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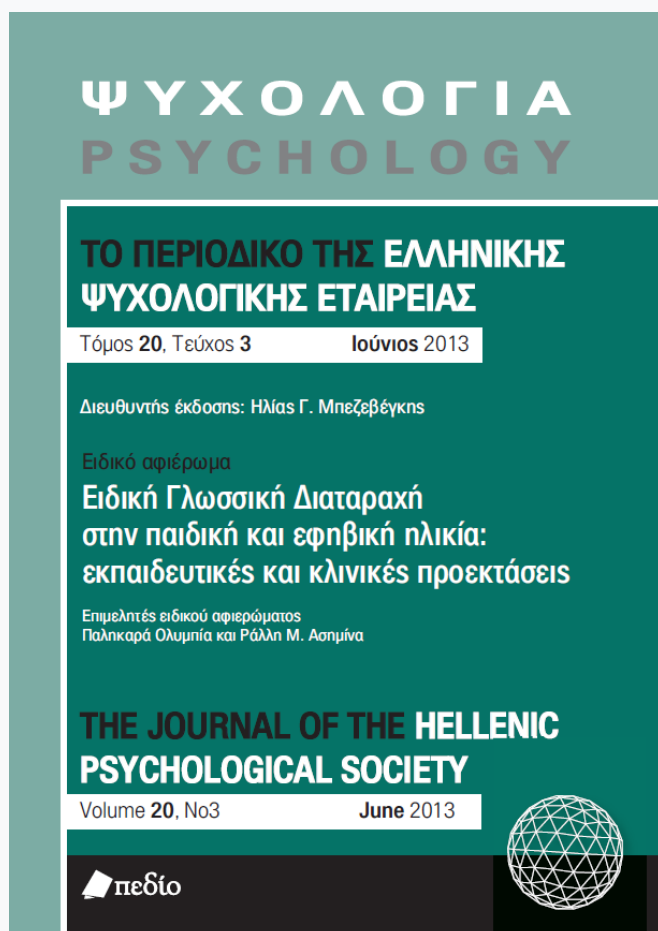
Language deficits and motor asymmetry in children with SLI

Αναστασία Γώγου, Σταυρούλα Σταυρακάκη, Γιώργιος Γρούϊος, Νικόλαος Τσιγγίλης

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Language deficits and motor asymmetry in children with SLI

Anastasia Gogou[1], Stavroula Stavrakaki[2]

George Grouios[3] & Nikolaos Tsigilis[4]

ABSTRACT

The present study aims at investigating whether a link between language deficits and upper and lower limb motor asymmetry can be established. We assessed language skills, handedness, and footedness in a group of 13 children with Specific Language Impairment (SLI) and two control groups matched on language age (LA) and chronological age (CA) respectively. Specifically, we tested the production of object wh-questions, object relative clauses and sigmatic past tense production for novel non-rhyming verbs, and administered hand and foot preference questionnaires. While significant between group differences were found in the language tasks, as participants with SLI performed significantly below CA controls, the same level of performance was shown for hand and foot preference. Further analysis revealed no correlation between foot and hand preference for the SLI group in contrast to typically developing children. Additional regression analysis showed that the non-right foot preference could predict participation in the SLI group. These results may be indicative of poor hand-foot coordination in the SLI group and increased chance for SLI individuals to be grouped as non-right footed. We interpret these findings as showing immature motor development in SLI and pointing to a weak correlation between motor laterality and language deficits. We discuss the implications of our findings for the characterisation of the deficit in SLI.

Keywords: SLI, Object wh-questions, Object relative clauses, Sigmatic past tense, Laterality, Motor immaturity.

1. Address: Achilleos 11, Naoussa 59200. E-mail: angogou11@yahoo.gr.
2. Address: Assistant Prof. of Linguistics with specialisation in Neurolinguisitcs. Dept. of Italian Language and Literature, School of Philosophy, Aristotle University of Thessaloniki, 54124 Thessaloniki. Tel.: +30 2310997452. E-mail: svoula@itl.auth.gt
3. Address: Professor of Motor Behaviour. Laboratory of Motor Learning and Control. Dept. of Physical Education and Sport Sciences. Aristotle University of Thessaloniki, 54124 Thessaloniki. Tel.: 2310.992178. E-mail: ggrouios@phed.auth.gr
4. Address: (elected) Lecturer of Methodology and Statistics of Social Sciences. Dept. of Journalism and Mass Communications. School of Economic and Social Sciences. Aristotle University of Thessaloniki, 54124 Thessaloniki. E-mail: ntsigilis@jour.auth.gr

1. Introduction

Specific Language Impairment (SLI) is a neuro-developmental disorder of language characterized by poor expressive and/or receptive verbal abilities while non-verbal IQ performance, as measured by standard psychometric IQ tests, is within the normal range (Leonard, 1998). In addition to language deficits, current studies indicate that other cognitive abilities, such as verbal short term memory, can be highly affected in SLI (Montgomery, 2003).

A bulk of studies deal with the linguistic deficits in SLI and interpret them within a linguistic framework. What these approaches share is the assumption that specific subcomponents of grammar, for example syntax and/or morphology, are affected to a certain extent in SLI (Clahsen, 1991; Leonard, 1998, for a review; Rice, Wexler & Cleave, 1995). As far as the syntactic impairment in SLI is concerned, recent studies indicate striking difficulties with the production and/or comprehension of complex sentences, such as wh-questions, relative clauses and passive structures. With regard to the morphological impairment, deficits in the domain of verbal inflection (tense and/or agreement marking) and selective deficiencies in the nominal domain (for example, production of object clitic pronouns) have been frequently reported (for a review, Leonard, 1998).

Other researchers interpret the deficits in SLI as a result of diminished cognitive capacity and suggest a different set of possible causes for SLI, such as processing limitations in incoming linguistic material (Leonard, Eyer, Bedore, & Grela, 1997) or in working memory capacity (Casalini et al., 2007; Jonsdottir, Bouma, Sergeant, & Scherder, 2005; Montgomery, 2003). Furthermore, recent neuroimaging studies on SLI provide new insights into this disorder by investigating the brain function and structure in this population. While SLI is not caused by a brain lesion, many studies explore whether there are any differences in the brain structure and function between SLI and typical population that can be associated/ correlated with the reduced abilities of language processing and acquisition exhibited by these children. The question of language lateralization in SLI and typical population attracted significant attention since minor differences detected in brain function might be sufficient enough to impact on language performance (Pecini et al., 2005). Many studies, indeed, report evidence for *atypical* brain function (and structure) in children with SLI compared to typical population and/or people with other disorders (Leonard et al., 2002; Whitehouse & Bishop, 2008). More specifically, SPECT measurements indicated more symmetric cerebral blood flow distributions in the left and right temporal regions in a group of children with SLI compared to a group of children with attention deficit hyperactivity disorder (Ors et al., 2005). A further study using MRI data indicated that smaller and symmetrical brain structures constitute a risk factor for SLI (Leonard, Eckert, Given, Virginia, & Eden, 2006).

In addition to neuroimaging studies, the question of brain function in SLI has been addressed by behavioural studies. Specifically, a behavioural study using dichotic listening tasks (Pecini et al., 2005) indicated differential patterns of cerebral organization in children with SLI compared to typically developing children, in particular, an enhanced contribution of the right hemisphere to the processing of linguistic material. By contrast, another study (Helenius, Parviainen, Paetau, & Salmelin, 2009) showed no significant differences in speech perception lateralization between adult language impaired individuals and controls, despite the lower performance of the SLI group on short term memory and vocabulary tests compared to that of controls. Similarly, studies that employed standard handedness questionnaires (Bishop, 2001; Bishop, 2005; Hill & Bishop, 1998) revealed no atypical lateralization in SLI, as they failed to detect differences in rates of non-right-handedness among children with SLI. However, another study, which employed a performance test (and not a questionnaire) developed to detect manual lateralization, in particular, the *quantification of hand preference* (QHP) (Bishop, Ross, Daniels, & Bright, 1996), showed weak hand preference in the SLI group. Bishop and collaborators (Bishop, 2005; Bishop et al., 1996) by means of this method suggested that individuals with SLI showed immature motor development.

In sum, studies on handedness in SLI revealed controversial findings. Some of them failed to establish a strong relationship between handedness and language deficits in SLI children and revealed no significant differences in hand preference between SLI and typical controls (Bishop, 2005; Francks et al., 2003; Hill & Bishop, 1998; Palmer & Corballis, 1996); by contrast, other studies showed increased frequency of non-right handedness in SLI groups (Bishop, 2001; Bishop, 2005; Leonard et al., 2006). Crucially, these studies employed different methods to study laterality in SLI. Purely behavioural tasks (such as the quantification of hand preference) or preference questionnaires which tap different aspects of handedness were employed. Furthermore, these studies differed in the sample tested. For example, Leonard et al. (2006) included only left handed children in their study and Pecini et al. (2005) found that the pattern of hemispheric specialization varies depending on the type of SLI (reduced left hemispheric specialization is mainly associated with the expressive type). In addition, it should be pointed out that different results in these studies did not come as a surprise due to significant variation in the population diagnosed with SLI (Leonard, 1998). Children[1] with SLI may differ in the severity of the linguistic deficit they show, as well as in the linguistic domains (phonology, morphology, syntax, semantics, and pragmatics) affected by the deficit. Specifically, some children show selective deficits in some domains (for example, morphology and/or syntax) (for a discussion, see Friedmann & Novogrodsky, 2007; van der Lely & Marshall, 2011) while others show deficits in all linguistic domains. Furthermore, while some children with SLI show selective impairment in production or comprehension, others show impairment in both modalities (Watkins, 1994). The present study aims at investigating whether SLI is linked to a reduced left hemispheric specialization for language and if so whether it is associated with language deficits in the domain of morphology and/or syntax. To this end, we employed language tests to assess linguistic abilities in SLI and self reports, such as hand and foot preference questionnaires, to study hemispheric specialization for language. The language tests employed in this study have been carefully selected from previous materials used in studies on Greek SLI. These tests, which assess morphology and syntax, revealed a significant weakness in the linguistic development of the Greek speaking population with SLI (Stavrakaki, 2001; 2002; 2005; 2006; Stavrakaki, Koutsandreas, & Clahsen, 2012).

With respect to the hand preference issue, we acknowledge the controversies attested in previous studies (summarized above) and we re-address the question of hand preference in SLI. In addition to the hand preference assessment, we added another measure of motor laterality, namely the foot preference assessment, in order to investigate the laterality question in SLI by means of a different measure. Moreover, we wanted to examine the relationship between handedness and footedness as a means of a more reliable predictor for cerebral dominance for language.

We point out that there is a relationship between hand and foot preference and cerebral dominance. The strong relationship between hand preference and cerebral dominance (which means that right handedness has been linked to left cerebral dominance for language) has been very well established (see Josse & Tzourio-Mazoyer, 2004; Knecht et al., 2000a; 2000b; Szaflarski et al., 2002). More specifically, higher percentages for right cerebral dominance for language are reported for those showing a strong preference for left hand than for right handed and ambidextrous individuals (Knecht et al., 2000a; Knecht et al., 2000b; Szaflarski et al., 2002).

By contrast, there are only a few studies on foot preference and its relationship with language laterality. These studies (Elias & Bryden, 1998;

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1. An anonymous reviewer points out that SLI exists in adults as well. We totally agree with this point. We nevertheless use quite often in the text the term 'children with SLI' for two main reasons. The first is that most of the studies in the field concern children with SLI (like the present study); the second is that SLI is not necessarily manifested in the same way in child and adult participants (see Conti-Ramsden, Durkin Simkin, & Knox, 2009, among others).

Peters, 1990) suggested that footedness is a more reliable measure of functional hemispheric asymmetry, since it is less biased by environmental or social factors. As far as the relationship between handedness and footedness is concerned, it should be noted that adult right-handers are more consistently right-footed than left-handers are left-footed. The same overall pattern has been found in young children to a lesser extent (Gabbard, 1992). In addition, a large scale developmental study indicated that right preference was not as pronounced in children aged 3-11 as instances of mixed footedness were very frequent (Gabbard, 1993).

In sum, on the one hand, foot preference is not necessarily correlated with hand preference, while a predominant pattern for the right sided preference can be seen even in young children. On the other hand, foot preference is considered a more reliable index of motor laterality as it is less influenced by environmental factors for bimanual usage compared to hand preference (Watson, Pusakulich, Ward, & Hermann, 1998). Consequently, we suggest that the assessment of foot preference may be informative about the relation between laterality and language disorders in SLI.

We point out that, to the best of our knowledge, our study is the first one to address the question of foot preference in SLI and its relationship to language deficits. In sum, by employing two measures of motor assessment and various measures of language assessment, we expect our study to illuminate the relationship between linguistic performance and motor lateralization in a sample of children with SLI whose traditional clinical diagnosis does not employ non-language tasks. In addition, we believe that our study examines this relationship from a different angle, as the linguistic data of this study comes from Greek, a language with richer morphology and more complex syntax than English from which most of the data is coming. Furthermore, in our view the investigation of the relationship

between hand/foot preference and language deficits has clinical implications for the definition of SLI: if children with SLI differ from typically developing children in other skills in addition to language abilities, then this population can be better described as having a primary language disorder co-existing with other non-verbal characteristics (Marton, 2009; Plante, Boliek, Mahendra, Story, & Glaspey, 2001; Schul, Stiles, Wulfeck, & Townsend, 2004; Ullman & Pierpont, 2005).

More specifically, for the purposes of the present study, we assessed the morphological and syntactic abilities, as well as the upper and lower limb motor asymmetry, in a group of 13 9-year-old children with SLI and two control groups: a group of 14 6-year-old "language-matched" controls (LA) and a group of 25 "age-matched" controls (CA). By assessing the language abilities and hand/foot preference in this sample, we evaluated two main hypotheses arising from the controversial research findings regarding the relationship between language abilities and hand preference in SLI. According to the first hypothesis, no relationship is expected between these domains (Bishop, 2005; Francks et al., 2003; Hill & Bishop, 1998; Palmer & Corballis, 1996), while according to the second hypothesis a positive correlation is expected between motor preferences and language deficits (Bishop, 2001; Bishop, 2005; Leonard et al., 2006). In addition, we investigated whether children with SLI exhibit clinical markers of non typical motor lateralization, as measured by increased incidence of non-right hand and foot preference, compared to their age-matched controls.

2. Method[2]

Participants

Three groups of children (SLI participants vs age- and language-matched controls) were tested. For all participants parental permission was

Table 1
Group characteristics: gender, means (sd) for age, IQ raw scores,
production of morphosyntax and sentence recall (raw scores)

Group	Gender girls:boys	age	IQ	Morphosyntax	Sentence recall
SLI	3:10	9.6 (1.33)	27.3 (3.8)	16.15 (2.48)	43.46 (2.11)
CA	7:18	9.8 (1.39)	27.7 (3.5)	18.84 (0.85)	45 (0)
LA	5:9	5.9 (0.65)	19.8 (4.8)	16.35 (1.86)	43.71 (2.87)

obtained while all children were given the opportunity to refuse to participate or leave the study at any point they wanted to. All children with SLI were exposed to formal instruction through schooling and received speech and language therapy services at the time of testing. Children raised in economic poverty were not included in the present study as they usually have below average development of language (Shera et al., 2006; Whitehurst & Fischel, 2000). All participants were tested individually at the speech and language therapist's office or at school by the first author of this study (AG), who is a qualified psychologist, experienced with children with disabilities. All instructions were given in a simple and slow manner so that the children had no difficulty in following them.

In total, 13 children (3 females, age range: 6.3-11.10) were recruited from speech and language therapy centres who met the diagnostic criteria for SLI (see Stark & Tallal, 1981; Leonard, 1998):
–   absence of mental retardation, performance IQ of 85 or higher
–   absence of sensory deficits, neurological or psychiatric disorders
–   no symptoms of autism
–   deficient performance in language ability tests, mainly in the domain of morphosyntax.

Two control groups were included in the study: a group of 14 6-year-old "language-matched" controls (LA) (5 females, age range: 5.4-7.2) and a group of 25 "age-matched" controls (CA) (7 females, age range: 6.11-12).

Non verbal intelligence was measured by Raven's Progressive Matrices[3] (Raven, Court, & Raven, 1986). Pre-experimental linguistic assessment included subtests from the Diagnostic Verbal IQ (DVIQ) Test (preschool), namely production of morphosyntax and sentence recall (see Stavrakaki & Tsimpli, 2000 for reliability and validity analysis). These particular subtests were selected as they can best capture the language disability shown by individuals with SLI. Indeed many studies on SLI report on striking difficulties in morphosyntax as well as in verbal short term memory (Leonard, 1998).

All children showed non-verbal intelligence within the normal range while the children with SLI performed below their CA peers in the tested subcomponents of the DVIQ test, with $Z = -3.76$, $p < .001$ for morphosyntax and $Z = -3.98$, $p < .001$ for sentence recall). Large effect size[4] were found with Cohen's $d = 1.45$ for morphosyntax and Cohen's $d = 1.03$ for sentence recall. No significant differences were found in Raven scores, $Z = -.24$, $p > .05$. Based on their performance on these subcomponents, the participants with SLI were

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3. While this test has not been standardised for Greek, it has been employed in many studies on Greek population (see for example, Protopapas & Skaloumbakas, 2007; Terzi et al., 2012).

4. In contrast to what an anonymous reviewer claimed, to the best of our knowledge, Cohen's d can take values over 1 (Rice & Harris, 2005).

matched with 6-year old children, which constituted the "language-age" (LA) control group. No significant difference was found between the SLI and the LA group in the production of morpho-syntax subtest of DVIQ test with $Z = -.19$, $p > .05$ nor in sentence recall, with $Z = -2.34$, $p > .05$. Details on the participant group profiles are reported in Table 1.

Experimental materials and procedure

The experimental materials included linguistic and motor tasks. All children were tested individually by the first author of this paper. Testing was completed in one session, which lasted around 30 minutes. The experimental task order was the same for all participants[5] as follows: object relative clauses, object Wh questions, novel non-rhyming verbs, hand and foot preference question-naires.

2.2.1. Language production tasks: Materials and procedure

In all language production tasks, a training session preceded the main experimental task. Three language production tasks were used for the purposes of the present study. All of them were extensively employed[6] in previous studies on Greek typically developing children and proved to be efficient in evaluating the language difficulties of Greek children with SLI and other disorders (for SLI: Stavrakaki, 2001; 2002; Stavrakaki, Koutsan-dreas, & Clahsen, 2012; for Downs' syndrome: Stathopoulou & Clahsen, 2010; for Williams syndrome: Stavrakaki & Clahsen, 2009b). Moreover, they led to the identification of some significant clinical markers for SLI population. In particular, Greek children were found to be impaired in the production of object wh-questions and object relative clauses (Stavrakaki, 2001, 2002, 2006; Stavrakaki, 2005, for a review of the

literature). In addition, Greek children with SLI showed limitations in the production of the sigmatic past tense form in a task with novel non-rhyming verbs, that is, novel verbs that did not rhyme with existing ones (Stavrakaki et al., 2012). In all experimental tasks, a training session preceded the main experimental task. This session aimed at familiarizing the participants with the task. The three tasks are described below:

Task I: O*bject wh-questions.*

In this task, the children had to produce 9 object wh-questions. This task was built on the basis of previous tasks used by Stavrakaki (2001, 2002), who followed Crain and Thornton (1998), to elicit wh-questions from Greek children. Children were presented with two pictures: for example, in the first picture a cat was washing a dog and in the second one a cat was pushing the dog. Children were probed to pose a question to a doll attending the procedure. While the experimenter pointed to the first picture, she said:

'We know that the cat washed somebody. Ask the doll whom'.

Target Response:

(1) Pion epline i gata?
    Who-ACC washed-3S the-NOM cat
    Who did the cat wash?

Task II: Object relative clauses

Children were shown 10 pictures and were probed to answer questions using object relative clauses (N=10). The picture showed four animals, for example, three chickens, one of which wore boots, and a bear, which was kissing a chicken. While the experimenter was pointing to the first picture, she said: 'Which chicken wears boots'?

Target response:

2. afti pu fila i arkuda
    The one that kiss-3s the-NOM bear-NOM
    'The one that the bear is kissing'

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5. This means that the task administration was not counterbalanced across participants, which is an apparent limitation of the present study.

6. No reliability or validity analysis was performed for these tests which was employed in previous studies of Greek population.

Task III: Novel non-rhyming verbs[7] (The Perfective Past Tense Test, PPTT, Stavrakaki, & Clahsen, 2009).

The novel non-rhyming verb task (10 verb forms) from the Perfective Past Tense Test (PPTT) (Stavrakaki & Clahsen, 2009) was employed in this study. The PPTT was used in a number of studies of Greek speaking population (Stavrakaki & Clahsen 2009; Stavrakaki, Koutsandreas, & Clahsen, 2012) as a production and comprehension task. In this study the production procedure was followed. The children were shown 10 pairs of two pictures, with the first picture presenting an action taking place in the present and the second one showing the corresponding completed action. The experimenter pointed to the first picture saying:

(3) Here the child keprathi the dragon.

Then she pointed to the second picture and asked:

'What did the child do here to the dragon?'

(4) Sigmatic response: The child kepra-s-e.

Sigmatic verb forms were calculated for each child.

2.2.2 Motor tasks: experimental materials and procedure

The Handedness Inventory (Briggs & Nebes, 1975) and the Waterloo Footedness Questionnaire Revised (WFQ-R) (Elias & Bryden, 1998) were administered to the SLI and CA groups. Although these tests have not been standardized, they have been employed for studies on Greek speaking population (Grouios, Sakadami, Poderi, & Aleuriadou, 1999; Grouios, Kollias, Koidou, & Poderi, 2002) and thus preferred over other similar tasks assessing the same functions, as they have been shown to provide a reliable evaluation of hand preference in Greek speaking population. The Handedness Inventory ascertained handedness by asking each participant about choice of side in performing 12 one-hand activities and other acts, including choice of hand for writing a letter legibly, throwing a ball to a target, holding scissors to cut a paper and hammering a nail into wood. Children were also asked to perform each activity so as to ensure their reported accuracy for left and/or right hand preference. A handedness score was obtained by assigning two points to "always" responses, one point to "usually" and none to "no preference". Scoring left preferences as negative and right preferences as positive gave a range of scores from -24 for the most left handed to +24 for the most right handed. Following Briggs and Nebes's (1975) scoring method, we grouped participants who received scores between +9 and +24 "right handed", those with scores between 8 and -8 "ambidextrous or mixed handed" and those with scores between -9 and -24 "left handed".

The Waterloo Footedness Questionnaire Revised (WFQ-R) assessed footedness for two types of tasks. Half of the questions assessed foot preference for the foot manipulating an object (mobilising tasks) such as kicking a ball and picking up a marble. The other half assessed foot preference for the foot providing support during an activity (stabilising tasks) such as standing on one foot, balancing on a railway track, etc. Children were also asked to perform each activity so as to ensure their reported accuracy for left and/or right foot preference. A footedness score was obtained by assigning two points to "always" responses, one point to "usually'" and none to "no preference". Scoring left preferences as negative and right preferences as positive gave a range of scores from -20 for the most left-footed to 20 for the most right-footed.We, following Elias and Bryden's (1998) scoring method, grouped participants who received scores of -7 to -20 as "left-footed", participants with scores between -6 and 6 were grouped as "mixed-footed", and scores from 7 to 20 indicated "right-footedness".

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7. It should be noted that past tense production in Greek SLI has been tested in many studies (Mastropavlou, 2006; Smith, 2008; Varlokosta & Nerantzini, 2012), which nevertheless did not include the task 'novel non-rhyming verbs' which is of interest in the present paper.

Table 2
Mean (standard deviation in parenthesis) for the language production tasks (percentages)

	SLI	CA	LA
Object relative clauses	68.46 (31.84)	99.2 (4)	79.23 (29.85)
Object wh-questions	46.07 (43.07)	100 (0)	62.06 (30.51)
Sigmatic past tense	43.08 (40.08)	70.4 (31.01)	22.5 (23.4)

Table 3
Performance of individual children with SLI (percentages in parenthesis; raw scores)

SLI	Object wh - questions	Object relative clauses	Sigmatic past tense
1	1/9 (11.1%)	5/10 (50%)	1/10 (10%)
2	0	5/10 (50%)	1/10 (10%)
3	1/9 (11.11%)	0	5/10 (50%)
4	1/9 (11.11%)	9/10 (90%)*	5/10 (50%)
5	2/9 (22.22%)	8/10 (80%)*	9/10 (90%)
6	0	5/10 (50%)	6/10 (60%)
7	9/9 (100%)	9/10 (90%)	10/10 (100%)
8	8/9 (88.88%)	10/10 (100%)	0
9	8/9 (88.88%)	9/10 (90%)	8/10 (80%)
10	9/9 (100%)	10/10 (100%)*	10/10 (100%)
11	9/9 (100%)*	9/10 (90%)	1/10 (10%)
12	1/9 (11.11%)	8/10 (80%)*	0
13	5/9 (55.55%)	2/10 (20%)	0

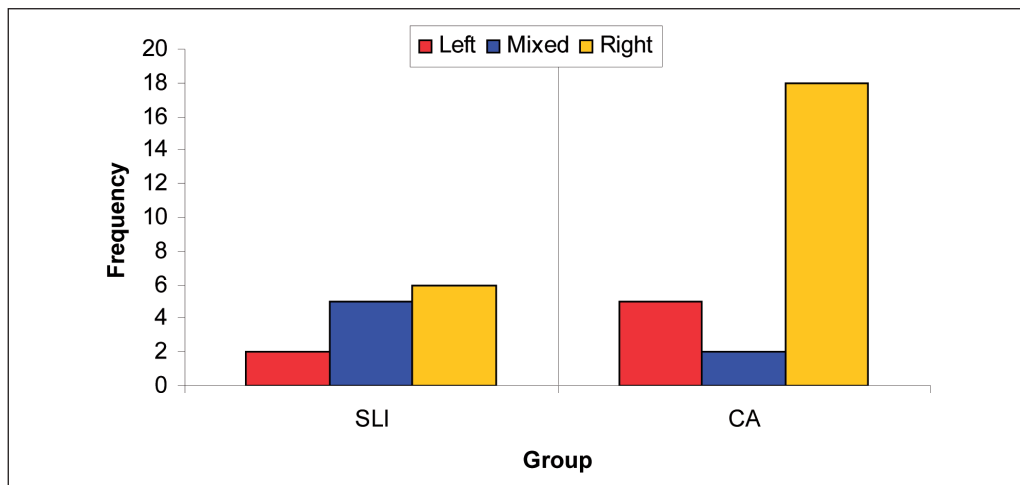*subject before the verb in sentence production.

Figure 1
Frequencies of right, mixed and left hand and foot preference in SLI and CA participants

3. Results

Language tasks

Table 2 presents the group results for the language production tasks.

The performance of the younger typically developing children (LA) as well as the performance of the children with SLI, dropped in the condition object wh-questions and object relative clauses while the performance of all children with typical development (CA) was at ceiling and near ceiling on the production tasks. Individual participant data for the SLI group are presented in table 3.

Statistics performed on the results presented in Table 2 confirmed the above observations. Specifically, the Kruskal – Wallis non parametric test revealed significant group differences among the three groups in all language tests (p <.001). In addition, we performed planned comparisons by using the non-parametric Mann–Whitney test to compare the performance shown by the (i) SLI and CA group and (ii) SLI and LA group on correct responses for object relative clauses, object wh-questions and sigmatic past tense responses for the non-rhyming verbs. The SLI children performed significantly worse than their CA peers on object

relative clauses and object wh-questions (with Z= -4.91, p < .001 and Z= -4.64, p < .001 respectively). These significant differences were substantial as shown by the large effect size found: Cohen's d =1.35 for object relative clauses, Cohen's d = 1.77 for object wh-questions In comparison to CA controls, SLI children produced a significantly lower number of sigmatic past tense verbs [Z = -2.02, p = .04, Cohen's d =.76]. No significant group difference was found between the SLI and LA group in all language tasks [object relative clauses: Z = -1.47, p > .05, object wh-questions: Z = -.73, p > .05, sigmatic past tense verbs: Z = -1.41, p > .05].

Motor tasks

The Mann - Whitney non parametric test revealed no significant group effect for hand and foot preference questionnaires (p >.05). While no between group significant differences were attested, we point out that group membership (right, mixed, left) for the foot preference inventory indicates an increased frequency of mixed foot preference in the SLI group (38.5%) compared to the CA (8%) and a reduced frequency of right foot preference in the SLI (46.2%) compared to the CA

Table 4
Logistic regression analysis for the SLI diagnosis

Predictors	β	SE β	Wald x^2	df	p
Hand preference	-.09	.05	3.11	1	.08
Foot preference	.13	.06	4.3	1	.04
test		x^2	df	p	
		6.28	2	.04	
2 Log likelihood		42.55			
Cox and Snell R Square		.15			
Nagelkerke R Square		.21			

group (72%). Frequencies of right, mixed and left hand and foot preference in SLI and CA participants are presented in Figure 1.

Correlation analysis and logistic regression analysis

Non-parametric correlation between all language and motor tasks revealed significant correlation between foot and hand preference, as expected, (Spearman $r =.62$, $p <.001$) for typically developing children (CA controls) while, surprisingly, no such correlation was found for the SLI group. On the other hand, a significant correlation between the foot preference and performance on the morpho-syntactic part of DVIQ (pre-experimental test) was found only for the SLI group (Spearman $r =-.76$, $p =.002$). These results are confirmed by the reliability coefficient Cohen K, which was used to investigate the correspondence between hand and foot preference scores in the two ability groups, the SLI and CA controls. Only in the CA group there was significant correspondence between hand and foot preference with Kappa = .59 ($p =.004$). No significant correspondence was found in the SLI group with Kappa = .13 ($p >.05$).

A two-predictor logistic model was applied to the data to test whether a relationship exists between the diagnosis of an SLI participant in our study and her/his hand and foot preference.

According to the model the odds of a child being diagnosed with SLI was not related to hand preference ($p >.05$) but was positively related to foot preference scores ($p =.04$). Logistic regression analysis is presented in Table 4. For example, when the child's average score increases by 1 unit in the foot preference questionnaire, the probability of s/he being diagnosed without SLI increases by about 14% (SLI was coded as 0 and without SLI as 1).

4. Discussion

Our study examined language production and motor abilities in children with SLI employing both linguistic materials as well as hand and foot preference questionnaires. Our main purpose was to investigate whether there is a link between language deficits and a lateralization index, namely, hand preference and footedness, in children diagnosed with SLI.

Children with SLI performed significantly below their CA peers and showed severe difficulties in complex linguistic tasks such as object relative clauses and object-wh questions in which the word order was Object-Verb-Subject. Our results confirm previous findings, according to which children with SLI show syntactic deficits in complex structures (for Greek, see, Stavrakaki, 2006; Stavrakaki & van der

Lely, 2010; Varlokosta, 2000; Zachou, 2013, among others). The difficulties that children with SLI show in complex structures have been at the centre of linguistic debates on SLI and interpreted as evidence of selective impairments in grammar, namely chain formation and/or movement operations (Friedmann & Novogrodsky, 2007; Stavrakaki & van der Lely, 2010). Our study also confirms previous findings reported by Stavrakaki et al. (2012) on SLI reliance on non-sigmatic verb forms. Specifically, these researchers found reduced generalizations of sigmatic forms and a greater reliance on non-sigmatic verb forms in children with SLI relatively to typically developing controls.

The results from the hand preference questionnaires confirmed the findings of previous studies that failed to detect differences in rates of non-right-handedness among children with SLI, using standard handedness questionnaires (Bishop, 2001; Bishop, 2005; Hill & Bishop, 1998). In our study, we added a foot preference questionnaire, considering that foot preference is less influenced by cultural and environmental factors and thus it can constitute a more valid indicator of laterality than hand preference (Watson et al., 1998). The between group comparisons did not show any significant differences between SLI participants and their CA peers. Further statistical analysis (correlation) revealed some discrepancies: significant correlation between hand and foot preference was found for typical population but not for SLI individuals. This finding was also confirmed by regression analysis.

On the other hand, significant correlation between foot preference scores and performance on the morphosyntactic pre-experimental task was found only for the SLI group but not for typical controls. In addition, the regression analysis revealed an increased incidence of non-right foot

preference in the SLI group compared to the control group. In other words, there was increased chance for a participant to fall in the SLI group than in the group of the typically developing children, if this participant showed non-right foot preference. Remarkably, no other significant correlations were found between the language and motor tasks for children with SLI nor for typically developing children. While the lack of correlation between hand and foot preference found in SLI was not attested in our typically developing sample, we should point out that such lack of correlation is reported in other studies especially for very young children (Gabbard, 1993). Taking into account that in adults hand and foot preferences are in most cases correlated (Gabbard, 1992), we suggest that such a lack of hand/foot coordination in the SLI participants of the present study may be indicative of a delay in motor development in these participants, especially because the control children showed such a correlation. This delay can be interpreted as a sign of motor immaturity[8] (cf. Bishop, 2002).

Collectively, these results do not point to a strong relation between linguistic performance and increased non-left hemisphere dominance in SLI due to the lack of significant correlation between groups in language and motor tasks, in addition to the absence of significance difference between group performances on the motor tasks. However, we believe that our results reveal some crucial differences between children with SLI and typical controls: Firstly, the lack of correlation between hand and foot preference in children with SLI; secondly, the significant correlation between one of the language tasks and the foot preference in SLI, not found in typical population; thirdly, the odds of a child being diagnosed with SLI was positively related to foot preference. We, thus, argue that

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8. As pointed out by an anonymous reviewer, Bishop and collaborators 'ascribed motor immaturity to children with difficulties in a hand skill task'. We totally agree with the reviewer's point. In our view, delay in motor development, shown by the lack of correlation between hand and foot preference in the SLI sample, may be a different sign of motor 'immaturity'. The term 'immaturity' is thus employed to describe findings from a different task than the one used by Bishop (2002).

while a strong indication of atypical lateralisation in SLI cannot be established, the increased possibility for a participant to be in the SLI group if s/he showed non-right foot preference indicates a, weak indeed but, existent relationship between deficits in language and motor abilities.

More specifically, the absence of a significant correlation between hand and foot preference in SLI may indicate a delay in motor development which can be interpreted as motor immaturity. This term has been used by Bishop and collaborators (Bishop, 2005; Bishop et al., 1996) to describe the increased difficulties that children with SLI had in performing a motor tapping task carried out with left and right hands. Our results shed light to the possible relation between motor and language abilities from a different angle: On the one hand, the coordination failure has been attested in the SLI group; on the other hand, the increased number of ambidextrous children in the SLI group points to the existence of a slight relation between the impairment in the linguistic domain and immaturity in motor development. However, we point out that the motor tasks did not offer a clear cut participant characterisation, as non-parametric statistics failed to detect significant between group differences. Notably, this clear cut participant characterisation was provided by the language tests that distinguished the participants with SLI from typically developing children. Therefore, we can safely conclude in agreement with a number of researchers that the primary deficit in SLI is indeed in the domain of language (for a review, Leonard, 1990; Ullman & Pierpont, 2005). However, this deficit is manifested in the presence of other characteristics concerning non-linguisitc development (in our case, *immature or delayed* motor development).

In other words, the deficit in SLI may be manifested mainly in the domain of language abilities but it is associated with a specific neuropsychological profile including increased chance for ambidexterity and immature motor development. This means that SLI can be perceived as a complex neurodevelopmental condition in which non-linguistic aspects of development can be affected (to a significantly lesser degree) in addition to linguistic ones (Marton, 2009; Plante, Boliek, Mahendra, Story, & Glaspey, 2001; Schul, Stiles, Wulfeck, & Townsend, 2004; Ullman, & Pierpont, 2005).

In this respect, we suggest that a better understanding of the deficit in SLI becomes feasible when detailed neuropsychological assessment of a wide range of abilities is performed. We, thus, conclude that interdisciplinary studies on SLI providing simultaneous assessment of different domains and abilities may enhance our understanding of the deficit.

Finally, we acknowledge that the generalizability of the present findings is limited perhaps by the small sample size given the number of comparisons made. Furthermore, the administration of tests was not counterbalanced across participants. Thus, future investigations should include large samples and employ counterbalanced administration. In addition, we acknowledge that the motor tasks used in our study provide us with a limited view of motor abilities in SLI. For example, hand skill is a more objective indicator of cerebral lateralization than hand preference and thus it should be employed in future studies investigating the relationship between language abilities and motor laterality in SLI. In addition, more studies on upper and lower limb motor asymmetry in SLI compared to typical population are required in order to establish whether there is any difference in brain structure concerning (a)symmetries in the two cerebral hemispheres and left hemisphere dominance (see for example, Leonard et al., 2006; Ors et al., 2005).

5. Conclusion

This study investigated the correlation of motor laterality with language abilities in SLI participants and compared their performance with that of typically developing children. To this end, measures of language abilities and motor preference tests were employed. Our results revealed significant between group differences in the language but not in motor tasks. Further

analysis (correlation and regression analysis) revealed differences between SLI and typical population, as significant correlation between hand and foot preference was not found for SLI participants contrary to typically developing children. By contrast, a significant correlation between foot preference and the pre-experimental morphosyntactic task was found only for the SLI group. In addition, the non-right foot preference was found to predict whether a participant belonged in the SLI group or not. We interpret the performance of the SLI participants on motor tasks as evidence for immature motor development and suggest that our results point to a weak correlation between motor laterality and language deficits. In this respect, we argue that SLI can be seen as a complex neurodevelopmental disorder in which non-linguistics aspects of performance may be affected in addition to linguistic ones. Finally, we acknowledge a number of limitations that the current study has including small samples and motor tasks assessing preference not skills.

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Γλωσσικά ελλείμματα και κινητική ασυμμετρία σε παιδιά με Ειδική Γλωσσική Διαταραχή.

Αναστασια Γωγου [1], Σταυρουλα Σταυρακακη[2]

Γιωργιος Γρουιος[3] & Νικολαος Τιγγιλης[4]

ABSTRACT

Η παρούσα μελέτη διερευνά την πιθανότητα σύνδεσης των γλωσσικών ελλειμμάτων και της κινητικής ασυμμετρίας άνω και κάτω άκρων παιδιών με Ειδική Γλωσσική Διαταραχή (ΕΓΔ). Αξιολογήσαμε τις γλωσσικές ικανότητες και την προτίμηση χεριού και ποδιού σε 13 παιδιά με ΕΓΔ και δύο ομάδες παιδιών τυπικής ανάπτυξης, μία που είχε εξισωθεί με τα παιδιά με ΕΓΔ ως προς τη γλωσσική ηλικία (ΓΗ) και μία ως προς τη χρονολογική ηλικία (ΧΗ). Συγκεκριμένα, ελέγξαμε την παραγωγή αναφορικών προτάσεων αντικειμένου, ερωτηματικών προτάσεων αντικειμένου και σιγματικού αορίστου για ψευδορήματα που δεν ομοιοκαταληκτούν με υπαρκτά ρήματα και χορηγήσαμε ερωτηματολόγια προτίμησης χεριού και ποδιού. Βρέθηκαν σημαντικές διαφορές μεταξύ των ομάδων στα γλωσσικά έργα καθώς η ομάδα παιδιών με ΕΓΔ είχε χαμηλότερη επίδοση από την ομάδα ελέγχου ΧΗ ενώ στα ερωτηματολόγια προτίμησης χεριού και ποδιού οι ομάδες δεν παρουσίασαν την ίδια επίδοση. Επιπλέον ανάλυση έδειξε απουσία συσχέτισης μεταξύ της προτίμησης χεριού και ποδιού στα παιδιά με ΕΓΔ σε αντίθεση με την ομάδα ελέγχου ΧΗ. Η ανάλυση παλινδρόμησης έδειξε ότι η προτίμηση ποδιού μπορεί να προβλέψει την ένταξη του παιδιού στην ομάδα παιδιών με ΕΓΔ. Τα αποτελέσματα φανερώνουν ενδεχομένως μειωμένο συντονισμό μεταξύ χεριού και ποδιού και αυξημένη πιθανότητα μη δεξιάς προτίμησης ποδιού σε παιδιά με ΕΓΔ. Ερμηνεύουμε τα ευρήματα αυτά ως αποτέλεσμα κινητικής ανωριμότητας των παιδιών με ΕΓΔ και ως ένδειξη χαμηλής συσχέτισης μεταξύ της κινητικής πλευρίωσης και των γλωσσικών ελλειμμάτων. Συζητούμε τις επιπτώσεις των ευρημάτων στο χαρακτηρισμό των ελλειμμάτων στην ΕΓΔ.

Λέξεις-κλειδιά: ΕΓΔ, Αναφορικές προτάσεις αντικειμένου, Ερωτηματικές προτάσεις αντικειμένου, Παραγωγή σιγματικού αορίστου, Πλευρίωση, Κινητική ανωριμότητα.

1. *Διεύθυνση:* Ψυχολόγος, Αχιλλέως 11, 59200 Νάουσα. E-mail: angogou11@yahoo.gr
2. *Διεύθυνση:* Επίκουρη Καθ. Γλωσσολογίας με ειδικό αντικείμενο Νευρογλωσσολογία. Τμήμα Ιταλικής Γλώσσας και Φιλολογίας, ΦΛΣ, ΑΠΘ, 54124 Θεσσαλονίκη. Τηλ.: 2310997452. E-mail: svoula@itl.auth.gt
3. *Διεύθυνση:* Εργαστήριο Μάθησης και Ελέγχου της Κίνησης, Τμήμα Επιστήμης Φυσικής Αγωγής και Αθλητισμού, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, 54124 Θεσσαλονίκη. Τηλ.: 2310.992178. E-mail: ggrouios@phed.auth.gr
4. *Διεύθυνση:* Λέκτορας Μεθοδολογίας και Στατιστικής των Κοινωνικών Επιστημών - υπό διορισμό. Τμήμα Δημοσιογραφίας και Μέσων Μαζικής Επικοινωνίας, Σχολή Οικονομικών και Πολιτικών Επιστημών, Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης, 54124 Θεσσαλονίκη. E-mail: ntsigilis@jour.auth.gr