is involved in processing the word sequences. However, both groups eliciting shorter reaction times on Verb–Object orders, confirms that also the computational system of grammar has a word order preference that is independent of participants' native language and orthogonal to the order preference we found for the direct interaction between the sensory-motor and the conceptual system.

When considering the differences between participants who could rely on their native language as opposed to participants who were faced with the production (Experiments 1 and 2) or comprehension (Experiments 3) of gestures, our findings show a crucial difference. On the one hand, with gestures, participants did not rely on their native syntactic structures nor could they utilize any lexical knowledge, since they had to improvise the gestures in the production experiments and interpret unknown gestures in the comprehension experiment. With artificially synthesized words, instead, participants could at least rely on the lexicon of their native language. Similarly, in homesign, children have to invent their gestures de novo, and when doing so, they introduce the Object–Verb order into their gesture strings (Goldin-Meadow & Mylander, 1983). In contrast, when children are exposed to the unstructured mix of pidgin words, whose meaning they learn from the input, they grammaticalize the pidgin and introduce the SVO order. It is therefore possible, that the prominence of the SOV and SVO orders in atypical language acquisition as well as in our experiments is not due to the fact that in one case participants dealt with gestures and in another with their native language, but to the fact that in one case they did, and in the other they did not, have a lexicon at their disposal.

Proposals concerning the preferences for certain linguistic structures over others in the computational system of grammar have been highly controversial. For instance, it has been argued that recursive structures are easier to understand and process in SVO languages like English and Italian, characterized by rightward embedding, than they are in SOV languages like Japanese and Turkish, characterized by centre embedding (Frazier & Rayner, 1988). It has, however, been shown that Japanese-speakers can very well disambiguate multiple centre-embedded clauses (Mazuka et al., 1989). Thus the preference for one order over the other in the computational system of grammar does not emerge from the inability of the system to process certain syntactic structures.

It has instead been proposed that the preferences for some structural regularities – such as the SVO order and right-branching syntactic structures in general – may arise from the optimality with which they are processed in the computational system of grammar (Hauser et al., 2002). For example, Hawkins (1994) has noted that left-branching languages are likely to violate the branching direction with syntactically heavy embedded clauses, which are often postposed to the right. Because this construction – where subordinate clauses follow the main clauses – is typical of SVO languages, it has been assumed that there is a performance advantage for the SVO order. However, because different languages are not directly comparable, this hypothesis has proven difficult to confirm. The results of Experiment 4 are, to our knowledge, the first experimental evidence of cross-linguistic preferences for one relative order of verb and object over the other, and show that these are even more fine tuned than previously thought: participants show a preference for Verb–Object orders even with simple artificially synthesized three-word strings in their native language, independently on the language's word order.

The reasons why SOV should be so widespread among the world's languages, as well as in simple improvised communication are less clear. Hawkins (1994) argues that the SOV order is not particularly good for the computational system of grammar because it is possible for adjacent nouns to assume different functions (e.g. a girl can be either the actor or the patient). Thus in SOV languages, it is has often proven useful to additionally overtly mark the grammatical function of nouns with morphological endings (Hawkins, 1994). The findings of Experiment 1–4 show that the preference for the SOV order is motivated outside the computational system of grammar, and must thus originate from either the sensory-motor or the conceptual system. While we know of no reason why SOV should be good for the sensory-motor system, Gentner and Boroditsky (2009) have argued that relational terms – such as verbs – require the presence of the entities they link – such as nouns; suggesting that the SOV order may originate from the requirements imposed by the semantic relations in the conceptual system of grammar. It is however also possible that the SOV order results from the different conceptual accessibility of nouns and verbs. For instance, Bickerton (1992) has argued that while nouns have concrete counterparts in the environment, the correspondence of a verb to an action is considerably more vague and therefore more abstract. This may mean that the concepts the nouns represent are more accessible than concepts pertaining to verbs. In fact, Bock and Warren (1985) have shown that the syntactic organization of words in sentences is influenced by the different conceptual accessibility of nouns and verbs. In either case, it appears that the SOV order may be best suited for the conceptual system of grammar.

One question that needs to be answered is how the computational system of grammar emerges in human communication. Goldin-Meadow and Mylander (1998) have observed that when homesigning children gesture sequences of one Noun and one Verb, the Noun they gesture is more likely to represent a patient than an agent, a tendency typical of ergative languages. Based on the idea that the production probability of specific constituents is evidence for syntactic structure, Goldin-Meadow (1982) has argued that also homesigners use the computational system of grammar. However, in situations where homesigns have been grammaticalized into a language, as has happened in the school for the deaf in Nicaragua (Senghas et al., 1997) and a Bedouin village in Israel (Sandler et al., 2005), there is no evidence of consistent agent omission. Thus the production probability of specific constituents is not sufficient evidence in favor of syntax. Since both languages rely on the SOV order (Senghas et al., 1997; Kegl, 2008; Sandler et al., 2005), this suggests that analyzing the production probabilities of specific constituents in homesigning children's gesture strings may be misleading. Thus, until there is evidence that also homesigners organize constituents hierarchically rather than simply beading them together sequentially, it may be concluded that – just as normally hearing adults asked to gesture – also homesigners do not use the computational system of grammar.

Comparing the cases of isolated homesigning children (Goldin-Meadow, 2005; Goldin-Meadow & Mylander, 1998) to the situations where a group of homesigners was brought together – as has happened in the school for deaf in Nicaragua (Shenghas et al., 1997) and the Bedouin village in Israel (Sandler et al., 2005) – it appears that children exposed to no linguistic input during the window of opportunity in which language can be acquired (Lenneberg, 1967), do not use the computational system of grammar. Consistent SOV order emerges – as happened in both Nicaragua and Israel – only when the gestures of homesigners are grammaticalized by a new generation exposed to them (Kegl, 2008). It is therefore likely that the processes that grammaticalize the SOV order of improvised gestures and trigger the computational system of grammar are similar to those explored experimentally by Hudson and Newport (2005) who have shown that children over-regularize the input they receive. While the presence of a group may thus considerably affect the process, Singleton and Newport (2004) have shown that the over-regularization can also occur when a single child receives inconsistent linguistic input from his homesigning parents. According to such a scenario the SOV order that emerges in improvised gestural communication – that relies on the direct link between the sensory-motor and the conceptual system – only grammaticalizes when a child's acquires the gesture system from the input received as its native language.

There are a number of questions that remain to be answered. For instance, why does an existing vocabulary engage the computational system of grammar in Experiment 4 and in the case of Creole languages, whereas when adults have to create the vocabulary while they produce the gesture expressions, it does not? Similarly, the differences between single homesigning children as well as individual adult participants asked to gesture on the one hand, and a group of homesigners brought together in Nicaragua and Israel on the other hand, suggests that also the factor of the group may play a role in how communication systems grammaticalize and engage the computational system of grammar. Further work is necessary to flesh out the necessary and sufficient conditions for the emergence of language in the individual.

In terms of the nature of the human language faculty our results suggest that the structural diversity observed in the world's languages does not emerge from the computational system of grammar alone. The computational system of grammar responsible for generating and interpreting unambiguous structures prefers Verb–Object orders (Experiment 4), and is possibly limited to the SVO order (Chomsky, 1995), thus to right-branching structures (Kayne, 1994). This means that all the alternative grammatical configurations must originate from elsewhere in the language faculty. We have shown that one of the alternatives – the SOV order that is at least as widespread as the SVO order in the world's languages – emerges from the direct interaction between the sensory-motor and the conceptual system. It is therefore likely, that also other word orders, may originate outside the computational system of grammar. Thus, the structural diversity observed among the world's languages may be the result of a struggle between the individual cognitive systems and their interactions trying to impose their preferred structure on human language.

On the basis of our results concerning the cognitive systems responsible for improvised gestural communication, we can also advance a hypothesis about the evolution of the human faculty of language. We have shown that communication that can satisfy the simple needs of interpersonal interaction is possible in the absence of the computational system of grammar. By relying on the direct interaction of the sensory-motor and the conceptual system, communication might have emerged as a non-linguistic interaction with its own structural regularities. We thus suggest that human language rests on more primitive cognitive systems still available to humans. Proto-capacities have been shown to co-exist with more modern and fine-tuned cognitive capacities in other cognitive domains as well. For example, it has been suggested that number representation derives from magnitude estimation, a cognitive capacity that is also separately present in modern humans (Feigenson, Dehaene, & Spelke, 2004). Our results suggest that also our linguistic abilities coexist with, and possibly derive from, a more primitive form of communication that relies on the direct mapping between the conceptual and the sensory-motor system.

Our findings also indicate that human language is not a perfect product of engineering, but rather, that evolution has tinkered a patchwork solution (Jacob, 1977) from different, partially conflicting, cognitive systems. We have shown that simple communication that relies on the direct interaction between the sensory-motor and the conceptual system prefers the SOV order. If the computational system of grammar had evolved gradually, to enhance the structural coherence and the computational complexity of human communication, we would expect it to have adapted to the structural preferences of the simpler – already existing – form of communication. In such a case, the computational system of grammar should also prefer the SOV order. However, as we showed in Experiment 4, the computational system of grammar prefers Verb–Object orders: orders that are orthogonal to the Object–Verb orders found for simple improvised communication. This suggests that in a particular period in the history of language, the computational system of grammar must have emerged through a process of "recycling" a pre-existing and evolutionarily older cognitive capacity (Hauser et al., 2002). This process of "recycling" has recently been proposed for a different cognitive domain: mental arithmetic. In an imaging study, Knops, Thirion, Hubbard, Michel, and Dehaene (2009) showed that participants recycle brain areas used for spatial attention – an evolutionarily older cognitive ability – when engaging in mental arithmetic – a newer cognitive ability for which evolution has not yet dedicated specific brain mechanisms. We suggest that also for human language, the computational system of grammar could have been recruited from pre-existing computational capacities that were already used to process information in a manner that in the language faculty translate to the SVO order.

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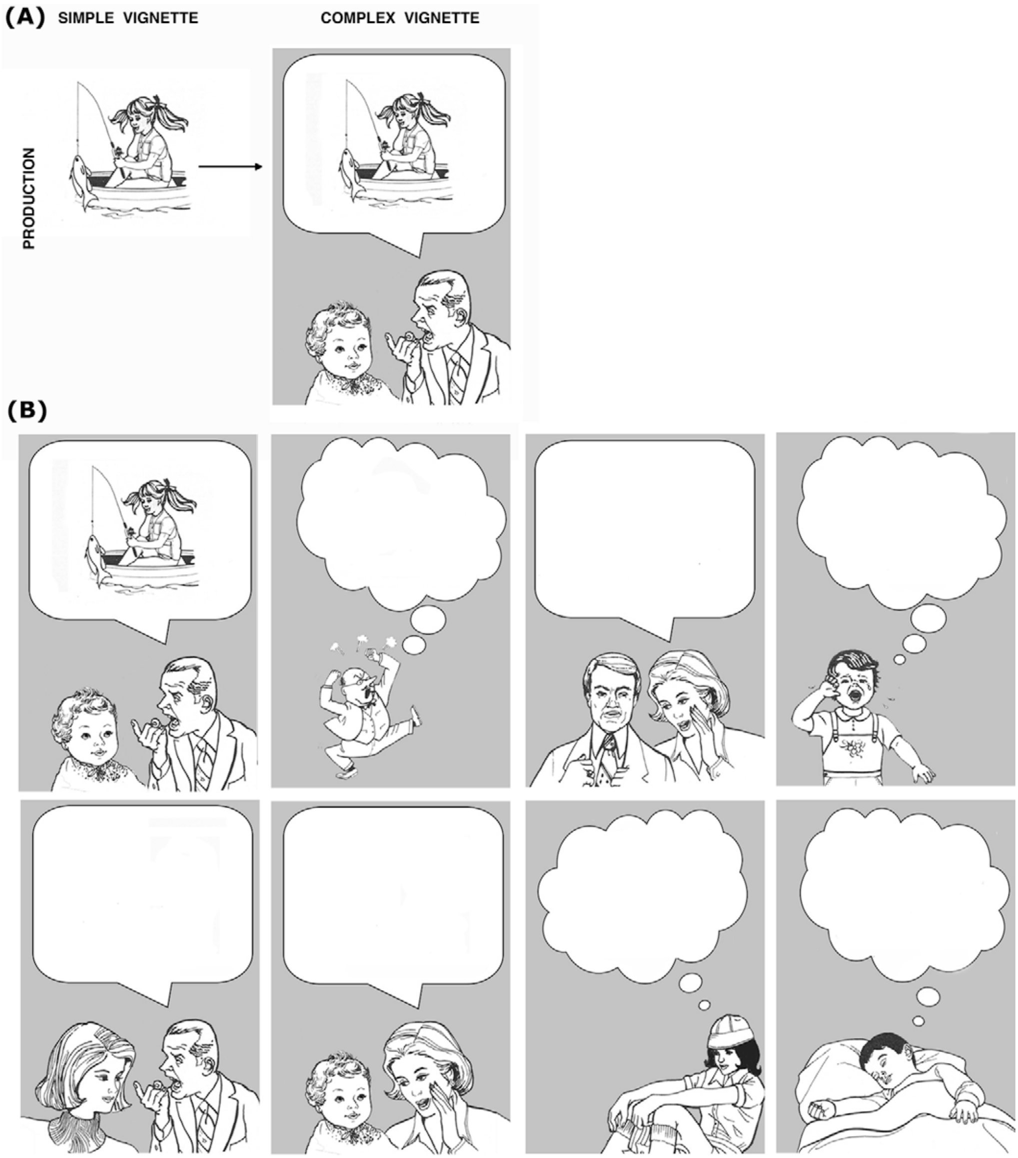
Appendix A

All the 32 simple vignettes.

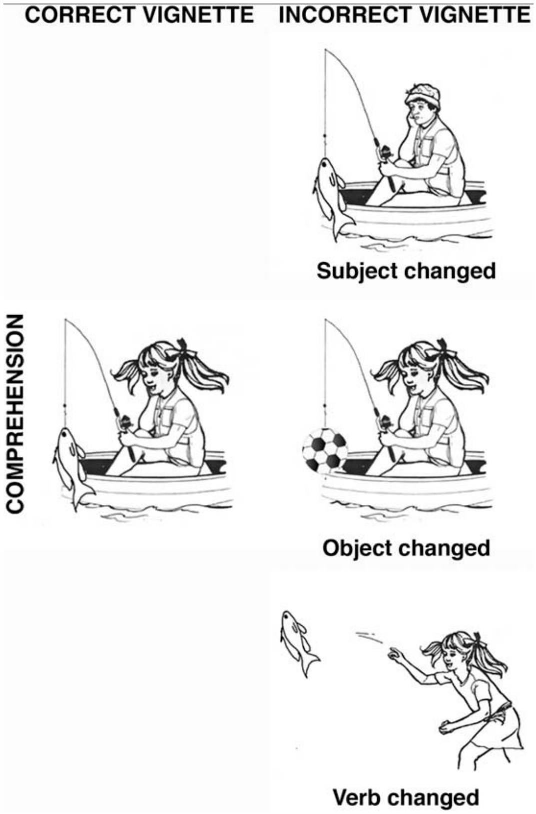
Appendix B

(A) An example of how a complex vignettes was created by embedding a simple vignette in a complex frame. (B) The eight complex frames into which the 32 simple vignettes were randomly embedded.



Appendix C

Examples of the correct and incorrect target vignettes in Experiment 3 and 4.



Appendix D

Turkish and Italian descriptions of the vignettes that were synthesized for Experiment 4.

1. Kız balığı yakalıyor (Turkish)
   girl fish-ACC catches-PRS-3SG
   La ragazza prende il pesce (Italian)
   girl catch-PRS-3SG fish
   A girl catches a fish (English)
2. Kız topu yakalıyor
   girl ball-ACC catches-PRS-3SG
   La ragazza prende la palla
   girl catch-PRS-3SG ball
   Girl catches a ball
3. Kız balığı atıyor
   girl fish-ACC throw-PRS-3SG
   La ragazza lancia il pesce
   girl throw-PRS-3SG fish
   Girl throws a fish

4. Kız topu atıyor
   girl ball-ACC throw-PRS-3SG
   La ragazza lancia la palla
   girl throw-PRS-3SG ball
   Girl throws a ball
5. Erkek balığı yakalıyor
   boy fish-ACC catch-PRS-3SG
   Il ragazzo prende il pesce
   boy catch-PRS-3SG fish
   Boy catches a fish
6. Erkek topu yakalıyor
   boy ball-ACC catch-PRS-3SG
   Il ragazzo prende la palla
   girl catch-PRS-3SG ball
   Boy catches a ball
7. Erkek balığı atıyor
   boy fish-ACC throw-PRS-3SG
   Il ragazzo lancia il pesce
   boy throw-PRS-3SG fish
   Boy throws a fish
8. Erkek topu atıyor
   boy ball-ACC throw-PRS-3SG
   Il ragazzo lancia la palla
   boy throw-PRS-3SG ball
   Boy throws a ball
9. Adam köpeği okşuyor
   man dog-ACC pat-PRS-3SG
   Il vecchio accarezza il cane
   man pat-PRS-3SG dog
   Man pats the dog
10. Adam kediyi okşuyor
    man cat-ACC pat-PRS-3SG
    Il vecchio accarezza il gatto
    man pat-PRS-3SG cat
    Man pats the cat
11. Adam köpeği besliyor
    man dog-ACC feed-PRS-3SG
    Il vecchio nutre il cane
    man feed-PRS-3SG dog
    Man feeds the dog
12. Adam kediyi besliyor
    man cat-ACC feed-PRS-3SG
    Il vecchio nutre il gatto
    man feed-PRS-3SG cat
    Man feeds the cat
13. Maymun köpeği okşuyor
    monkey dog-ACC pat-PRS-3SG
    La scimmia accarezza il cane
    monkey pat-PRS-3SG dog
    Monkey pats the dog
14. Maymun kediyi okşuyor
    monkey cat-ACC pat-PRS-3SG
    La scimmia accarezza il gatto

monkey pat-PRS-3SG cat
Monkey pats the cat

15. Maymun köpeği besliyor
monkey dog-ACC feed-PRS-3SG
La scimmia nutre il cane
monkey feed-PRS-3SG dog
Monkey feeds the dog
16. Maymun kediyi besliyor
monkey cat-ACC feed-PRS-3SG
La scimmia nutre il gatto
monkey feed-PRS-3SG cat
Monkey feeds the cat
17. Kadın arabayı çekiyor
woman carriage-ACC pull-PRS-3SG
La vecchia tira il caretto
woman pull-PRS-3SG carriage
Woman pulls the carriage
18. Kadın atı çekiyor
woman horse-ACC pull-PRS-3SG
La vecchia tira l'unicorno
woman pull-PRS-3SG unicorn
Woman pulls a horse/unicorn
19. Kadın arabayı itiyor
woman carriage-ACC push-PRS-3SG
La vecchia spinge il caretto
woman push-PRS-3SG carriage
Woman pushes a carriage
20. Kadın atı itiyor
woman horse-ACC push-PRS-3SG
La vecchia spinge l'unicorno
woman push-PRS-3SG unicorn
Woman pushes a horse/unicorn
21. Robot arabayı çekiyor
robot carriage-ACC pull-PRS-3SG
Il robot tira il caretto
robot pull-PRS-3SG carriage
Robot pulls the carriage
22. Robot atı çekiyor
robot horse-ACC pull-PRS-3SG
Il robot tira l'unicorno
robot pull-PRS-3SG unicorn
Robot pulls the horse/unicorn
23. Robot arabayı itiyor
robot carriage-ACC push-PRS-3SG
Il robot spinge il caretto
robot push-PRS-3SG carriage
Robot pushes the carriage
24. Robot atı itiyor
robot horse-ACC push-PRS-3SG
Il robot spinge l'unicorno
robot push-PRS-3SG unicorn
Robot pushes the horse/unicorn

Appendix E. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.cogpsych.2010.01.004.

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